BIOMASS FEEDSTOCK SUPPLY AVAILABILITY ASSESSMENT FOR YAVAPAI COUNTY

Prepared for:
Upper Verde River Watershed Protection Coalition

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September 13, 2016
Final Report

This study was made possible by an Arizona Biomass Enterprise Grant administered by the Arizona Department of Forestry and Fire Management.

ACKNOWLEDGMENTS

The authors wish to thank several individuals and organizations for their significant efforts in support of this project. These include, but are not limited to:

Patrick Rappold, Arizona Department of Forestry and Fire Management
John Munderloh, Town of Prescott Valley; Upper Verde River Watershed Protection Coalition
Melody Reifsnyder, Upper Verde River Watershed Protection Coalition; Sage Consulting
Rich Van Demark, Southwest Forestry, Inc.

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ABBREVIATIONS

4FRI	4 Forest Restoration Initiative
ARRA	American Recovery and Restoration Act
BDT	Bone dry ton(s)
BLM	Bureau of Land Management
CCF	Hundred cubic feet
DBH	Diameter at breast height
EA	Environmental assessment
FIA	Forest Inventory Analysis
FIR-BBER	Forest Industry Research, Bureau of Business and Economic Research
GIS	Geographic information system
GT	Green ton(s)
MBF	Thousand board feet
MW	Megawatt
NEPA	National Environmental Policy Act
PJ	Pinyon and juniper woodlands
SAF	Society of American Foresters
SRM	Society of Range Managers
TSA	Target study area
TSS	TSS Consultants
USDA	United States Department of Agriculture
USFS	USDA Forest Service
4FRI	4 Forest Restoration Initiative

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BACKGROUND

The Upper Verde River Watershed Protection Coalition (UVRWPC, the Coalition) provides local government leadership on water resource concerns in central Yavapai County. The membership is comprised of Yavapai County, the Yavapai-Prescott Indian Tribe, the City of Prescott and the Towns of Prescott Valley and Chino Valley. The Coalition's goal is to protect the perennial flows of the Upper Verde River while obtaining "Safe-Yield", or a long-term balance in the aquifer, in the Prescott Active Management Area. In 2014, the Coalition developed a Watershed Restoration and Management Plan in conjunction with numerous land, water and natural resource stakeholders that identified the overgrowth of woody vegetation in Coalition watersheds, primarily the Big Chino Sub-basin, as a threat to current and future water supplies. The USGS (Blasch, 2006)[1] determined that less than 2% of the precipitation landing on the watershed recharges the aquifer, while a similar small percentage runs off to the Verde River. The remaining 96% of total precipitation is consumed by vegetation and evaporation from the soil surface.

In addition to water supply impacts from woody vegetation overgrowth is the immediate concern about intense wildfire. Although the vegetation types found in the watersheds are well adapted to low intensity fires, the current over-stocked vegetation now creates high intensity fires that bake soils and create flooding and erosion during rain events. Recent fires provide stark examples of how poor, overstocked watershed conditions are compounded by high intensity fires. For example, an August 2, 2016 rain event on the area burned by the 2016 Tenderfoot fire near Yarnell created flooding and soil erosion that had not previously been an issue.[2]

Various agencies and landowner have attempted to address the woody overgrowth issue in Yavapai County for many years. There has been little or no cost recovery for these efforts since the cut material is primarily left in place. The scale of the effort needed and the high costs involved to manage vegetation across the watershed has led the Coalition to try to find some value in the cut material to offset or even pay for the cost of treatment.

The Coalition is seeking alternative value-added utilization opportunities for woody biomass generated as a byproduct of watershed restoration, fuels reduction activities and wildlife and rangeland habitat improvement in the Upper Verde watershed and across Yavapai County in west-central Arizona. The key challenge to this biomass utilization objective lies in the fact that the majority of this study area consists of pinyon-juniper and juniper woodlands vegetation types. Current known commercial uses for this type of woody biomass are limited and new products and market opportunities need to be explored and developed. Discussions with forest product industry leaders who have expressed interest in juniper woodlands have pointed out that there is no estimate of the practically available amounts of harvestable material in Yavapai

[1] Blasch *et al*, Hydrology of the Upper and Middle Verde River Watersheds, Central Arizona, 2006 (Version 2 updated 2007). USGS Report 2005-5198. http://pubs.usgs.gov/sir/2005/5198/pdf/sir20055198.pdf;
[2] "Flash Flood Hits Yarnell", the Daily Courier, August 2, 2016. http://www.dcourier.com/news/2016/aug/02/flash-flood-hits-yarnell/. And "Following Fire, Yarnell Faces Flood", WesternMass News, August 1, 2016. http://www.westernmassnews.com/story/22881391/following-fire-yarnell-faces-flood

County. This is a key consideration for any kind of large-scale commercial utilization of woody biomass. This study addresses this important issue.

For decades, the pinyon-juniper ecosystems of the western United States have been a topic of study and concern for range scientists and wildlife biologists. Estimated to cover almost 30-million acres throughout Arizona and New Mexico[3] alone, this ecosystem represents a significant potential woody biomass resource. Historical fire suppression efforts over much of this ecosystem have resulted in high levels of juniper encroachment and increased canopy cover. As a result, there has been a loss of perennial grass cover and an increase in water runoff and exposed soil. Furthermore, wildlife habitat and rangeland productivity have been adversely impacted by this encroachment. Within the study area, numerous projects have been undertaken on public and private lands to counter juniper encroachment. The most commonly undertaken efforts appear to be either manual chainsaw felling accompanied by lopping and scattering or mechanical shearing followed by crushing or burning the individual tree "carcasses." Mastication has also been utilized; however, higher per acre costs appear to limit this option. Most recently (March 2016), shearing and forwarding trials were undertaken in the study area using a feller buncher and forwarder to accomplish juniper thinning and removal.

Relatively recent efforts at commercial-scale mechanical shearing and removal of juniper for biomass have been ongoing within the western United States. Beginning in the early 1980s, western juniper was identified and used as a suitable biomass fuel supply for biomass power plants in northeast California. More recently, and closer to the study area, the biomass power plant in Snowflake, Arizona has been utilizing juniper as a fuel. These large-scale commercial biomass power generating facilities represent perhaps the most promising use of this juniper resource.

Efforts at developing new markets for juniper biomass have recently begun and need continued support. Although juniper does not lend itself to "typical" forest products such as dimensional lumber, the wood has unique and desirable characteristics. Juniper is highly durable and resistant to rot. It is aromatic and has an attractive wood grain that is desired for decorative furniture.

There is however issues related to the large-scale utilization of pinyon and juniper biomass. Juniper species are typically slow growing with multiple stems originating from a single root system. Their growth form makes them difficult to harvest, handle and process. In addition, foliage makes up a relatively large portion of the total above ground tree biomass; in some cases, as much as 20% of the total living tree biomass is foliage.[4] Bole wood[5] larger than five inches in diameter is a traditional measure of merchantable timber. It forms a relatively small portion of total juniper biomass. Due to the multi-stem and low branching structure of the juniper species found in Arizona, bole wood may be less than 1% by weight of the total available biomass.[6]

[3] Biomass distribution and productivity of Pinus edulis-Juniperus monosperma woodlands of north-central Arizona, Grier CC, Elliot KJ, Northern Arizona University, April 1991.
[4] Biomass Distribution, Grier CC and Elliot KJ, 1992.
[5] The tree bole is the stem or trunk of the tree from the stump to a 4 inch diameter top portion
[6] Based on USFS FIA EVALADator data compiled by TSS Consultants, June 2016.

Considering the limited commercial markets and value for juniper biomass, it is not surprising that data regarding density and volumes per acre within the study area are limited. During the course of this review, TSS was surprised to find that even US Forest Service, National Environmental Policy Act (NEPA) documents covering thousands of acres of this ecosystem failed to provide any extensive level of juniper stand density or volumes per acre. Two of the most detailed efforts to develop accurate juniper biomass volumes per acre within the study area were an American Reinvestment and Recovery Act (ARRA) grant in 2010[7] and a more recent project in 2016.[8] While these studies covered only a small area of juniper and pinyon-juniper woodlands within Yavapai County, they do provide some very accurate data regarding yields per acre for these stands. The challenge, of course, comes in correlating this data to the entire target study area (TSA).

In March, 2016 UVRWPC received an Arizona Biomass Enterprise Grant administered by the Arizona Department of Forestry and Fire Management. The Coalition retained the services of TSS Consultants to conduct a comprehensive biomass supply availability assessment that can be used to attract investment in commercial-scale biomass conversion facilities in central Arizona. The TSA of Yavapai County was chosen by UVRWPC committee leadership and technical advisory committee members.

[7] 2010 ARRA Grant Project #AR 10-001, USFS Recovery Act Agreement #10-DG-11039702-109, April 2012.
[8] Savannah-Grasslands Pre-Investment Pilot Project, Southwest Forestry, Inc., D.R. Systems NW, Inc., June 30, 2016.

KEY FINDINGS

Biomass Feedstock Supply Availability

The predominate vegetation types of interest within the study area are the juniper and pinyon-juniper woodlands. This vegetation type represents over 960,000 acres or approximately 18.5% of the study area. While conifer forest types do exist within the study area, they are of minor relative importance, making up about 2% of the area. Although the juniper and pinyon-juniper (PJ) woodlands types are abundant within the study area, TSS found limited data regarding potential aboveground biomass volume for this vegetation type within the TSA. Utilizing a wide range of aboveground biomass estimates for PJ stands within Arizona and the Southwest US, TSS estimated a range of 4.7 bone dry ton/acre (BDT)[9] to 10.6 BDT/acre, averaging around 7.65 BDT/acre. TSS estimates that 2,500 to 3,300 acres of juniper and pinyon-juniper woodlands are treated annually within the TSA; however, little if any of this material is currently utilized. In terms of other forms of biomass potentially available, such as conifer forest and urban-derived material, TSS found these to be around 10,000 BDT per year. Obviously the current and future biomass opportunities within the TSA are with the juniper and pinyon-juniper woodlands.

Feedstock Competition Analysis

Markets for processed woody biomass are currently limited within the study area. Both personal use and commercial fuelwood harvest and sale are traditional markets within the TSA. Juniper is a preferred fuel wood because it provides a significant amount of energy relative to the amount of effort required to harvest and process. It's aromatic and clean burning properties are also desirable. The Prescott National Forest sells approximately 4,885 cords, or 5,862 BDT, of fuel wood per year.[10, 11] Data was not available on the amount of additional commercial fuel wood harvested from private lands within the TSA.

TSS observed processed greenwaste mulch being loaded and given away for free at the Sundog Transfer Station in Prescott for transport 139 miles south to the Scotts Miracle-Gro facility in Maricopa. In addition, discussions with timber operators and truckers in the region indicated that the only markets for processed woody biomass generated from U.S. Forest Service timber harvest residues are either Scotts in Maricopa, Gro-Well in Phoenix, or Novo BioPower, a 27 megawatt (MW) biomass power plant located in Snowflake. TSS estimates that haul distances to these markets range from 141 miles to 125 miles.

While the primary focus of this project was to assess the potential volumes of biomass that could be available for commercial use within the TSA, TSS did take a cursory look at some markets and associated competition from other biomass outside the immediate study area. One of the major competitive forces impacting the potential for developing markets for the pinyon and juniper biomass resource within the study area is the Four Forest Restoration Initiative (4FRI).

[9] One bone dry ton = 2,000 pounds of dry wood fiber.
[10] Prescott National Forest – Forest Plan Monitoring and Evaluation Report. FY 2015. Five year average FY 2011 – FY 2015.
[11] 1 cord juniper = 1.2 BDT

The 4FRI is the largest U.S. Forest Service stewardship contract in the agency's history and is located along the northern and eastern border of Yavapai County. This massive, 10-year, 300,000 acre project is producing sawlogs, posts, poles and thousands of tons of woody biomass. TSS believes that much of the woody biomass generated from the 4FRI will be in direct market competition to any woody biomass generated in Yavapai County. TSS found that woody biomass produced by contractors on the 4FRI project is being hauled to some of the same mulch and landscape market outlets that TSS contacted as part of this assessment. Much of the biomass off the 4FRI projects consists of high-quality chipped pine and is being transported directly through Yavapai County to Scotts Miracle-Gro and Gro-Well south of Phoenix. The fact that the 4FRI contract requires removal of all woody biomass from the contract area suggests that these woody biomass producers will be extremely competitive. However, the 4FRI project will also reinvigorate the flailing wood products industry in Arizona which will introduce new markets and demand centers and individuals with specialized knowledge and skills. This in turn could drive innovation, harvesting and transportation networks and new market sources for pinyon-juniper products.

Based on discussions with the largest wood pellet manufacturer in Arizona, TSS found that juniper is not as desirable a feedstock for densified fuel pellet production.[12] The abrasive characteristics of the juniper can cause excessive wear of the pellet dies. This manufacturer also indicated that delivered prices for PJ woody biomass were currently not competitive with pine and conifer woody biomass. However, TSS interviewed a local businessman utilizing a process that compresses PJ chips, including the needles, into a fuel brick format that is being marketed as a replacement to fuelwood in wood stoves.

Product testing and development of juniper as biochar or torrefied wood is currently active with a number of biomass energy producers. Indications are that juniper processed in this fashion has similar characteristics to other wood products and holds promise as a replacement product to coal. Within the study area, only one industrial facility, Drake Cement, uses coal and may be able to use torrefied juniper as a replacement supply or co-supply to coal.

Feedstock Cost Forecast

TSS is aware of only one wood grinder operating within the TSA, a Vermeer Horizontal Grinder that is owned by Yavapai County. This machine is currently used by Yavapai County at the City of Prescott transfer station. With such a limited number of actual wood processors in the TSA, it was necessary for TSS to rely on the recent PJ woodlands research projects as well as anecdotal information from operators in other PJ regions of the Southwest. Based on this information, TSS estimated that PJ areas could be processed and delivered within a 40 mile one-way haul distance for $55 to $75 per BDT. Timber harvest residues and forest management material were estimated at $45 to $50 per delivered BDT. In terms of biomass fuel forecast, the largest single expense related to biomass fuel harvesting and processing is the cost of diesel fuel. Over the next five years, TSS expects diesel fuel prices to remain flat. As such, TSS is projecting just a minimal 1.5% per year increase in these biomass feedstock costs.

[12] Personal Communication, large scale pellet manufacturer, Show Low, AZ, June 2016

Recommendations

In order to more accurately determine the actual aboveground biomass volumes within the PJ woodlands of the TSA, TSS recommends that some form of remote-sensing effort be undertaken throughout the TSA. As a result of this assessment, TSS uncovered recent research conducted by the U.S. Department of Agriculture (USDA) Agricultural Research Service, Eastern Oregon Agricultural Research Center that appears to address this very issue.[13] Using object-based image analysis (OBIA) techniques and National Agriculture Imagery Program (NAIP) imagery in combination with ground measurements, researchers were able to develop very accurate estimates of juniper and pinyon-juniper ecosystem canopy cover and aboveground biomass volumes.

In addition to more accurate aboveground biomass tonnage estimates, TSS also recommends that the alternative fuel conversion activities at Drake Cement be carefully monitored. TSS believes this project has the highest probability of success within the next three to five years of any of the other woody biomass technologies available (tributary to the TSA). TSS was informed that pilot scale testing of biomass at Drake Cement is planned for late summer or early fall 2016.

It is also important to note that Drake Cement currently has a railroad spur to take delivery of coal. Drake Cement has recently opened up capacity in this spur, along with space within its industrial foot print, for lease to other businesses. Drake Cement is located in the heart of Yavapai County's PJ landscape. This spur provides a potential low-cost shipping option for Yavapai County biomass to reach other markets.

At least one landscape products business is interested in juniper as a decay resistant and insect repellant mulch product.[14] More product testing is required, along with market research and market development.

[13] Utilizing National Agriculture Imagery Program Data to Estimate Tree Cover and Biomass of Pinon and Juniper Woodlands. April Hulet, Rangeland Ecology & Management 67(5): 563-572: 2014.
[14] Scotts Miracle Gro, Pers. Comm. May, 2016

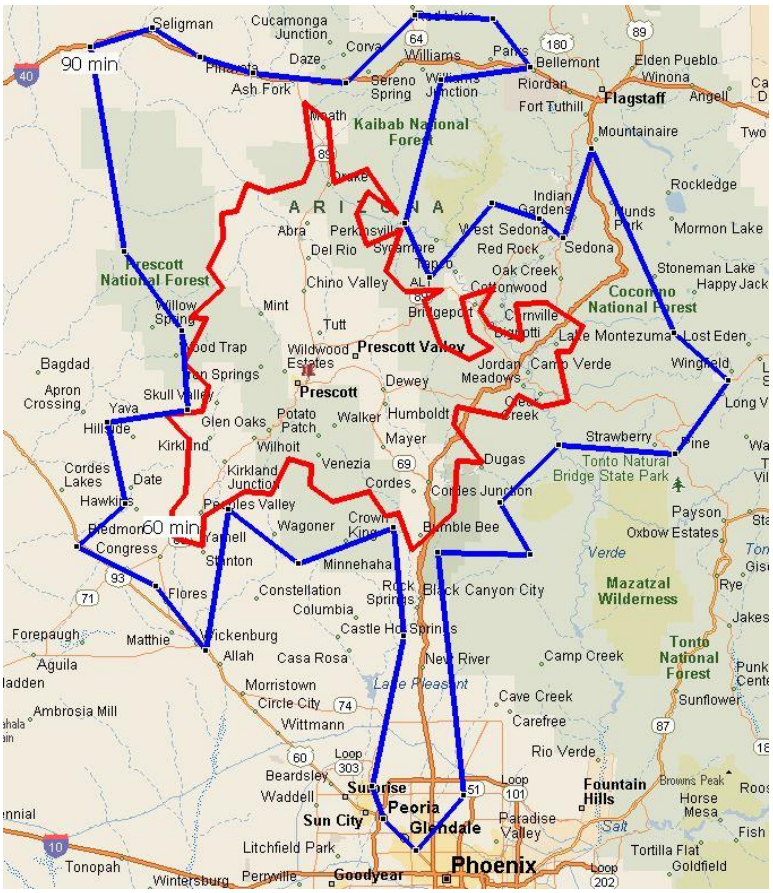
TARGET STUDY AREA AND ENVIRONMENTAL SETTING

The Upper Verde River Watershed Protection Coalition in discussion with TSS staff chose Yavapai County boundaries as the Target Study Area (TSA). For the purposes of this report, biomass feedstock supply and availability were estimated for the area within the Yavapai County TSA.

Yavapai County is approximately 8,128 square miles in size. It had a population of 215,133 in the 2013 census, and the county seat is in Prescott. Yavapai County is located near the center of the state of Arizona, with the metropolitan Phoenix area to the south and Flagstaff to the northeast. Haul distances and drive times from Prescott are shown in Figure 1. The drive time zones are computer generated and reflect a generalized map of areas that can be reached within a 60-minute or 90-minute drive. Much of the TSA can be reached within a 90-minute drive time from the Prescott area.

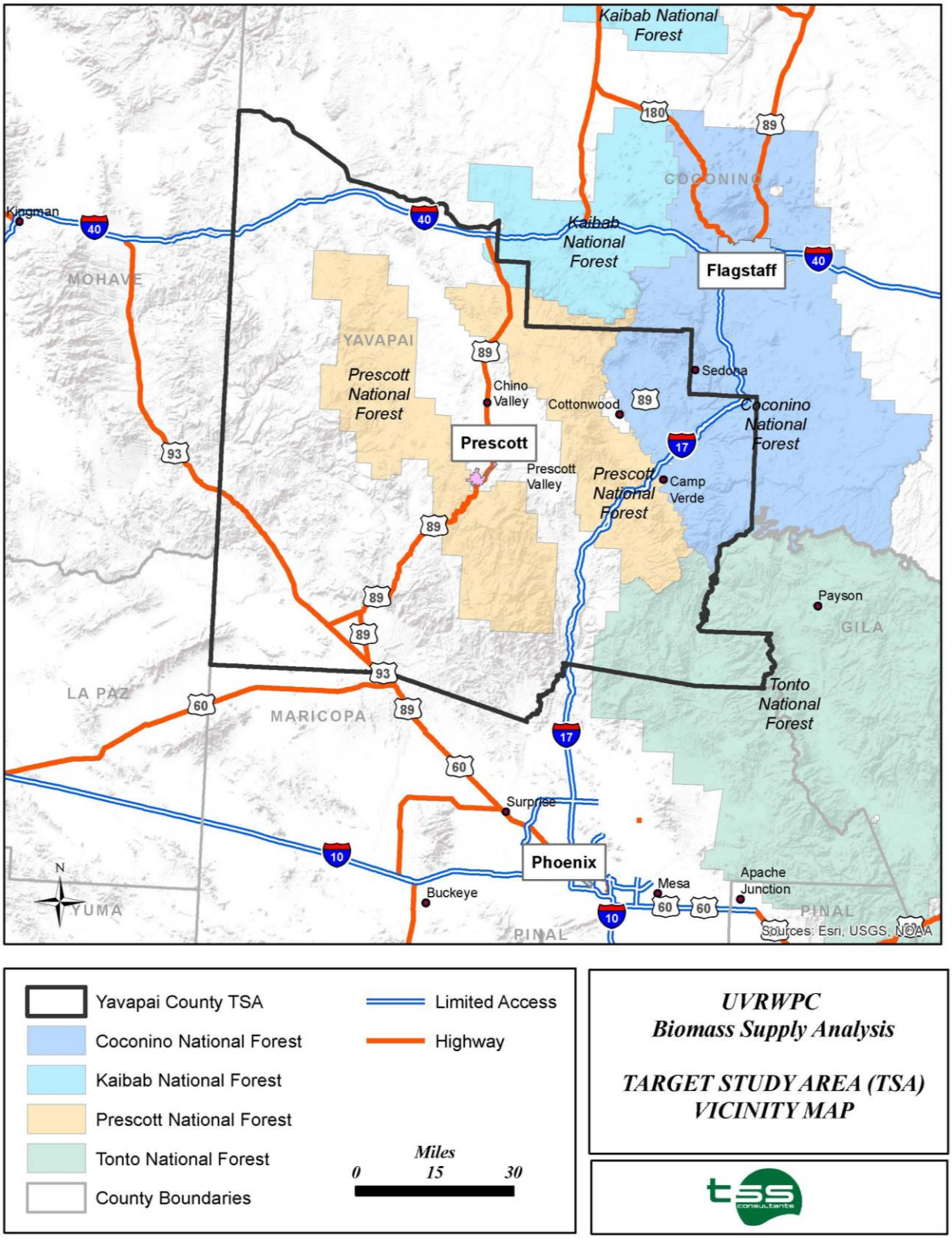
Figure 2 shows the TSA and vicinity. All or parts of four national forests fall within the TSA. Almost all (97%) of the Prescott National Forest is located in the TSA in addition to 24% of the Coconino National Forest, about 11% of the Tonto National Forest and almost 2% of the Kaibab National Forest.

Figure 1. Drive Time Zones Within the TSA from Prescott.



Note: Drive time zones are shown for 60 minutes (red) and 90 minutes (blue).

Figure 2. Target Study Area (TSA) and Region



Map Projection Lambert Conformal Conic; Datum NAD 83

Woody biomass availability for any given region is dependent on vegetation cover and topography, and on land ownership and management objectives. Initial assessment for the TSA characterizes these important factors.

Vegetation Cover

Vegetation cover types for the TSA were mapped using US Geological Survey LANDFIRE 2011 datasets.[15] LANDFIRE existing vegetation (EVT) describes species composition currently present, utilizes USGS GAP Analysis Program vegetation classifications, and includes cross reference lists for Society of American Foresters (SAF) and Society for Range Management (SRM) vegetation cover classes.[16]

The major land cover classes and vegetation cover types in the TSA are tree-covered types (i.e., conifer forest, pinyon-juniper woodland, juniper woodland, oak woodland), shrub-covered types (i.e., shrubland, chaparral, mesquite, desert scrub), and grass-covered types (i.e., native grasslands and grassland-steppe). There are a few scattered riparian areas. Agriculture is limited, although in the classifications system of this report, low-density rural areas, which could be considered small-scale agriculture, are classed under development. Barren indicates sparsely vegetated or rock outcrop terrain. Developed includes high and low density urban areas and roads. The specific plant communities found within each major vegetation class are shown in Table 1. Figure 3 maps the major vegetation cover classes.

Woodlands were dominated by juniper or a mix of pinyon and juniper. The juniper and pinyon-juniper woodlands occupy an elevation range from about 4,500 to 7,500 feet and occur in transition zones from grassland or shrubland at lower elevations to ponderosa pine forests at higher elevations. Juniper is more abundant than pinyon at lower elevations with pinyon dominating at higher elevations. "Pinyon-juniper woodland" is the general vegetation classification name given to these woodlands by most ecosystem classification systems. None of the vegetation classification systems listed above consistently separate juniper dominated woodlands from the more general pinyon-juniper classification. Therefore, juniper woodlands (Madrean or Intermountain Basin juniper savannah) and pinyon-juniper woodlands (Madrean, Great Basin or Colorado Plateau pinyon-juniper woodlands) were grouped for the purposes of discussion in this report. The report uses the term 'juniper and pinyon-juniper' to serve as a reminder that the vegetation under discussion may be dominated by juniper trees in some areas. The term 'pinyon-juniper' was used for brevity, especially in maps and charts.

Desert Scrub occurs in the southern and southwestern portion of the TSA and consists mostly of Sonoran Paloverde-Mixed Cacti Desert Scrub and Sonoran Mid-Elevation Desert Scrub. Chaparral, also called Mogollon Chaparral, can intergrade with pinyon-juniper woodlands and is characterized by manzanita and short oak species. Conifer forest in the TSA is predominantly ponderosa pine often occurring in ponderosa pine savannah or open pine woodland settings.

[15] USGS LANDFIRE: http://www.landfire.gov/index.php

[16] Vegetation units were originally based on NatureServe's Ecological Systems Classification and the National Land Cover Database life form types. Later, USGS GAP analysis classes were added. LANDFIRE data products are created at a 30-meter grid spatial resolution.

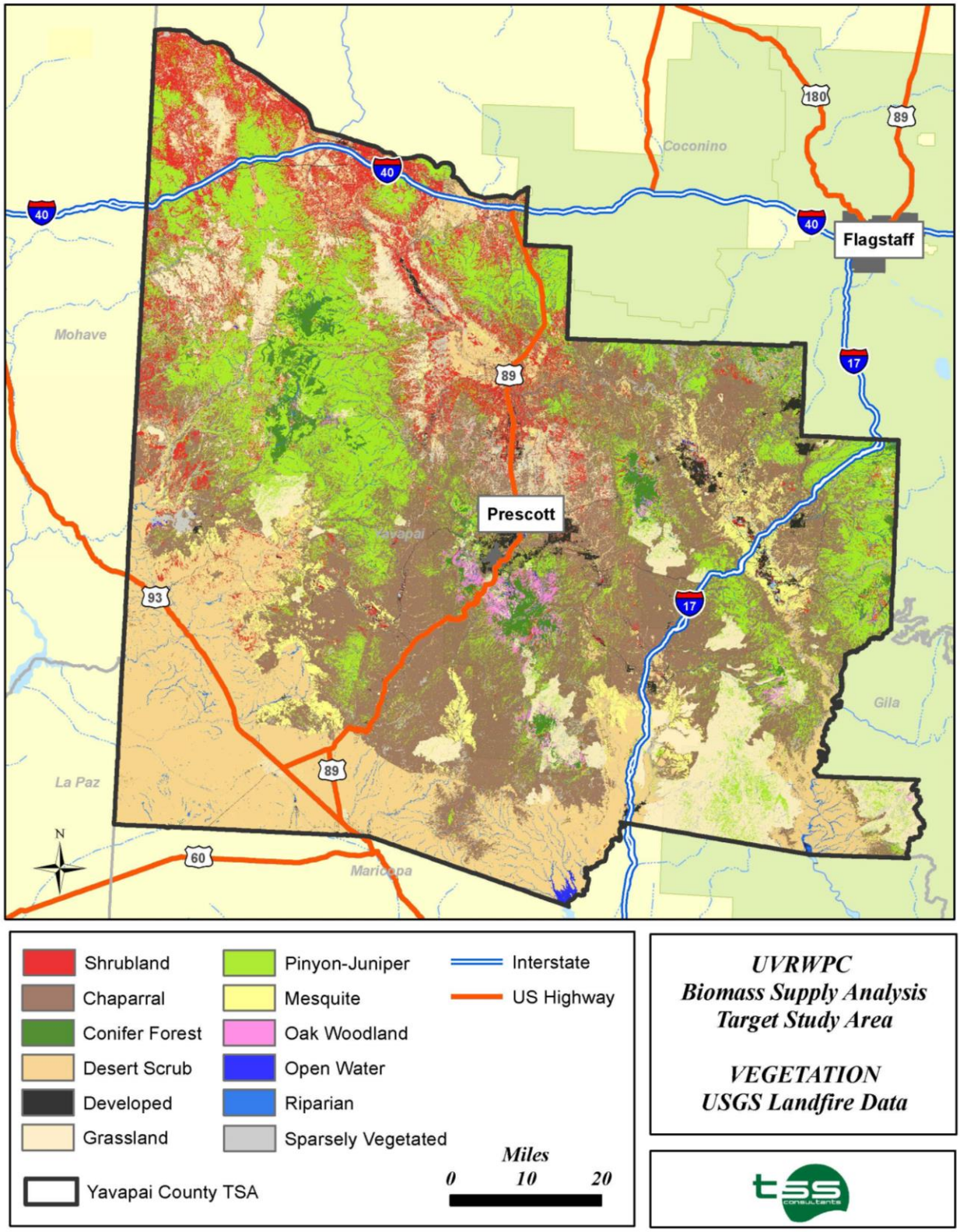
Most of the pinyon and juniper woodlands are to the north of the County's east-west centerline, while most of the Desert Scrub is south and southeast of the County's center.

Table 1. Vegetation Types and Acreage in the TSA

VEGETATION TYPE		TSA		
		ACRES	ACRES	PERCENT
Conifer Forest		**111,313**		2.1%
	Douglas Fir, Grand Fir, White Fir		*598*	
	Douglas Fir, Ponderosa Pine, Lodgepole Pine		*5,055*	
	Ponderosa Pine Forest and Savanna		*105,661*	
Juniper and/or Pinyon-Juniper Woodland		**962,101**		18.5%
	Juniper Woodland and Savannah[17]		*53,872*	
	Juniper - Oak		*6,734*	
	Pinyon-Juniper Woodland[18]		*901,495*	
Oak Woodland		**49,028**		0.9%
Aspen		**285**		<0.1%
Shrubland		**396,180**		7.6%
	Big Sagebrush Shrubland and Steppe		*262,384*	
	Blackbrush Shrubland		*31,037*	
	Deciduous Shrubland		*102,758*	
Chaparral		**1,566,249**		30.1%
Mesquite		**164,647**		3.2%
Desert Scrub		**1,108,395**		21.3%
	Creosotebush Desert Scrub		*52,168*	
	Desert Scrub		*1,002,374*	
	Salt Desert Scrub		*53,853*	
Grassland		**532,493**		10.2%
	Grassland		*360,752*	
	Grassland and Steppe		*143,294*	
	Introduced Annual Grassland		*28,447*	
Riparian		**72,442**		1.4%
Sparsely or Non-Vegetated		**142,631**		2.7%
Open Water		**6,872**		0.1%
Agriculture		**3,865**		0.1%
Developed		**86,037**		1.7%
TOTAL		**5,202,511**		**100.0%**

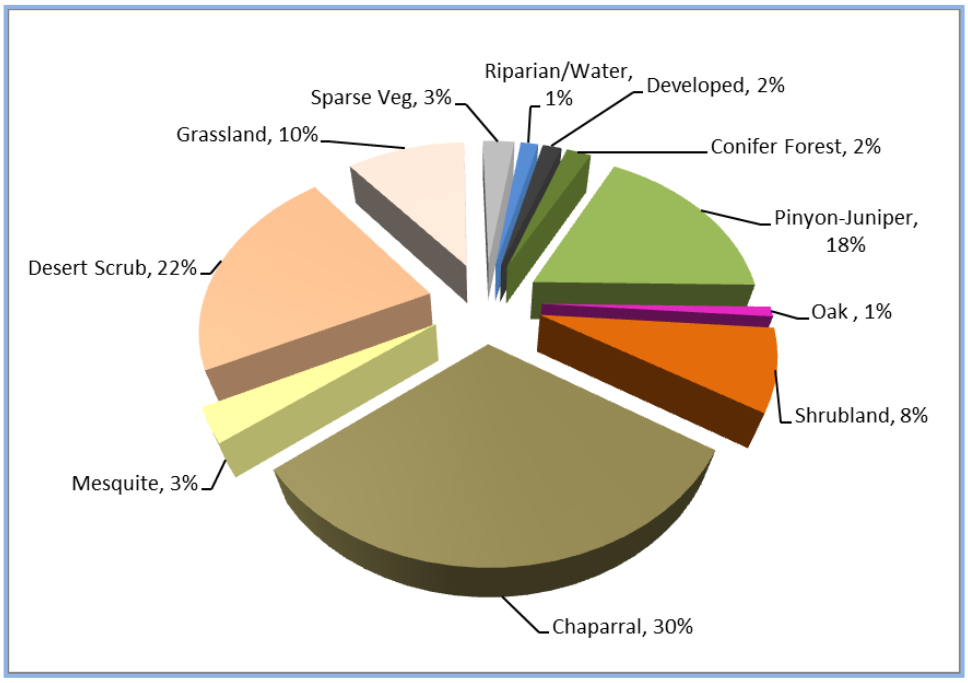
[17] Juniper dominated areas specifically called out as juniper woodland or savannah by SAF and SRM vegetation classification.
[18] Pinyon-Juniper is a general vegetation classification that can include areas dominated by either juniper or pinyon.

Figure 3. Major Vegetation Types in the TSA



Distribution of the vegetation types listed in Table 1 is shown in Figure 4. The distribution chart illustrates the dominance of shrub landscapes and the relative lack of conifer forest. Conifer forest cover accounts for just over 2% of the land area within the TSA. Approximately 59% of the TSA consists of shrublands, desert scrub or chaparral. Juniper and pinyon-juniper woodland occurs on approximately 18% of the TSA. It is important to note that the woodlands are concentrated in the northwest and northeast portions of the TSA rather than being distributed throughout. Although the percent cover of pinyon and juniper woodlands vegetation in the TSA is 18%, the relative portion of woodlands vegetation cover is greater in the areas north of Prescott that are most relevant to the UVWPC.

Figure 4. Vegetation Type Distribution



Topography

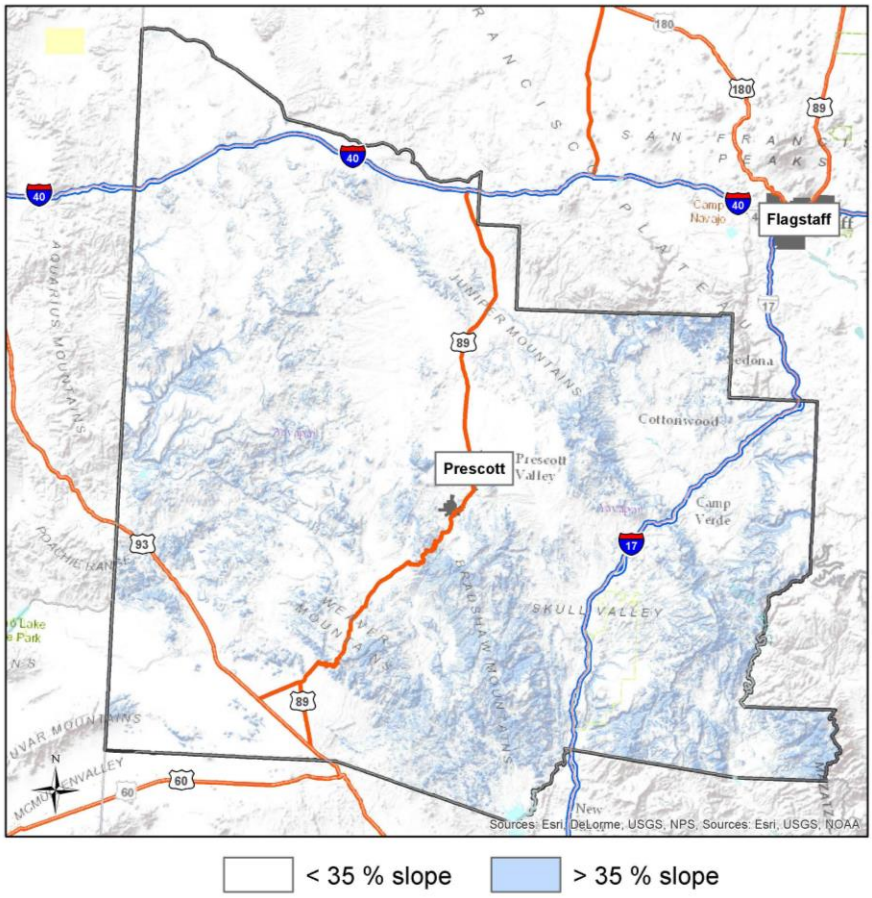
Forest biomass collection activities are generally restricted to topography that will allow ready access for equipment and crew. Steep topography over 35% slope gradient is considered to be the breakoff point for ground-based logging and/or biomass recovery equipment on federally managed lands (USFS and BLM). Private land managers may use ground-based equipment on slopes up to 50%, but the cost of operating on sustained slopes above 35% are quite high and often considered prohibitive. Areas with 35% slope or higher are mapped in Figure 5 (steep slope is shown in blue).

Table 2 summarizes the results of the slope gradient analysis for the conifer forest and juniper woodland landscapes. Approximately 19.8% (22,037 acres) of conifer forest occurs on slopes above 35%. Approximately 15.4% (148,333 acres) of juniper or pinyon-juniper woodlands occurs on these steep slopes.

Table 2. Slope Assessment for Conifer Forest and Pinyon-Juniper Woodlands

COVER CATEGORY	ACRES	
	< 35% SLOPE	> 35% SLOPE
Conifer	80.2%	19.8%
Juniper/Pinyon-Juniper Woodland	84.6 %	15.4%
WEIGHTED AVERAGE	84.2%	16.0%

Figure 5. Areas with Steep Slopes Above 35% Gradient



Land Ownership

Land ownership is important as a driver of vegetation management objectives and therefore the potential supply of biomass feedstock. Ownership of landscapes capable of producing biomass is critical to the long-term sustainable availability of feedstock. Ownership and management jurisdiction directly impact policy, regulations, and management with regard to operations. In forest and woodland ecosystems on privately managed lands, the level of management activity is typically higher and operational limitations are less restrictive. Federal land administration is focused on multiple objectives (e.g., recreation, habitat, fire resiliency) that significantly influence vegetation management and dictate woody biomass availability and quantity.

Table 3 summarizes land ownership acreage within the TSA. Figure 6 maps the major landowner categories (land ownership classes with very small acreages are not mapped because they are not visible at the scale of the entire TSA). The ownership analysis was prepared from spatial data obtained from multiple sources and compiled into an ownership database for the county. Ownership sources include the United States Forest Service (USFS),[19] Bureau of Land Management (BLM),[20] Protected Area Database of the US (PAD-US)[21], Arizona State Land Department,[22] and Yavapai County.[23]

There are over 5.2 million acres within the TSA (Table 3). Land ownership is dominated by public lands. The three major public entity landowners cover 3,857,288 acres or 74% of the TSA (USFS 1,986,295 acres, BLM 604,535 acres, and State Trust Land 1,266,459 acres). The USFS is the largest single landowner with almost 2 million acres. The USFS manages four national forests that fall within the TSA: the Coconino, Kaibab, Prescott and Tonto. The largest is the Prescott National Forest, which covers over 1.2 million acres of the TSA. The Kaibab has only a small corner of the forest extending into the TSA. The State of Arizona has over 1.2 million acres of State Trust lands widely scattered in non-contiguous township and range sections across the northwest section of the TSA or in a large contiguous block in the southwest (Figure 6). Private lands occupy 1,323,123 acres and are often intermingled with State Trust lands. National forest boundaries have complex land ownership patterns containing both federal lands, owned and managed by the USFS, and private lands, owned or managed by private landowners. For lands located within a national forest administrative boundary, acreages for federal and private ownership were kept separate for analyses in this report.[24]

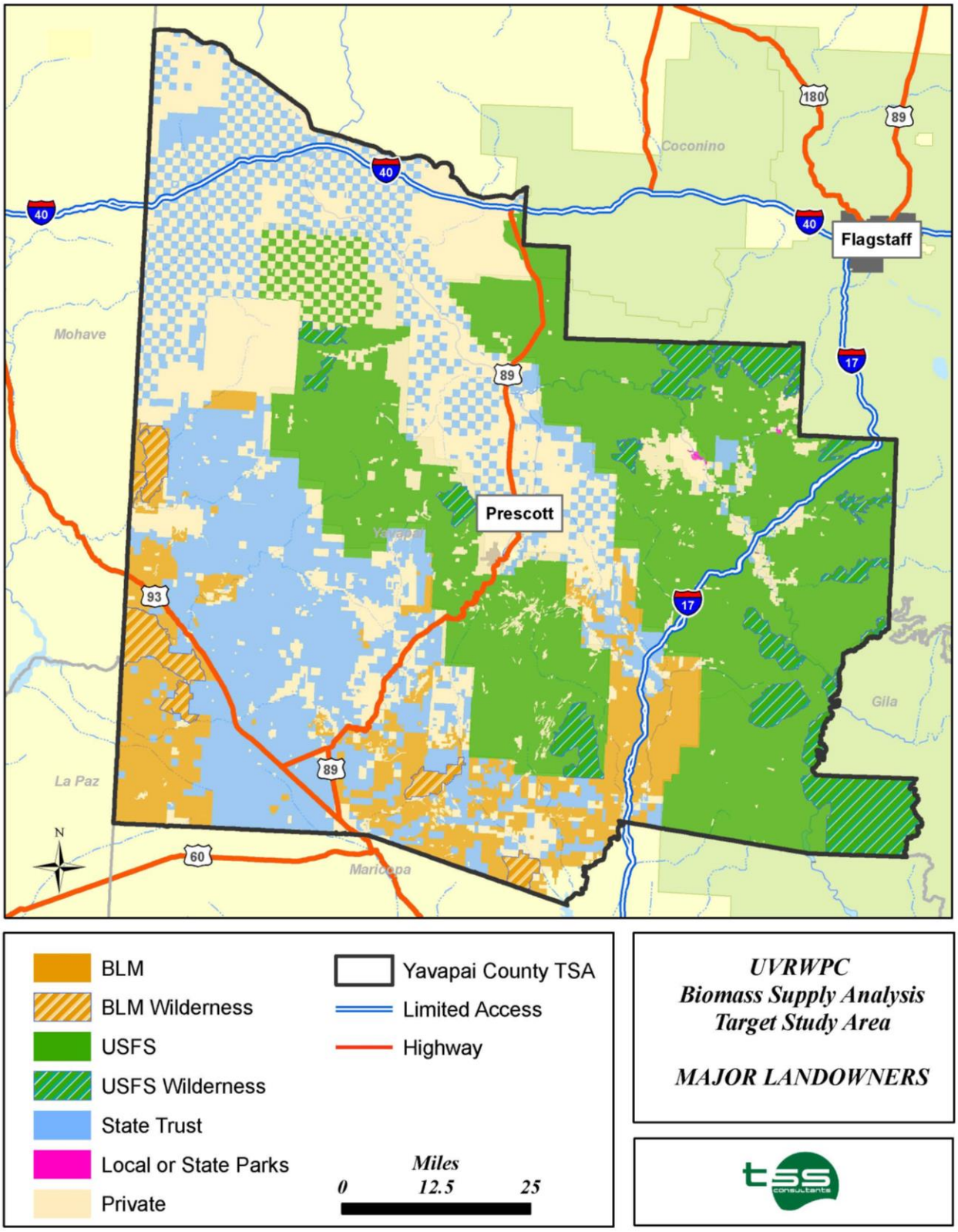
[19] US Forest Service Region 3 Geospatial data; http://www.fs.usda.gov/detail/r3/landmanagement/gis/?cid=stelprdb5202474
[20] Bureau of Land Management Arizona Mapping Products; http://www.blm.gov/az/st/en/prog/maps/gis_files.html
[21] PAD-US; gapanalysis.usgs.gov/padus
[22] Arizona State Land Department GIS Data Sources https://land.az.gov/mapping-services/sco/gis-data-sources
[23] Yavapai County GIS; http://www2.yavapai.us/gis/gis-mapping-applications/
[24] USFS ownership always refers to those lands owned and managed by the Forest Service, not private lands within national forest boundaries.

Table 3. Land Ownership and Acreage in the TSA

OWNERSHIP		TSA		
		ACRES	**ACRES**	**PERCENT**
US Forest Service*		**1,986,295**		38.2%
	Coconino National Forest		*427,379*	
	Kaibab National Forest		*25,422*	
	Prescott National Forest		*1,212,997*	
	Tonto National Forest		*320,497*	
US Bureau of Land Management		**604,535**		11.6%
Arizona State Trust Lands		**1,266,458**		24.3%
State, County or Local		**8,102**		0.2%
	Arizona Game and Fish		*1,023*	
	State or Local Parks		*1,467*	
	County		*5,613*	
Other Federal		**8,996**		0.2%
	Military		*214*	
	Bureau of Reclamation		*8,781*	
National Park Service		**1,364**		<0.1%
	Montezuma Well		*995*	
	Tuzigoot National Monument		*369*	
Native American		**3,136**		0.1%
	Hualapai Indian Reservation		*852*	
	Indian Allotments		*241*	
	Yavapai Apache Indian Reservation		*667*	
	Yavapai Prescott Indian Reservation		*1,376*	
Private		**1,323,123**		25.4%
TOTAL		**5,202,009**		**100%**

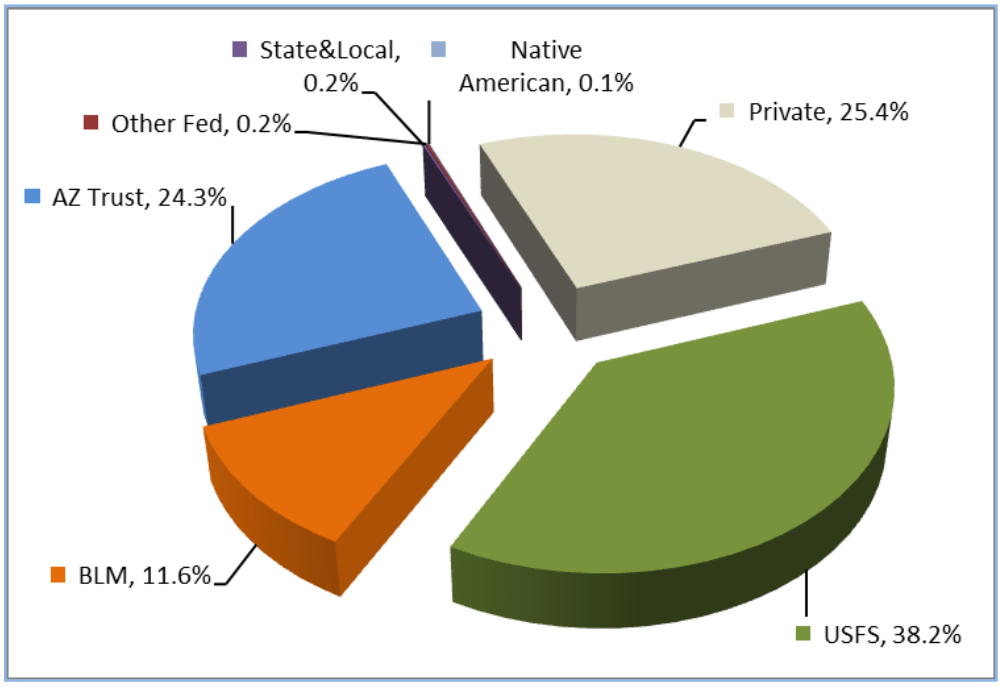
*Acres within the national forest boundary that are under USFS management. Private land acreages within the forest boundary are included under Private.

Figure 6. Major Land Owners in the TSA



Land ownership distribution is shown in Figure 7 using the major landowner categories in Table 3. When Arizona State Trust lands are included, the predominance of government lands is clear. Government lands cover 74.5% of the TSA land base.[25] The USFS has the largest portion of land (38.2%) followed by Arizona State Trust land (24.3%). Private land constitutes about one quarter of the TSA.

Figure 7. Land Ownership Distribution



Exclusions

Table 4 shows lands within the TSA which would likely, but not necessarily, be excluded from management treatments. A conservative approach to exclusions includes all wilderness areas, parks or recreational areas, and other federal lands such as those managed by the Bureau of Reclamation or military. Native American lands were not considered exclusions. The TSA has a total of 373,650 excluded acres.

[25] Arizona State Trust lands are considered government lands in this report, but are not "public lands" as are Federal lands under the management of the U.S. Forest Service or the Bureau of Land Management. Federal public lands are managed for the benefit and use of the public, while State Trust lands are managed for the benefit of 13 Trust beneficiaries which include Arizona public schools and prisons.

Table 4. Potential Exclusions from Biomass Feedstock Availability

OWNERSHIP	EXCLUDED ACRES	TOTAL EXCLUDED ACRES
US Forest Service		**269,480**
Coconino		
Munds Mountain Wilderness	*5,225*	
Red Rock-Secret Mountain Wilderness	*31,935*	
West Clear Creek Wilderness	*8,442*	
Wet Beaver Wilderness	*5,706*	
Sycamore Canyon Wilderness	*26,510*	
Prescott, Tonto		
Cedar Bench Wilderness	*15,990*	
Pine Mountain Wilderness	*20,030*	
Prescott		
Apache Creek Wilderness	*5,628*	
Castle Creek Wilderness	*25,427*	
Granite Mountain Wilderness	*9,798*	
Juniper Mesa Wilderness	*7,559*	
Woodchute Wilderness	*5,881*	
Coconino, Tonto		
Fossil Springs Wilderness	*2,852*	
Mazatzal Wilderness	*98,497*	
US Bureau of Land Management		**85,708**
Arrastra Mountain	*32,820*	
Hassayampa River Canyon	*12,186*	
Hells Canyon	*10,351*	
Tres Alamos	*8,347*	
Upper Burro Creek Wilderness	*22,004*	
State, County or Local	*8,102*	**8,102**
Other Federal	*8,996*	**8,996**
National Park Service	1,364	**1,364**
EXCLUSION TOTAL		**373,650**

Vegetation and Land Ownership

Table 5 summarizes land ownership for the vegetation types most likely to generate suitable woody biomass: conifer forest and juniper or pinyon-juniper woodland. Percentages are calculated as percent of the forest or woodland acreage occurring on lands owned by the BLM,

USFS, private landowners, or Arizona State Trust. The total does not sum to 100% because there are a few acres owned by other federal agencies (e.g., National Park Service). Conifer forest occurs predominantly on lands managed by the USFS at 76.4%, although private landowners own almost 22% of conifer forest in the TSA. The majority of pinyon-juniper woodlands, almost 57%, occur on USFS lands. State Trust lands do not have conifer forests, but about 15% of pinyon-juniper woodlands occur on state ownership. The BLM is not a significant land manager for vegetation with the potential to produce woody biomass.

Table 5. Vegetation by Land Owner

	PINYON-JUNIPER WOODLANDS		CONIFER FOREST	
OWNERSHIP	**ACRES**	**PERCENT**	**ACRES**	**PERCENT**
BLM	14,984	1.6%	11	<0.1
USFS	546,247	56.8%	85,094	76.4%
Private	247,848	25.8%	24,256	21.8%
State Trust	148,299	15.4%	1,780	1.6%
TOTAL	**957,377**	**99.5%**	**111,142**	**99.8%**

BIOMASS FEEDSTOCK SUPPLY AVAILABILITY

Based on the vegetation cover types described in the previous section, TSS estimated the available biomass that could be generated within the TSA. The feedstocks considered in this analysis include forest and woodland sourced material and urban wood waste:

- Timber harvest residuals from sawlog harvest operations (limbs, tops, and small diameter stems typically considered non-commercial).
- Forest management, hazardous fuels or restoration project removal of small diameter trees (considered submerchantable).
- Treatment of juniper or pinyon-juniper woodlands for restoration purposes.
- Urban wood waste (tree trimmings, pallets, clean construction wood).

Methods

Feedstocks considered in this analysis include forest and woodland sourced material (referred to as forest-sourced) and urban wood waste (referred to as urban sourced). For all biomass sources, TSS has estimated a potentially, technically, and economically available volume.

The potentially available volume is the total amount of biomass estimated to be produced annually. It is worth noting that for the forest-sourced analysis, this is not a potential amount based on standing inventory in national forests or on private lands. Rather it is the amount actually being produced by public and/or private landowners that is used to estimate future annual availability.

Recoverable biomass is judged to be technically available considering physical constraints such as terrain (steep slopes), transport (road systems that support removal) or policy constraints (environmental regulation, wilderness). For example, not all road systems will accommodate biomass recovery operations and access by harvest equipment or biomass transport by chip vans. Slope gradient has a significant impact on both forest road layout and on the ability to perform biomass processing and collection operations.

Economical biomass is the amount available considering existing competition for the wood waste. Economically available biomass in this report is not an analysis of costs and profitability. Rather it is the amount of biomass that is available considering other biomass users and industries that source biomass from within the TSA.

Forest and Woodland Sourced Biomass

The primary forest-sourced biomass consists of the residues or slash (limbs, tops) generated during timber harvest operations. This low-value residue is typically a byproduct of timber harvesting activities and as such is heavily dependent upon higher-valued markets such as sawlogs, poles, posts or pulpwood to carry the cost of timber extraction. The higher-valued markets essentially subsidize the cost of collection and concentration of the biomass material. Due to the low value of biomass, it is critical that operators have higher margin products to keep their operations profitable. According to the Prescott National Forest Monitoring and Evaluation

Report,[26] the existing timber industry infrastructure is sufficient to actively participate in timber sales and service contracts that are offered by the forest. TSS believes this timber harvesting infrastructure and higher-valued markets are critical for the generation of any forest-sourced biomass.

In addition to harvesting infrastructure, another important consideration for forest biomass production is operating season. For most of the TSA, the operating season is year round with occasional shutdowns for wet weather in the winter and the summer monsoon period (mid-June through mid-September). TSS was informed that the typical operating period is 300 days per year, with longer shutdowns often occurring in the pinyon-juniper woodlands due to poorly draining soils.

Timber Harvest Residuals

Timber harvest residuals can provide significant volumes of woody biomass material. Typically available as limbs, tops and unmerchantable logs,[27] these residuals are byproducts of commercial timber harvest operations. As such, residuals have very limited market value though they can be a relatively economic raw material feedstock source for end uses such as soil amendment (e.g., compost), or bioenergy production (e.g., power or thermal energy). In addition, top wood can be utilized as chip logs if the pulp/paper market values support the additional costs to delimb, load and transport. Landowner analysis shows the majority (about 75%) of conifer forest occurs on USFS managed lands. There is neither a significant nor a consistent supply of commercial timber harvest from private landowners in the TSA.[28]

Timber harvest activity on USFS land is reported by the USFS in Cut and Sold Reports.[29] Cut and Sold Reports show total volumes and values of all convertible forest products sold and harvested from the National Forest System lands. The data is made available quarterly and annually for every national forest. Cut volumes are reported in hundred cubic feet (CCF) and thousand board feet (MBF).[30] A review of the 2011 through 2015 cut and sold data was conducted to quantify previous timber harvest activities within the TSA. Table 6 shows results for timber harvested in the Coconino, Kaibab, Prescott and Tonto national forests for a five-year period from FY 2011 to FY 2015 expressed in MBF per year.

[26] Prescott NF – Forest Plan Monitoring & Evaluation Report 2015.
[27] Unmerchantable logs are typically too small or defective (diseased or dead) for manufacturing into lumber.
[28] Personal communication, Patrick Rappold, Arizona Department of Forestry and Fire Management.
[29] USFS Forest Products, Cut and Sold Reports: http://www.fs.fed.us/forestmanagement/products/sold-harvest/cut-sold.shtml
[30] MBF = thousand board foot measure. One board foot is nominally 12" long by 12" wide and 1" thick.

Table 6. USFS Cut and Sold Reports Five-Year Timber Harvest Volume

FOREST	FY2011 (MBF/YR)	FY2012 (MBF/YR)	FY2013 (MBF/YR)	FY2014 (MBF/YR)	FY2015 (MBF/YR)	AVERAGE (MBF/YR)
Coconino National Forest						
Sawtimber	6,196	6,050	4,937	5,277	7,541	6,000
Pulpwood	2,661	920	2,010	2,287	1,566	1,889
Poles	13	67	38	119	51	58
TOTAL	8,870	7,037	6,985	7,683	9,158	**7,947**
Kaibab National Forest						
Sawtimber	6,986	5,124	3,545	6,588	6,322	5,713
Pulpwood	775	1,033	1,117	1,207	2,520	1,330
Poles	21	16	9	17	31	19
TOTAL	7,782	6,173	4,671	7,812	8,873	**7,062**
Prescott National Forest						
Sawtimber	1,682	2,758	1,106	987	2,077	1,722
Pulpwood	370	545	255	201	876	449
Poles	0	32	51	33	16	26
TOTAL	2,052	3,335	1,412	1,221	2,969	**2,198**
Tonto National Forest						
Sawtimber	589	955	397	269	3,999	1,242
Pulpwood	11	3	0	56	975	209
Poles	11	2	2	2	0	3
TOTAL	611	960	399	327	4,974	**1,454**

USFS utilization specifications in Region 3 identify sawtimber to be trees greater than 9 inches diameter breast height (DBH). Pulpwood trees range from 5 to 9 inches DBH. Poles are typically sold for utility lines. There is a growing utility pole market in Mexico.[31] In Arizona this class of timber may also be sold for use as vigas in home building. Poles vary in size but are not smaller than 9 inches DBH and follow the same utilization specifications as sawtimber.

Estimating timber harvest volume within the TSA requires apportioning the forest level data to reflect the amount of forest located within the TSA boundary. Geographic Information System (GIS) analysis is used to calculate these acreages. About 97% of the Prescott National Forest, 24% of the Coconino, 10.8% of the Tonto, and 1.6% of the Kaibab lie within the TSA. Timber harvest weighted average volume shown in Table 7 was estimated using average timber harvest volume (Table 6) multiplied by percent of the national forest within the TSA. Forest Industry Research, Bureau of Business and Economic Research (FIR-BBER), University of Montana, assisted TSS with applying a logging residuals factor for commercial timber harvests in the

[31] Personal communication, Patrick Rappold, Arizona Department of Forestry and Fire Management.

ponderosa pine and Douglas fir-mixed conifer stands found in the TSA.[32] The estimate for green tons (GT) of logging residue produced by commercial harvesting operations was made using both the Timber Products Output (TPO) database and a current field study of logging utilization in New Mexico (New Mexico ponderosa pine forests are similar to those in the Prescott and Coconino).[33] The FIR-BBER analysis indicates approximately 1.57 green tons, or 0.8 BDT, of residue are generated for every MBF of harvest in these forests. Table 7 applies this woody biomass residue factor to the timber harvest volume estimates and calculates timber harvest residuals in BDT/year.

Table 7. USFS Average Annual Timber Harvest Volume and Residuals in the TSA

NATIONAL FOREST	PERCENT IN TSA	TIMBER HARVEST WEIGHTED AVERAGE (MBF/YR)	TIMBER HARVEST RESIDUALS (BDT/YR)
Coconino	23.6%	1,877	1,501
Kaibab	1.6%	114	91
Prescott	96.9%	2,129	1,703
Tonto	10.8%	158	126
TOTAL		**4,277**	**3,421**

Per the methods described above, TSS has estimated a potentially, technically and economically available volume for timber harvest residuals. Total biomass feedstock available from harvest residuals is 3,421 BDT/year (Table 8). TSS estimates that 60% of the total would be practically available to chipping equipment and vans due to environmental constraints such as steep slopes and limited road access. The adjustment for competing uses represents an estimate of residuals taken from the forest by local community members for firewood.

Table 8. Timber Harvest Residuals Summary

SOURCE	TIMBER HARVEST RESIDUALS (BDT/YEAR)
Coconino	1,501
Kaibab	91
Prescott	1,703
Tonto	126
POTENTIALLY AVAILABLE	3,421
ADJUSTMENT FOR RECOVERY	-1,368
TECHNICALLY AVAILABLE	2,053
ADJUSTMENT FOR COMPETING USES	-500
ECONOMICALLY AVAILABLE	**1,553**

[32] Forest Research Institute, http://www.bber.umt.edu/FIR/Default.asp, and personal communication and report prepared by Eric Simmons, June 24, 2016.
[33] Ibid, and "Logging Utilization in New Mexico," Sacramento Mountain Wood Industry Summit presentation by Eric Simmons.

Forest Management and Restoration

One of the largest land management organizations in the TSA is the Prescott National Forest, with management responsibility for over 1.2 million acres. As such, TSS believes that a key driver of land management activities within the TSA is the Prescott National Forest Plan. According to the Prescott National Forest Monitoring and Evaluation Report in FY 2015, the forest began a 3-year hazardous fuels reduction project in the Prescott Basin. Known as the Prescott Basin Cross Boundary Project, this $2.2 million program is expected to annually treat 1,750 acres of federal land. These treatments include prescribed fire, mastication, and hand thinning. Over the past 10 years, the Prescott National Forest has treated approximately 3,900 acres in the pine vegetation types, but only about 12% (468 acres) of this area has actually been treated as an intermediate timber harvest. In fact, since 2000 the Prescott National Forest has only offered and sold one timber sale per year. It is obvious that timber production and biomass fuel generation from the conifer forest vegetation types of the TSA currently produce very limited volumes of biomass. During fiscal year 2015, the Prescott National Forest sold almost as much firewood as sawlogs, further confirming the conclusion that timber production within the TSA is not a significant factor in woody biomass availability.

Some forest biomass is removed as a result of forest management and fuels treatment activities within the TSA. Treatments are typically conducted as a result of federal and state funding allocations. Funding can be inconsistent and so too are the acres treated. For the purposes of this assessment, TSS forecasts 1,500 BDT per year of biomass material as potentially available. Due to terrain and road conditions, about 65% of this material is recoverable and considered technically available. Some of this material will be utilized as firewood, with about 800 BDT per year considered economically available.

Juniper and Pinyon-Juniper Treatment

Juniper and pinyon-juniper woodlands cover approximately 962,101 acres or 18% of the TSA. The extensive acreages of juniper and pinyon-juniper woodlands within the TSA are the most likely sources of any significant woody biomass. For decades, these vast areas of juniper and pinyon-juniper covering much of the Southwest United States have been the subject of research and study. However, simply considering the tremendous acreage covered by this vegetation type is not enough. The low volumes of biomass per acre, the slow growth rates, and the wide variation in shape and size of the trees make it a difficult woody biomass source to assess.

Woodland tree species have not traditionally been utilized by the wood products industry. Forestry research on their abundance and distribution, and on attributes such as density - number of stems per acre, or volume - aboveground biomass, have only recently become of interest. Estimation of biomass feedstock supply in the TSA from the removal of woodland species requires input of two variables: 1) an estimate of the acreage intended for pinyon or juniper tree removal under forest management projects in the TSA, and 2) an estimate of BDT per acre that could be removed as a byproduct from these treatments. These noncommercial woodland species, (juniper and pinyon), lack a merchantable bole which makes traditional forestry measurements in cubic feet difficult if not impossible. TSS believes that the more accurate approach for dealing with juniper and pinyon-juniper woodlands is to utilize metrics that focus on aboveground biomass weight when estimating usable woody material.

Juniper and Pinyon-Juniper Treatment Projects in the TSA

Within the TSA there have been numerous pinyon-juniper treatment projects, the majority of which have occurred on state and private lands. TSS is not aware of any treatments involving the actual removal of pinyon-juniper on a large scale. Within the Chino Valley Ranger District, the Wagontire Juniper Treatment project is thinning 1,108 acres. On private land, the National Resources Conservation Service estimated approximately 1,500 acres of juniper treatment at a cost of approximately $160 per acre. Under Arizona State Trust land management regulations, pinyon and juniper biomass must go through a procedure to estimate its value before removal. Although federal and private ownerships make up over 82% of juniper or pinyon-juniper woodlands within the TSA, State Trust lands have 148,295 acres or 15% of woodlands ownership. Future efforts regarding State Trust policy to be make PJ removal activities easier would be of ecological and economic benefit to the region. As the acreage data above indicates, juniper and pinyon-juniper treatment projects and biomass removal is limited. Firewood is the largest end-use, accounting for an estimated 5,366 cords sold[34] from the Prescott National Forest in 2015. However, data on private land restoration and treatment projects, or on private and commercial pinyon-juniper harvest for firewood, were not available despite TSS attempts to interview contractors.

Perhaps the most informative data related to pinyon-juniper treatment and removals in the TSA are two small-scale demonstration projects that have occurred during the past six years. Beginning in 2010-2012 with an American Recovery and Reinvestment Act grant to investigate biomass utilization at the Drake Cement facility near Paulden, Arizona, and the Savannah-Grasslands Pre-Investment Pilot Project this past spring 2016, these projects actually assessed the weight and volume of biomass potentially available from woodlands within the TSA.

Estimation of Juniper and Pinyon-Juniper Volume

A number of previous and ongoing studies have examined factors related to potential volumes achieved with pinyon-juniper and juniper removal. These studies look at either 1) stems per acre as a measure of density, 2) percent cover as a measure of density, 3) aboveground standing biomass, or 4) harvest and weight of removed trees. Estimates of these properties vary widely as shown in the following brief overview. Although some of the variability can be attributed to methodology, the greatest sources of variability are environmental and historic. Tree size and density is often a factor of climate, elevation, slope and aspect, and soil conditions. Tree density is also a function of the historic rate of encroachment into grasslands, disturbance by fire, and stand age.

Examples of research studies are listed below to provide a brief overview of work in the region and supply a range of values used by this report for estimating biomass feedstock supply.

- USFS Interior West Forest Inventory and Analysis (IW FIA) Forest Attribute Mapping. The USFS IW FIA produced a spatial database of map products for a variety of forest attributes including forest type/forest group and forest biomass.[35] The attributes are

[34] Prescott NF – Forest Plan Monitoring and Evaluation Report Fiscal Year 2015, USDA Forest Service, Southwest Region.
[35] IW FIA Map Products, http://www.fs.fed.us/rm/ogden/map-products/intwest/iwmaps.shtml

modeled at a 250 m^2 resolution from FIA plot data combined with satellite remote sensing and environmental variables. TSS used these geospatial products for GIS analysis in the TSA. The pinyon-juniper forest type group within the TSA was isolated and extracted. Forest biomass, defined as live tree above ground weight and expressed in BDT per acre, was then analyzed for the pinyon-juniper group. The range for pinyon-juniper biomass is quite large, as would be expected, and extends from 1.03 to 39.58 BDT/acre. However, when broken into classes using Jenks natural breaks,[36] higher estimates of biomass per acre are rarer, and biomass of less than 11.92 BDT/acre accounts for over three quarters (77%) of the pinyon-juniper woodland area; biomass ranging from 5.7 to 11.9 BDT/acre occurs on two thirds (64%) of the land considered to be pinyon-juniper forest group type; biomass ranging from 5.72 to 9.95 BDT/acre occurs on almost half (48%) of the land considered to be pinyon-juniper forest group type.

These amounts represent BDT per acre calculated from live standing tree biomass. Translating aboveground standing biomass values directly into BDT of harvested biomass feedstock is not well researched, but it is assumed that harvested feedstock volumes are lower.

- USFS Forest Resources of the Prescott National Forest. The IW FIA conducted forest resource inventories in the Southwestern Region in 1996 and reported on highlights of the Prescott National Forest inventory.[37] Aboveground biomass in dry tons per acre calculated from FIA measured field plots was 5.6 tons/acre for pinyon-juniper stands and 5.0 tons/acre for juniper stands.[38] Translation of these estimates into BDT of harvest is not available.

- Drake Biomass Utilization Accomplishment Report. The Drake Biomass Utilization ARRA grant was awarded to Arizona State Forestry and Prescott Area Wildland Urban Interface Commission (PAWUIC). One of the grant's primary goals was evaluation and development of vegetation harvesting methods on juniper woodlands in the Prescott area. The study is unique in that the vegetation harvesting trials included information on vegetation density, and data collection included the actual weighing of tree biomass removed. Biomass removals are presented in BDT/acre. Biomass removed from the eight sites are: Maughan Ranch, Peeples Valley, 1.8 BDT/acre; Maughan Ranch, Wilhiot, 2.52 and 5.8 BDT/acre; Sorrels Ranch, 6.9 BDT/acre; Wagontire demonstration at Paulden, 17.6 BDT/acre for three different locations; and Drake Quarry, 16.3 BDT/acre. The differences in BDT/acre removed across these sites represent variation in pinyon-juniper size and density and to some lesser extent, differences in the harvest methods applied.

- Southwest Forestry Juniper Density Project. Southwest Forestry (Richard Van Demark) made ocular estimates of juniper density for five hydrologic units in the Big Chino

[36] Classification method that determines how to break a range of data into classes; minimizes variance within a class and maximizes variance between classes
[37] USFS Rocky Mountain Research Station, Forest Resources of the Prescott National Forest, 2003, http://www.fs.fed.us/rm/ogden/pdfs/prescott.pdf
[38] Ibid, Table 3.

watershed sub-basin on private and State Trust lands. Satellite imagery was used to delineate low, moderate and heavy woodland tree or brush stocking on individual 640 acre sections. Low, moderate and heavy stocking were not correlated to stems per acre, but rather done by eye on a relative scale. For each satellite image, the percent cover of the three woodland stocking classes plus grassland sum to 100 percent. Juniper is the most common woodland type across the study landscape, but some areas of 'mixed brush' shrubs were included. The average woodland tree density across the 53,845 acres that were delineated is approximately 10% grassland (5,323 acres), 63% low-density woodland (33,861 acres), 25% medium-density woodland (13,778 acres) and 2% (883 acres) high-density woodland. Future work by the project will install field sample plots and link density estimates to operating costs for biomass removal.

- In spring 2016 the Savannah-Grasslands Pre-Investment Pilot Project[39] conducted a mechanized juniper thinning project within the Upper Verde River Watershed. Utilizing Scandinavian mechanized harvesting and forwarding equipment, the project attempted to develop estimates of the tonnage of biomass per acre and the costs associated with removal. While the data is still being reviewed from this project, TSS estimates that between 5 BDT to 7 BDT of biomass are available per acre within this mixed juniper and pinyon-juniper vegetation type.

- Discussions with a current juniper biomass user in the Snowflake AZ area[40] indicated a range of 2 green tons/acre (GT/acre)[41] to 10 GT/acre with an average of 5 GT/acre. Assuming an average harvested moisture content of 30%, this would equate to 3.5 BDT/acre to 7 BDT/acre. While these harvest sites are outside of the TSA, it does provide some useful real world operational data.

- Charles Grier at Northern Arizona University, School of Forestry, evaluated the aboveground biomass distribution of pinyon-juniper woodlands in north central Arizona.[42] This research examined the aboveground biomass for a 90 year old pinyon-juniper stand and a 350 year old pinyon-juniper stand located near Winona, Arizona on the Coconino Plateau. Although outside of the TSA, this data is useful for comparative purposes. Results of this research found that the 90 year old stand contained approximately 10 GT/acre and the 350 year old stand contained approximately 24 GT/acre. Assuming 30% moisture content, this equates to 7 BDT/acre and 16.8 BDT/acre respectively.

- One of the more thorough overviews of juniper woodland biomass volumes that TSS reviewed as part of this project was work by the Bureau of Land Management (BLM).[43] While this data covered the Great Basin area of Nevada, it did provide specific biomass

[39] Savannah-Grasslands Pre-Investment Pilot Project, Southwest Forestry Inc, D.R. Systems NW, Inc., June 30, 2016.
[40] Pers. Comm. with Brad Woorsley, General Manager of Novo BioPower, June 2016.
[41] One green ton = 2,000 pounds of wood fiber with no adjustment for moisture content.
[42] Biomass distribution and productivity of Pinus edulis-Juniperus monosperma woodlands of north-central Arizona. Grier, C.C. et al, 1992. Forest Ecology and Management, 50 (1992) 331-350.
[43] Guide for Quantifying Fuels in the Sagebrush Steppe and Juniper Woodlands of the Great Basin. Andrea Stebleton, Stephen Bunting. 2009 Technical Note 430 BLM/ID/PT-09/002+2824.

volumes by juniper species. Using canopy cover designations of Phase I (< 10% canopy cover), Phase II (10% to 30% canopy cover) and Phase III (> 30% canopy cover), this guide provides an estimate of fuel loading per acre. Fuel loadings for Phase I are estimated at 3.5 BDT/acre, Phase II 10.2 BDT/acre, and Phase III 23.0 BDT/acre. For the Great Basin area it is estimated that approximately 34% of the juniper and pinyon-juniper woodlands are considered Phase I, 40% Phase II, and 27% Phase III. Combining this data results in an average fuel loading of 11.5 BDT/acre. It should be noted that multiple field studies have found strong linear relationships between individual tree canopy cover and aboveground biomass.[44]

- Land managers in northeastern California has been harvesting western juniper for use as biomass fuel on and off for over two decades. Discussions with chipping contractors in this region indicate a range of 7.5 BDT/acre to 13 BDT/acre. Obviously this region is located some distance from the TSA and is a different species of juniper entirely; however, the average does fall within the high end of the volumes per acre for Arizona.

Table 9 provides an overview of the research projects listed and described above. The studies do not measure the same attribute of juniper and pinyon-juniper stands. Some studies measure volume (weight or mass) of biomass either standing live or after harvest. Some studies estimate density using stems/acre or ocular percentages.

[44] Utilizing National Agriculture Imagery Program Data to Estimate Tree Cover and Biomass of Pinion and Juniper Woodlands. April Hulet, Rangeland Ecology & Management 67(5): 563-572: 2014.

Table 9. Overview of Juniper and Pinyon-Juniper Biomass Research

	ATTRIBUTE ESTIMATED		
STUDY	**VOLUME STANDING BDT/ACRE**	**VOLUME HARVESTED BDT/ACRE**	**DENSITY**
USFS IW FIA Forest Attributes	5.7 to 9.5		
USFS Prescott National Forest	5.0 to 5.6		
Drake Biomass Utilization Report		1.8 to 17.6	
Southwest Forestry Juniper Density			63% low, 25% moderate, 2% high
Savannah-Grasslands Pre-Investment Pilot Project		5.0 to 7.0	
Novo BioPower, Snowflake AZ		3.5 to 7.0	
Winona, AZ Research Study	7 to 16.8		
BLM Quantifying Fuel Loading in the Great Basin	11.5		Phase I canopy cover <10% Phase II canopy cover 10%-30% Phase III canopy cover >30%
Western Juniper, Northeastern CA		7.5 to 13.0	

Based on the research and studies reviewed, TSS estimates that between 4.7 and 10.6 BDT/acre of biomass are available from the juniper and pinyon-juniper woodlands within the TSA. Furthermore, TSS estimates that between 2,500 and 3,300 acres of these woodlands are currently treated per year across public and private lands within the TSA. Table 10 summarizes a low range and high range of biomass supply from pinyon-juniper woodlands.

Table 10. Juniper and Pinyon-Juniper Treatment Summary

STUDY	**LOW RANGE**	**HIGH RANGE**
Acres of Pinyon-Juniper Treated	2,500	3,300
BDT/Acre of Removal Biomass	4.7	10.6
TOTAL (BDT/Acre * Acres)	**11,750**	**34,980**

Based on this review, TSS believes that very little of this potentially available biomass is currently removed from the site. Using the mid-point figure of this range, TSS estimates that approximately 23,365 BDT[45] of juniper and pinyon-juniper biomass is potentially available annually. However, due to technical and environmental constraints, TSS assumes that only about 65% of this volume, about 15,187 BDT/year would be technically available.

[45] The midrange of potentially available feedstock is 23,365 BDT: (11,750 + 34,980)/2.

Summary of Forest and Woodland Sourced Biomass Availability

Table 11 summarizes the sources of forest-sourced biomass. The annual volume of 17,540 BDT/year of forest-sourced biomass material is considered technically available in the near term of the next three to five years. TSS is aware that regional stakeholders (including the Coalition) would like to see a significant increase in the pace and scale of forest and woodland treatments. Assuming that value-added uses for residuals produced are expanded as a result of forest and woodland treatments (possibly as a result of the 4FRI project), and there is additional state and federal funding available to support landscape-level treatments, there could be opportunities to ramp up treatments in the longer-term of six to ten years. This increased pace and scale could double or triple the annual technically available volume.[46]

Table 11. Summary of Forest and Woodland Sourced Biomass

SOURCE	POTENTIALLY AVAILABLE (BDT/YEAR)	TECHNICALLY AVAILABLE (BDT/YEAR)	ECONOMICALLY AVAILABLE (BDT/YEAR)
Timber Harvest Residuals	3,421	2,053	1,553
Forest Management and Fuels Removal	1,500	975	800
Juniper and Pinyon-Juniper Woodlands Treatment	23,365	15,187	15,187
TOTAL	**28,286**	**18,215**	**17,540**

Urban-Sourced Biomass

The municipal solid waste stream generates woody biomass debris. This comes in several different forms including crating and packaging materials, residential construction and cleanup, and commercial and industrial wood waste such as pallets. In addition, yard waste (consisting of prunings and small branches) is also generated. TSS observed several collection sites around the county where this urban wood waste was stockpiled. Periodically the county brings in a Vermeer Horizontal Grinder (owned by the Prescott Area Wildland Urban Interface Commission) to process this material. Processed yard waste and green waste was observed being transported to Scott Miracle Gro in Maricopa from the Prescott transfer station.

Construction and Demolition Wood

Local residents, businesses, and construction projects within the TSA regularly produce wood waste in the form of construction debris, demolition woodand industrial byproducts (e.g., wood pallets). Based on TSS' research on urban waste generation in Arizona, approximately 5.69 pounds per capita of municipal solid waste (MSW) are generated daily in the state (1.04 tons per capita annual).[47] 2013 US EPA estimates indicate about 6.2% percent of the solid waste stream

[46] The UVWPC and local stakeholders would like to restore approximately 24,000 acres each year over a 40 year time period from the Upper Verde and Big Chino watersheds. Using a mid-range estimate of 7.65 BDT/acre of biomass, the resulting technically available supply would be approximately 119,340 BDT/year.

[47] "The State of Garbage in America: 17th Nationwide Survey of MSW Management in the US." Biocycle, October, 2010.

in the United States is made up of wood waste.[48,49] Urban wood feedstock is assumed to have a 20 percent moisture content factor.[50] Approximately 15.2% of the total potential volume of urban wood feedstock is recoverable as clean[51] wood waste and is considered technically available.[52] Population in the TSA was estimated using county and town census data. Table 12 shows 1,662 BDT per year of urban wood waste considered technically available.

Table 12. Urban Wood Waste

COUNTY	2013 POPULATION	SOLID WASTE VOLUME (LBS/YEAR)	WOOD WASTE VOLUME (LBS/YEAR)	WOOD WASTE FEEDSTOCK (BDT/YEAR)
Yavapai County	215,133	446,798,971	22,161,229	11,081
POTENTIALLY AVAILABLE				11,081
ADJUSTMENT FOR RECOVERY				-9,419
TECHNICALLY AVAILABLE				**1,662**

Residential Tree Trimming Material

EPA estimates from 2013 indicate that approximately 13.5% of the municipal waste stream is made up of residential tree trimmings suitable for feedstock.[53] However, TSS experience has shown that only about 20 percent of this wood waste is recoverable as biomass feedstock. Residential woody debris and tree trimming materials in small towns and rural areas in Arizona are often used for compost or firewood and not hauled to a regional transfer station. Table 13 shows 6,032 BDT per year of tree trimming material is considered technically available.

Table 13. Tree Trimming Wood Waste

COUNTY	2013 POPULATION	SOLID WASTE VOLUME (LBS/YEAR)	TREE TRIM VOLUME (LBS/YEAR)	WOOD WASTE FEEDSTOCK (BDT/YEAR)
Yavapai County	215,133	446,798,971	60,317,861	30,159
POTENTIALLY AVAILABLE				30,159
ADJUSTMENT FOR RECOVERY				-24,127
TECHNICALLY AVAILABLE				**6,032**

[48] US EPA, "Advancing Sustainable Materials Management: 2013 Fact Sheet, June 2013. https://www.epa.gov/sites/production/files/2015-09/documents/2013_advncng_smm_fs.pdf
[49] See also "Wood Waste Generation and Recovery in the US," Bratkovich et al, September, 2014. http://www.dovetailinc.org/report_pdfs/2014/dovetailwoodrecovery0914.pdf
[50] From TSS' experience procuring urban wood waste feedstocks.
[51] Clean wood waste is woody debris that is free of paint, resins, pesticides or chemical treatment.
[52] Ibid, Bratkovich et al, September, 2014.
[53] Ibid, US EPA.

Summary of Urban-Sourced Biomass Availability

Table 14 shows a summary of urban-sourced biomass availability. Although wood waste materials generated each year are a significant amount (about 82.5 million lbs./year), the amount actually recoverable as biomass feedstock is not large (approximately 7,694 BDT/year).

Table 14. Summary of Urban-Sourced Biomass

SOURCE	VOLUME (LBS/YEAR)	WOOD WASTE FEEDSTOCK (BDT/YEAR)
Urban C&D Wood Waste	22,161,229	
Residential Tree Trimming Material	60,317,861	
POTENTIALLY AVAILABLE	82,479,090	41,240
ADJUSTMENT FOR RECOVERY		-33,546
TECHNICALLY AVAILABLE		**7,694**

Summary of Forest and Woodland Sourced and Urban-Sourced Biomass Availability

TSS estimates that there are approximately 25,234 BDT per year of woody biomass material economically available per year within the TSA. Table 15 provides a summary.

Table 15. Summary of Forest-Woodland Sourced and Urban-Sourced Biomass in the TSA

SOURCE	POTENTIALLY AVAILABLE (BDT/YEAR)	TECHNICALLY AVAILABLE (BDT/YEAR)	ECONOMICALLY AVAILABLE (BDT/YEAR)
Timber Harvest Residuals	3,421	2,053	1,553
Forest Management and Restoration	1,500	975	800
Juniper and Pinyon-Juniper Woodlands Treatment	23,365	15,187	15,187
Urban C&D Wood Waste	11,081	1,662	1,662
Residential Tree Trimming	30,159	6,032	6,032
TOTAL	**69,526**	**25,909**	**25,234**

Since markets for this material are currently in development phase, there is little reason to expect increased biomass production over the next three to five years. The ability to remove any significant volumes of biomass from the Prescott National Forest is severely restricted due to the lack of widespread NEPA and Archaeological clearances. The Prescott National Forest is attempting to address part of this regulatory restriction through the Chino Valley Ranger District Restoration Project. This will address the NEPA, but not the Archaeological Survey requirements to allow vegetation harvesting activity. The 4FRI stewardship contract may increase market competition for biomass products in the near term as that product stream enters the market place. However, the new innovations, markets and expertise of a revitalized forest-products industry in Arizona may provide opportunities that have not yet been explored.

FEEDSTOCK COMPETITION ANALYSIS

Demand for woody biomass and other forest products within Yavapai County is currently limited to fuelwood use and a limited number of timber sales. However, local leadership provided by the Coalition and the desire of a variety of stakeholders, including landowners and land managers, indicates community support to manage vegetation density to reduce wildfire risk and improve water supply security. During the course of this review, TSS observed processed greenwaste at the City of Prescott transfer station being loaded on a walking floor trailer for transport to Scotts Miracle Gro, 139 miles south in Maricopa. The City of Prescott provides this material free, and Scotts pays for the trucking.

Current Competition

TSS believes that current market demand for woody biomass within the TSA is limited to fuelwood and some greenwaste. As mentioned above, the City of Prescott transfer station provides processed greenwaste for free. Perhaps the most significant competition for Yavapai County biomass are the forest residues generated from the 4FRI stewardship contract located to the north and east of the TSA. During this investigation, TSS was informed that thousands of tons of chipped and ground pine timber harvest residues must be removed from the 4FRI harvest units. This material is generally easier to process than pinyon and juniper and has much less foliage; as such, it will likely be difficult for pinyon and juniper biomass to compete in the current woody biomass marketplace.

Potential Markets and Risks

TSS believes the most promising opportunity for woody biomass utilization in the TSA is the Drake Cement operation located in Paulden. This is one of the newest cement kilns in North America. Over the past six years, Drake has been actively pursuing the conversion of their cement kiln to utilize biomass fuels. While TSS is aware of numerous cement kilns operating on alternative fuels such as biomass, it can be a long and costly conversion process. In addition, the size requirements of the material can be an obstacle to the use of biomass in cement kiln operations. TSS has worked with several cement kilns that require a ¼ inch to $^{3}/_{8}$ inch fuel size. Such a specification greatly increases the processing cost of biomass fuel. TSS was informed that Drake plans on conducting pilot scale test burns during late summer 2016 using biomass. The results of these test burns will be critical to future biomass utilization at Drake and a potentially viable long-term biomass fuel market for pinyon and juniper sourced from Yavapai County.

The biggest risk to future supply is the current lack of viable markets for woody biomass. Without a large-scale industrial user within close proximity of the resource, it will be very difficult to develop a pinyon and juniper biomass fuel program in the TSA. There are a number of new and innovative technologies under various stages of development that utilize pinyon and juniper biomass as a feedstock. Considering the fact that the 4FRI stewardship project has had an ongoing effort trying to identify and develop markets for the thousands of tons of pine chips that are being developed off this project, TSS believes that pinyon and juniper may be a low priority feedstock consideration for most of these technologies. Another risk consideration is the slow growth rates for juniper and pinyon-juniper woodlands. Most large-scale industrial users of

biomass consider a 30-year project life span. TSS believes that slow regeneration rates for juniper on most of the TSA will limit the economical removal to a single harvest per acre over a 30-year project life cycle. However, once a supply stream for this feedstock is developed, the pinyon-juniper source may be a viable niche for the right business. Notable possible advantages for marketing material in this TSA is its relative proximity to a railroad shipping center and its closer proximity to markets in California.

Emerging Pinyon-Juniper Utilization

Utilization of pinyon and juniper residuals resulting from woodlands restoration is an active area of research by stakeholders, universities and private industry. Utilization ranges from small-scale, low technology uses such as on-site erosion control 'Juniper Silt Dams' to large-scale high technology uses such as bioenergy facilities. This report does not include an assessment of markets and technologies suitable for pinyon and juniper utilization in the TSA. However, five example processes and products are shown in Table 16. The TSA has an existing well-developed firewood market, but there could be potential for other densified fuel products, such as fuel pellets and fuel bricks. In New Mexico, PJ Woodlands, LLC has co-developed with the USFS Forest Products Lab a durable wood fiber composite called Altree that is made from pinyon and juniper feedstock. It is currently used to manufacture road signs for USFS lands.[54, 55] The use of juniper and pinyon for their essential oils is an emerging market.[56] The oils are bottled and used in aromatherapy and personal care products; example businesses include Young Living Farms and Floracopiea.[57] Landscape products are a well-established use of wood chips, and at least one business in the TSA is interested in juniper as a decay resistant and insect repellant mulch product.[58]

[54] Altree Industrial Grade Composites, made by PJ Woodlands, Albuquerque, NM: http://www.altree.com/
[55] Altree wood chip and plastic panel substitute finds use in road signs. Woodworking Network. May, 2016. http://www.woodworkingnetwork.com/wood/panel-supply/altree-wood-panel-substitute
[56] USU Forestry Extension Volume 20, Number 1, 2016: http://forestry.usu.edu/files/uploads/UFNSpring2016Final.pdf#page=5:
[57] Young Living Essential Oils: https://www.youngliving.com/en_US/discover; Floracopiea: http://www.floracopeia.com/about/sangre-de-cristo-project/
[58] Scotts Miracle Gro, Pers. Comm. May, 2016

Table 16. Pinyon and Juniper Utilization Examples

PROCESS OR PRODUCT	FEEDSTOCK SPECIFICATIONS	PRIMARY EQUIPMENT	MARKET POTENTIAL AND COMMENTS
Wood fuel pellets	Clean, dry (<10% mc) chip, needs to be <1% ash.	Pellet mill, dryer, cooler, hammermill (grinder or chipper), packaging.	Market is domestic stoves and larger-scale biomass boilers. Can be co-fired with coal. Could seek access to international markets. Locally, Drake Cement is an example of co-firing with biomass. Use of either roundwood or biomass from forest possible (e.g., small logs or chips low in bark). Key issue and expense is drying system. Larger scale facility may face challenges in gaining market share for domestic stoves from existing competition. International energy markets for co-firing with coal depend on transport costs and currency fluctuations.
Compressed wood fuel bricks	Chip, dry (<15% mc), needles, bark okay.	Brick machine, dryer, cooler, hammermill (grinder or chipper), packaging. May also be field dried and no dryer needed.	Primary market is substitute for firewood. Also used for camping, lighter and more portable. Small scale can sell by pallet or truckload. Larger scale operations may need packaging equipment. Utilizes pinyon and juniper residuals including needles and bark. Potential to use field-dried material as feedstock with no kiln drying. Smaller mobile units can follow woodcutters or restoration operations and utilize residual piled slash.
Plastic/Wood Fiber Composites (WPC)	Clean, dry (2-12% mc) wood flour. Wood is ~55% of feedstock along with plastic and additives. Recycled wood use common.	Blender (compounder extruder), extrusion line, cooler, cut-off saw.	Composite woods are used for landscape (bender board), decking, fencing, park furniture (picnic tables and seats). The composite wood furniture market is growing due to interest in sustainability. Increasingly used in buildings, exterior siding. Requires cost effective thermoplastic feedstock (HDPE, LDPE, PP, PVC). Utilize recycled plastics (milk jugs, plastic bags). Commercial facilities typically use pine, oak and maple. However, Altree is a wood plastic composite made with pinyon and juniper. Blending (compounding) of wood and plastic may be two processes or single process depending upon equipment.
Compound pellets for WPC production	Same as above	Compounder extruder.	Existing WPC mills. Cheaper way to get into WPC market place than making finished products.
Essential Oils	Clean juniper or pinyon chip. Debarked.	Steam distillation. Oil extraction by a cold press technique.	Niche use for juniper which has an oily, aromatic extract. There are also some pinyon essential oils. Little or no data yet (not well-studied) on capital costs and revenues. Marketing is both by internet sales and in specialty shops.

FEEDSTOCK COST FORECAST

With virtually no existing markets for woody biomass within the TSA, and very limited removal operations, the cost of harvest, collection, processing and transport is hard to determine. During this review, TSS learned that clean pine wood chips are in demand at Scotts Miracle Gro and Gro-Well in the Phoenix area. Also, Novo BioPower in Snowflake, AZ has been purchasing some pine biomass fuel. As stated earlier, the City of Prescott is currently giving away processed greenwaste from their transfer station.

Current Market Prices

Markets are limited for woody biomass in the TSA and nonexistent for pinyon and juniper except as fuelwood. TSS did find that mulch material made from conifer chips from the 4FRI Stewardship Contract is selling for about $1,150 per load to Gro-Well. This works out to about $47 to $50 per GT delivered. This market appears fairly robust, with one 4FRI operator indicating that this past winter they shipped 40 loads per day into Gro-Well. However, the seasonality of these mulch and landscape markets can create boom and bust market cycles. It is unclear how much material these two users might purchase over an entire year. Additionally, TSS was informed that these buyers seek clean conifer chip material, and there is some concern that it will be difficult to meet the feedstock specifications with juniper and pinyon. Scotts is willing to try a test load of chipped juniper to determine if it would be feasible to use in their mulch process. TSS also contacted Novo BioPower in Snowflake, Arizona. This 27 MW biomass power plant does burn pinyon and juniper biomass fuel and currently pays $36 to $38 per delivered BDT. Considering the fact that this facility is 211 miles from Prescott, it would not appear to be a viable market for Yavapai County due to excessive transport costs.

Delivered Cost Forecast

With no current markets for PJ biomass, it is difficult to make any kind of projection as to where delivered prices might go. Based on cost data developed from the ARRA Study and the Savannah-Grasslands Pre-Investment Pilot Project as well as anecdotal information from other producers, TSS estimates that cost for PJ biomass harvested, collected and processed into a chip truck will be in the range of $45 to $65 per BDT. Assuming an average one-way haul distance of 40 miles equates to around $10 per BDT, the total delivered cost for PJ biomass would be $55 to $75 per BDT.

As discussed earlier, the Drake Cement operation could be a potential market. Potential demand of up to 65,000 GT per year has been reported.[59] A key consideration for Drake Cement would be the cost to replace the coal currently used in their kiln. TSS estimates that Drake pays around $3.20/MMbtu[60] for coal, and assuming pinyon and juniper biomass to be around 16.8 MMbtu per BDT,[61] this equates to approximately $3.87/MMBtu (assuming $65 per delivered BDT for pinyon and juniper biomass). As previously discussed, the delivered price of pinyon and juniper

[59] Completed Project Report: Drake Biomass Development Project Results and Applications, Arizona State Forestry Division, Nov. 2012.
[60] MMBtu is one million British thermal units, a measure of heating value.
[61] Based on 8,400 Btu/dry pound for high heat value from a recent study.

biomass for use by Drake would be highly dependent upon the sizing requirements. If biomass fuel needs to be ¼ to $^{3}/_{8}$ inch, the cost of processing would increase substantially.

Table 17. Delivered Cost Forecast 2017 through 2021

FEEDSTOCK TYPE	DELIVERED PRICES BASE CASE*		DELIVERED PRICES WORST CASE*	
	LOW RANGE ($/BDT)	HIGH RANGE ($/BDT)	LOW RANGE ($/BDT)	HIGH RANGE ($/BDT)
Timber Harvest Residuals	$45	$50	$50	$55
Forest Management and Restoration	$45	$50	$50	$55
Juniper and Pinyon-Juniper Treatment	$55	$75	$60	$85

* Assumes 40 mile one-way haul.

Base case cost forecast assumes forest density conditions at the mid to high density removal levels (5 to 15 BDT/acre) which are typically lower cost. Worst case forecast assumes relatively low forest density conditions (3 to 5 BDT/acre) for removal, resulting in higher costs to collect and process material.

When considering biomass fuel cost forecasts, it is important to understand that the largest single variable affecting the cost of this material is the price of diesel fuel. At approximately 4 gallons of diesel to harvest, collect, process, and transport a BDT of woody biomass, it is easy to see how diesel fuel pricing can impact delivered biomass fuel costs. For the next five years, TSS is projecting relatively flat diesel fuel prices and therefore a relatively flat price increase of 1.5% per year.

FINDINGS

Planned Projects

TSS found that the Prescott National Forest, Chino Ranger District, is preparing the Chino Restoration Project. This is a two-tiered project covering approximately 430,000 acres. The Tier 1 portion of the plan is expected to treat approximately 90,000 acres and includes pinyon-juniper woodlands restoration. The Forest Service expects to have the plan out for public comment by end of summer 2016. Recently the Kaibab National Forest finalized the 550,000 acre South Zone Restoration project; some 270,000 acres of the project are on the Williams Ranger District. While only a small part of this project acreage is actually located within Yavapai County, there is some pinyon and juniper biomass removal anticipated within this project. The final decision on this project is expected sometime in September 2016. In terms of large-scale pinyon-juniper treatments, it was found that the Kaibab National Forest, Williams Ranger District, has been the most active over the past decade or more. This district has treated thousands of acres of this vegetation type and helped to develop some of the mechanical treatment methods that are prominent today.

While neither of these projects were able to shed much light on the potential biomass volumes across these large project landscapes, TSS believes over the long-term, the NEPA and EA documents will be critical for opening up large US Forest Service acreages of pinyon-juniper vegetation type to future treatments. The NEPA and EA analysis process can require 24 to 36 months to reach a Record of Decision, so lead time planning is critical.

TSS believes that any attempt to increase the pace and scale of forest and woodland treatments will require significant investment of time and resources on the part of the major land manger in the region – US Forest Service. This agency manages over 56% of the pinyon-juniper woodlands and over 76% of the conifer forests within the TSA. If improved value-added markets can be developed and federal funding appropriated, there is significant opportunity to ramp-up the pace and scale of treatment of both forest and woodland landscapes within the TSA.

Biomass Feedstock Supply Availability

The predominate vegetation types of interest within the study area are the juniper and pinyon-juniper woodlands. This vegetation type represents over 960,000 acres or approximately 18.5% of the study area. While conifer forest types do exist within the study area, they are of minor relative importance, making up about 2% of the area. Although the juniper and pinyon-juniper (PJ) woodlands types are abundant within the study area, TSS found limited data regarding potential aboveground biomass volume for this vegetation type within the TSA. Utilizing a wide range of aboveground biomass estimates for PJ stands within Arizona and the Southwest U.S., TSS estimated a range of 4.7 bone dry ton/acre (BDT)[62] to 10.6 BDT/acre, averaging around 7.65 BDT/acre. TSS estimates that 2,500 to 3,300 acres of juniper and pinyon-juniper woodlands are treated annually within the TSA; however, little if any of this material is currently utilized. In terms of other forms of biomass potentially available, such as conifer forest and urban-derived material, TSS found these to be around 10,000 BDT per year. Obviously the

[62] One bone dry ton = 2,000 pounds of dry wood fiber.

current and future biomass opportunities within the TSA are with the juniper and pinyon-juniper woodlands.

Feedstock Competition Analysis

Markets for processed woody biomass are virtually non-existent within the study area. TSS observed processed greenwaste mulch being loaded and given away for free at the Sundog Transfer Station in Prescott, for transport 139 miles south to Scotts Miracle-Gro. In addition, discussions with timber operators and truckers in the region indicated that the only markets for processed woody biomass generated from U.S. Forest Service timber harvest residues are either Scotts in Maricopa, Gro-Well in Phoenix, or Novo BioPower, a 27 megawatt (MW) biomass power plant located in Snowflake. TSS estimates that haul distances to these markets range from 211 miles to 125 miles.

While the primary focus of this project was to assess the potential volumes of biomass that could be available for commercial use within the TSA, TSS did take a cursory look at some markets and associated competition from other biomass outside the immediate study area. One of the major competitive forces impacting the potential for developing markets for the pinyon and juniper biomass resource within the study area is the Four Forest Restoration Initiative (4FRI). The 4FRI is the largest U.S. Forest Service stewardship contract in the agency's history and is located along the northern and eastern border of Yavapai County. This massive, 10-year, 300,000 acre project is producing sawlogs, posts, poles and thousands of tons of woody biomass. TSS believes that much of the woody biomass generated from the 4FRI will be in direct market competition to any woody biomass generated in Yavapai County. TSS found that woody biomass produced by contractors on the 4FRI project is being hauled to some of the same mulch and landscape market outlets that TSS contacted as part of this assessment. Much of the biomass from the 4FRI projects consists of high-quality chipped pine and is being transported directly through Yavapai County to Scotts Miracle-Gro and Gro-Well south of Phoenix. The fact that the 4FRI contract requires removal of all woody biomass from the contract area suggests that these woody biomass producers will be extremely price competitive.

Based on discussions with the largest wood pellet manufacturer in Arizona, TSS found that juniper is not a desirable feedstock for pellet production. The abrasive characteristics of the juniper cause excessive wear of the pellet dies. This manufacturer also indicated that delivered prices for PJ woody biomass were not competitive with pine and conifer woody biomass.

Feedstock Cost Forecast

TSS is aware of only one wood grinder operating within the TSA, a Vermeer Horizontal Grinder that is owned by Yavapai County. This machine is currently used by Yavapai County at the City of Prescott transfer station. With such a limited number of actual wood processors in the TSA, it was necessary for TSS to rely on the recent PJ woodlands research projects as well as anecdotal information from operators in other PJ regions of the Southwest. Based on this information, TSS estimated that PJ material could be processed and delivered within a 40 mile one-way haul distance for $55 to $75 per BDT. Timber harvest residues and forest management material were estimated at $45 to $50 per delivered BDT.

In terms of biomass fuel forecast, the largest single expense related to biomass fuel harvesting and processing is the cost of diesel fuel. Over the next five years, TSS expects diesel fuel prices to remain flat. As such, TSS is projecting just a minimal 1.5% per year increase in these biomass feedstock costs.

RECOMMENDATIONS

Based on this assessment, TSS believes that any significant volume of woody biomass within the TSA will come from the juniper and pinyon-juniper woodlands. Yavapai County and the Prescott National Forest are not traditional conifer forest products producing areas. With the onset of the 4FRI stewardship project, TSS believes that any commercial demand for conifer-derived biomass would likely locate to the north and east of Yavapai County, closer to the 4FRI project area. In consideration of these facts, TSS recommends that future efforts at quantifying biomass focus solely on the pinyon and juniper resource. Much has been researched and written about the juniper and pinyon-juniper woodlands of Yavapai County over the past six years. However, clear juniper and pinyon-juniper inventory data is still missing. During this review, TSS did attempt to pull together a significant amount of data related to pinyon-juniper aboveground biomass within the TSA. As was pointed out by one US Forest Service employee, however, "it is lots of work to quantify the volume" of these woodlands. Yavapai County is certainly not alone in this pinyon-juniper inventory dilemma; many jurisdictions across the southwest United States are faced with a similar issue, and it is not new. Attempts at devising age class and volume tables can be challenging. Pinyon-juniper often grows inconsistently, physical characteristics vary based on site conditions, and it can be difficult to assess tree age.

Recent research conducted by the USDA Agricultural Research Service may help to develop better estimates for aboveground biomass of pinyon-juniper woodlands. Utilizing object-based image analysis (OBIA) techniques and National Agricultural Imagery Program (NAIP) imagery in combination with ground measurements, researchers were able to develop a method to provide land managers with quantitative data that can be used to evaluate pinyon-juniper woodland cover and aboveground biomass rapidly over a broad landscape.[63] TSS recommends that any further investigation into the availability of pinyon-juniper woodland biomass within the Upper Verde River Watershed and Yavapai County consider incorporating this remote-sensing methodology to better describe the aboveground biomass within this TSA.

The Drake Cement alternative fuel project appears to offer the most promising opportunity for developing a biomass fuel market in the TSA. TSS recommends that the UVRWPC monitor this project closely, as it could provide an important catalyst for initiating a local biomass energy market.

[63] Utilizing National Agriculture Imagery Program Data to Estimate Tree Cover and Biomass of Pinon and Juniper Woodlands. April Hulet et al, Rangeland Ecology & Management 67(5): 563-572: 2014.