Extraction and Utilization of Saltcedar and Russian Olive Biomass

By Dennis P. Dykstra

Chapter 6 of

Saltcedar and Russian Olive Control Demonstration Act Science Assessment

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Chapter 6. Extraction and Utilization of Saltcedar and Russian Olive Biomass

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Introduction

Controlling saltcedar and Russian olive leaves behind "biomass" that typically must be disposed of or used before revegetation can occur. Biomass here refers to woody organic material that is not usually used in conventional wood products and includes small stems (typically <15 cm in diameter), branches, twigs, and residues of harvesting or other processing. Potentially these materials could be converted into bioenergy, biofuels, or bio-based products. Trees and shrubs with larger stem diameters, but for which local forest-product markets do not exist, also may be considered "biomass." This definition is consistent with usage in the *Woody Biomass Utilization Strategy* recently published by the U.S. Forest Service (Patton-Mallory, 2008).

Removing and Transporting Biomass

Saltcedar and Russian olive trees are often classified as phreatophytes, plants that depend on groundwater (Osterkamp, 2008). Both species often have extensive root systems that may be difficult to excavate without significant soil disturbance. Moreover, both saltcedar and Russian olive tend to resprout after cutting (National Park Service, 2005a,b). Saltcedar in particular sprouts vigorously, and poisoning the stumps or complete removal of the roots is often considered necessary to prevent regrowth (Shafroth and others, 2005; see also chap. 5, this volume). Thus, extraction and transportation programs need to consider not only the main stems and branches but the stumps and root systems as well.

Historically, most efforts to mechanically eradicate saltcedar and Russian olive have involved cutting or uprooting the trees without removing the wood from the site. Such operations are reported to have cost between $3,700 and $15,500 per hectare, depending on the density of plants and the scale of the treatment (Shafroth and others, 2005; see also chap. 5, this volume). A review of the refereed literature revealed only one publication (Felker and others, 1999) with information on harvesting saltcedar for potential biomass use. No similar publications were found describing extraction of Russian olive for this purpose. In this section we discuss current systems for harvesting saltcedar and Russian olive biomass that might be considered for further testing.

Methods

Once saltcedar and/or Russian olive have been felled, the resulting biomass could be collected and removed for eventual use elsewhere in any of the ways described below. The catalog by Windell and Bradshaw (2000) provides information on a wide range of equipment appropriate for these efforts.

Conventional forestry skidders can be used, probably with hydraulically operated grapples (fig. 1), to collect one or more whole trees and skid them to a landing at roadside, either for further processing at that point or for loading into a container for transport to a biomass processing facility. Such a system is described for a eucalyptus plantation in California by Spinelli and Hartsough (2001). Forestry skidders are ruggedly built and can operate efficiently over relatively long distances. However, skidders will be constrained by the bulk of the biomass as there will be large masses of limbs and comparatively few main stems, and production rates would tend to be much lower than in commercial timber stands or plantations as described by Spinelli and Hartsough (2001). Soil disturbance and compaction from the rubber tires may be a concern in riverine areas.

Large agricultural balers might be used to bundle the felled trees and their limbs into a compact mass that can be more easily transported to a roadside. This would require the felled trees to be arranged into windrows, either by crews working by hand or by a bulldozer or an excavator with a grapple. However, stumps may interfere with the baling process, especially if the trees are not cut level with the ground. Felker and others (1999) tested several conventional balers with mesquite, a native species with a general structure similar to that of saltcedar and Russian olive, and found that large balers producing 300- to 600-kg bales were generally satisfactory. On the other hand, their tests were conducted in a farm field using artificially constructed windrows of unreduced woody material, so the balers did not have to contend with the rough conditions typical of a woodland setting. It is also not clear

Figure 1. Grapple skidder in a conventional timber harvesting operation. Deere & Company photograph.

whether the balers were able to handle larger tree stems in addition to branch material.

Specialized biomass balers that might be more robust in a forestry setting are currently under development (see for example, Dooley and others, 2008). However, these have not yet been fully tested, so production rates and operating characteristics are not presently known.

Commercial slash bundlers might be used to compact the trees and their limbs into a form that could be more easily transported. "Slash" is a term used to describe material such as the limbs and tops of trees left behind in a conventional logging operation, which is similar to saltcedar and Russian olive biomass. Only one commercially available slash bundler currently exists, the John Deere 1490D Slash Bundler (Rummer and others, 2004; fig. 2). This relatively expensive but efficient machine has the requisite ruggedness needed for operating under forest conditions. It was designed to collect small stems and limbs and compress them into cylindrical bundles that are bound with polypropylene twine. These bundles can then be transported to the roadside landing by a forwarder (fig. 3). The bundles (referred to as "slash logs" because of their cylindrical shape) may be processed with a chipper or grinder at the landing, or transported by truck (fig. 4) to a central facility for further processing.

A combination harvester/baler has recently been developed by a company in Canada to cut small-diameter woody stems and then compact them into bales in a single operation (FLD Biomass Technology, 2009). The machine is designed to be towed behind a tractor and would operate best when stems are relatively uniform in size and density. Stems up to about 12-cm diameter can reportedly be processed by the hammer-type cutting heads. Round bales with diameters of about 1 m and lengths slightly more than 1 m are produced. Cost and operating data are not yet available for this newly developed machine.

Self-propelled chippers could be used to reduce the felled trees into small particles that could be blown into a trailer towed behind the chipper. When filled, the trailer could be transferred to a roadside and taken directly by truck to a bioenergy facility. Several self-propelled chippers are available commercially (see for example, the catalog developed by Windell and Bradshaw, 2000). These machines generally chip tree stems that have already been felled and could operate efficiently on windrows of felled trees. However, none of the self-propelled chippers described in the catalog is self-loading, so a separate machine is required to load material into the chipper's infeed.

Self-propelled mulchers, combined with towed trailers to collect the mulched biomass, have been tested recently in a cooperative effort involving researchers at North Carolina State University and FECON, a company that produces and markets in-woods mulching machines (Livingston, 2008). Details of tests with the system are not yet available, but it will reportedly convert stems up to 15 cm in diameter. Unlike

Figure 2. The John Deere 1490D Slash Bundler in operation. In the photograph, one of the twine-wrapped cylindrical bundles produced by the machine has just been released. From Rummer and others (2004); U.S. Forest Service photograph.

Figure 3. Forestry forwarder collecting slash bundles for transport to a roadside landing. From Rummer and others (2004); U.S. Forest Service photograph.

Figure 4. Log truck loaded with slash bundles for transport to a bioenergy facility. From Rummer and others (2004); U.S. Forest Service photograph.

chippers, mulchers are designed to cut standing trees and shrubs in a manner similar to the combination harvester/baler described above. Rather than producing bales, however, this system captures the particles in a towed trailer that could then be hauled directly to a biomass processing facility. Development and testing of a similar system for converting mesquite into biomass particles was reported by Ansely (2007). This effort involved a purpose-built mulching machine with an integrated collection bin for capturing the mulched particles. The mulching machine is towed behind a tractor rather than being self-propelled but is nevertheless a one-pass machine that collects the biomass material, which must later be transferred to a trailer or other conveyance for transport to the biomass facility.

Case Study

Felker and others (1999) developed and tested a specialized harvester for cutting small-diameter woody vegetation and producing small particles from the stemwood, branches, and leaves. The authors refer to these particles as "chips," although they probably would not meet pulpwood chip standards. Here they are referred to as "particles."

The system described by Felker and others (1999) was developed to harvest mesquite (*Prosopis glandulosa*) as a bioenergy resource in Texas. Mesquite is a small tree that is generally similar in structure to saltcedar and Russian olive. The mesquite harvester was subsequently field-tested in New Mexico in stands of saltcedar and piñon-juniper, a common southwestern native woodland type. The harvesting machine was modified from a 216-kW John Deere silage harvester. It proved capable of cutting stems up to 10 cm in diameter with little difficulty. It could also cut some stems up to 20 cm in diameter but with only marginal success, and the authors concluded that 10 cm was a more reasonable upper-limit diameter for this particular machine.

In their tests, Felker and others (1999) reported that the harvester achieved an average production rate in saltcedar of 2.36 Mg/h green weight (1.82 Mg/h dry weight). This is well below the target rate of 8 Mg/h that the authors considered necessary for a practical operation (although their target is higher than actual production rates commonly reported for harvesting operations in short-rotation woody crops; see Hartsough and others (1996) for examples of such rates). A major problem during the study was collecting the wood particles: a pickup truck with a plywood box had to be driven alongside the harvester to capture the particles produced by the harvester. This problem could be avoided by mounting a particle recovery unit directly on the harvester or towing it behind the machine as shown in figure 5.

An alternative strategy for collecting the particles is to windrow them as the trees are harvested and subsequently bail them for transport. Felker and others (1999) did not attempt to bail residues from the saltcedar harvest but did conduct a baling test with mesquite harvested in Texas. The baling was not done on-site but rather at the New Holland

Figure 5. Modified forest mulching machine developed by North Carolina State University in cooperation with FECON, a producer of forestry machines. The modified mulcher shown here includes a device to blow ground particles into a trailer towed behind the mulching vehicle. From Livingston (2008).

Research Center in Pennsylvania. Mesquite particles totaling 16 m^3 were shipped from Texas to Pennsylvania. These particles were used to test three commercial balers: a small baler and two large balers. One of the large balers produced round bales, and the other produced square bales. Mesquite bales produced by the small baler were considered unsatisfactory; apparently the baler was unable to apply sufficient pressure to produce firm, well-shaped bales. Both of the large balers produced satisfactory bales. The authors concluded that large square bales would be more practical than round bales from a transportation standpoint.

One problem not considered in Felker and others' (1999) baling analysis is the fact that, on an actual operation, the stumps from previously harvested stems tend to interfere with baling. Balers being developed specifically for woody biomass allow for this and rely on hydraulic grapples or a similar loading system to move limbs and small-diameter stems from the ground into a hopper on the baler (see for example, Rummer and others, 2004). Balers designed for woody biomass work much differently than conventional hay balers, which are designed to work in fields where woody residues are not present.

During the harvesting tests, the mesquite harvester's agricultural frame was too weak for sustained use under the rugged conditions typical of woodland harvesting, and the authors concluded that a commercial version would need to be built on a heavy-duty frame similar to that of a forestry skidder, with higher clearance above the ground surface. To date, there are no known heavy-duty harvesters designed specifically for harvesting small-diameter woody vegetation under woodland conditions. Various machines have been developed for harvesting short-rotation woody crops (SRWC) grown for bioenergy generation (Hartsough and others, 1996), but conditions in SRWC plantations are typically more like farm fields than the uneven, rocky ground surface common in woodland areas.

Complete Removal of Biomass

No matter which transportation method is used, it is unlikely that all of the saltcedar or Russian olive biomass can be removed from the site. Grado and Chandra (1998) pointed out that reported recovery rates on biomass removal operations range from 50–90 percent and that the actual quantities removed are often less than the anticipated recovery rates, even when operations are in evenly spaced plantations located on level ground. Operations on rougher ground with unevenly spaced invasive plants are likely to remove even less of the biomass. In some cases reducing the remaining biomass into chips or mulch may be needed to reduce fire hazards or for other reasons. Such mulch might be used to improve

conditions for revegetation after saltcedar and Russian olive removal; however, plant growth can be inhibited when a mulch layer is too thick (see chap. 7, this volume).

Wood Properties of Saltcedar

Tests on one species of saltcedar conducted by the U.S. Forest Products Laboratory (FPL) in 1939–1940 and summarized by Gerry (1954) indicate that the wood is relatively dense, with a specific gravity of 0.62 when green and 0.67 when air dried. This compares with a specific gravity of 0.71 for oak and maple (Forest Products Laboratory, 1999). Saltcedar is somewhat inelastic, with a modulus of elasticity lower than those of many hardwood species. Overall, most strength properties of saltcedar appear to be about average for hardwoods. However, its shearing strength, tensile strength, and hardness values are unusually high, so it may be difficult to cut, and the cutting knives or blades may become dull quickly. Table 1 summarizes some of the important properties from the Forest Products Laboratory (FPL) tests. No similar test data have been found for Russian olive.

Solid Wood Products

Saltcedar wood has been used in the Middle East for millennia. Support beams from buildings excavated at a site near the border between Egypt and Israel were identified as saltcedar and were radiocarbon dated to as early as 2,800 years before present (B.P.) (Weizmann Institute, 1996). Use of saltcedar in Middle Eastern cultures goes much further back: excavations at a site known as el-Wad Cave near Mount Carmel, Israel, show that saltcedar was extensively used in the Natufian culture (12,800–10,500 yr B.P.), although the specific type of use could not be identified (Lev-Yadun and Weinstein-Evron, 1994). According to Kuniholm (1997), saltcedar was generally considered a “lesser wood” in the ancient world and was probably used for such things as ordinary carpentry, fuel, and pottery production. It is known to have been one of the woods commonly used for making caskets and domestic objects such as vases and bowls. A story from Babylonian literature inscribed on clay tablets around 4,000 yr B.P. reportedly describes the king’s table, couch, and eating bowl as having been made from saltcedar, and mentions that the king’s clothes were sewn with tools of saltcedar wood (Dalley, 1993). Perhaps because it exudes salt from the leaves, in ancient times saltcedar was considered to have medicinal value, and bowls made from the wood were reportedly prescribed for patients with certain ailments to use for eating and drinking.

Saltcedar wood is light in color and has only moderate figuring from grain. However, according to Gerry (1954), a silver-grained or wavy appearance can sometimes be obtained by quarter sawing. According to Internet websites that sell specialty wooden lamps and decorative objects, saltcedar is one of several species favored by woodturning artisans when a piece with the appropriate color, grain, and size can be obtained

Table 1. Selected wood properties of saltcedar (*Tamarix aphylla* [L.] Karst.) as measured by the U.S. Forest Products Laboratory during 1939–1940 and reported by Gerry (1954).

[kPa, kilopascals; MPa, megapascals; kJ/m^3, kilojoules per cubic meter; mm, millimeter; N, newtons of force required for a test hammer to penetrate a wood sample to a standard depth]

Property	Green	Air dry
Moisture content (percent)	86.9	12.0
Specific gravity	0.62	0.67
Static bending properties		
Modulus of rupture (kPa)	59,000	91,000
Modulus of elasticity (MPa)	7,000	9,500
Work to maximum load (kJ/m^3)	79	93
Impact bending to complete failure (mm)	960	1,010
Compression parallel to grain–maximum crushing strength (kPa)	26,600	42,700
Compression perpendicular to grain–fiber stress at proportional limit (kPa)	4,800	5,900
Shear parallel to grain–maximum shearing strength (kPa)	10,900	15,600
Tension perpendicular to grain–maximum tensile strength (kPa)	6,800	7,900
Side hardness (N)	5,800	6,400

(see for example, *http://www.tias.com/cgi-bin/showcase-tem.cgi?itemKey=3923197793&store=/stores/aplc*, accessed 12 May 2008). Woodturning artisans produce sculptures, bowls, vases, lamps, and other wood-based household objects.

Woodturning artisans also use Russian olive but somewhat more broadly. Russian olive wood is moderately dark with an attractive grain figure, especially around knots. It is often confused with olive wood by woodworkers, although the two trees are not related. Russian olive is an oleaster (genus *Elaeagnus*, family Elaeagnaceae), whereas true olive is in the genus *Olea*, family Oleaceae.

One common artistic use is for wooden ballpoint pens. Several Internet websites regularly offer Russian olive pen blanks for sale, and a wood shop in Nebraska also offers larger pieces as slabs for uses such as taxidermy plaques or sign boards (see at *http://stores.ebay.com/Wings-Wood-Shop*, accessed 24 May 2008).

However, most saltcedar and Russian olive wood offered for sale comprises individual pieces selected for color, grain, and size, which suggests that the market is small and rather specialized. Whereas any effort to use saltcedar and Russian olive wood extracted from eradication projects might profitably select individual pieces for marketing to specialized buyers, most of the wood from such projects is likely to be commodity wood that could be used for bioenergy, biofuels, or products such as wood-plastic composites that can use almost any kind of wood.

For the most part, both saltcedar and Russian olive trees have short, small-diameter stems that often are crookedly formed, making them unsuitable for conversion into conventional solid-wood products. This suggests that efforts to use the wood might best focus either on composite products or on using the material as feedstock for bioenergy or biofuels.

Composite Wood Products

Composite wood products are a natural outlet for small-diameter, shrubby species such as saltcedar and Russian olive. Composite products effectively utilize small particles, and any defects in the wood raw material are distributed throughout the composite, which should theoretically dilute their influence on performance of the final product. In a series of studies conducted at the FPL in Madison, Wis., saltcedar wood has been shown to have promise as a constituent in particleboard and as a filler in wood-plastic composites (WPC) (Winandy and others, 2005; Winandy and Hiziroglu, 2005; Clemons and Stark, 2007; Stark and Clemons, 2008; Clemons and Stark, 2009). Englund (2006) conducted an independent study on the use of saltcedar in WPC, with results consistent with those of Clemons and Stark (2009).

Particleboard. Particleboard is produced by mechanically reducing wood material into small particles, applying adhesive to them, and then treating the mixture with heat and pressure to consolidate the particles into a panel product. In tests done at the FPL, particleboard test panels were made both from saltcedar wood alone and with a mixture of saltcedar wood and bark. Saltcedar made up 95 percent of each panel by weight, with the remainder made up of a standard phenolic resin. Modulus of elasticity values measured on the particleboard panels ranged from 1,172 to 1,770 megapascals (MPa) and modulus of rupture values ranged from 9.2 to 14.0 MPa. Panels with bark included in the mixture had 14–18 percent lower average values than those made from wood and phenolic resin alone. Overall the stiffness values were relatively low because the samples were small, allowing little opportunity to optimize the fabrication process. However, Winandy and others (2005) concluded that saltcedar has considerable potential as a base for particleboard production, especially in applications where high stiffness values are not essential, for example, as backing material for sign boards. It should be noted that the high salt content of the wood may require the use of fasteners designed to resist corrosion, such as those made from galvanized metals.

Wood-Plastic Composites. Historically, inorganic fillers have often been added to plastics to improve performance or reduce cost. In recent years considerable research has been done, especially by FPL and several university laboratories, on wood flour as a filler material in place of the inorganic compounds. The resulting WPCs are now being produced commercially for a wide variety of uses. Typically, WPCs are used in building applications where strength is less important than stiffness. Durability under ambient weather conditions is often important because many WPCs are used outside, for instance as decking, railings, fencing materials, and sign boards.

No studies related specifically to using Russian olive in wood composites have been identified in the literature.

Case Study

Scientists at the FPL conducted a series of studies using saltcedar in composite wood products, including WPC (Winandy and others, 2005; Winandy and Hiziroglu, 2005; Clemons and Stark, 2007; Stark and Clemons, 2008; Clemons and Stark, 2009). The FPL tests used wood from both saltcedar (*Tamarix ramosissima*) and Utah juniper (*Juniperus osteosperma*). In addition, wood flour from a blend of western pine species was obtained from a commercial supplier and used as a reference material in the tests. Saltcedar was found to contain the most minerals and water-soluble extractives of the three wood flours. Salt crystals were also readily apparent in many of the ray cells of the wood. The extractive content of saltcedar was at least twice as large as those of the other two flours, and the saltcedar extractives had more color than the others. This would give saltcedar WPCs a greater potential for leaching of extractives and staining of adjacent surfaces. According to the authors, it should be possible to limit this potential by careful formulation of the WPCs.

Injection-molded and extruded WPCs were made from the three wood flours using several different formulations, with wood content varying from 36–50 percent by weight. Saltcedar WPCs were considerably darker in color than those

made from pine flour, but they were similar to the WPCs made from Utah juniper. All three types of WPCs performed similarly in accelerated weathering tests. The mechanical properties of saltcedar WPCs were generally lower than the properties of the composites made from the reference pine flour, but the authors concluded that careful selection of applications and proper design could help compensate for these deficiencies.

Because most WPCs are used outdoors, weathering is an important consideration. The FPL study includes a long-term natural weathering test (fig. 6) in which investigators are assessing changes over time in the appearance and mechanical properties of the composite boards. Initial monitoring suggests that treating the saltcedar WPCs to protect against ultraviolet radiation would be necessary when color changes due to weathering are undesirable because many of the samples without ultraviolet protective treatment have lightened substantially.

The FPL study (Clemons and Stark, 2009) concluded by observing that the economic feasibility of using saltcedar or other invasive species in WPCs will depend on a variety of factors, including the costs for harvesting and transporting the material, manufacturing the wood flour, local pricing of plastics and additives, and the availability of facilities to manufacture WPCs. Some of the potential uses suggested in the FPL study for such WPCs include pedestrian bridges, sign boards, or other outdoor structures for which a combination of inherent durability with low maintenance is preferred.

Biofuels

Biofuels such as wood pellets, bio oil, and charcoal derived from biomass are a promising source of energy. Dozier (2002) has suggested that saltcedar and Russian olive might be used as feedstocks for bioenergy or biofuels and for producing charcoal or chemicals such as resins and polymers.

Wood Pellets

Saltcedar and Russian olive biomass could be used to produce wood pellets, but apparently neither species has been tested for that purpose. Wood pellets can be used for heating, either in private homes or in district-level heating for buildings such as schools or government installations. Wood pellets are significantly denser than raw wood, making shipping over longer distances more economically feasible. They also burn with very low emissions (Johansson and others, 2004). A possible disadvantage of wood pellets is that the production process requires clean chips, without bark or contaminants such as dirt or stones. Thus a mechanism for removing the bark and screening out stones or other contaminants would be needed, and other uses for the bark would need to be considered. For Russian olive, the bark might be used as landscaping mulch, but this would not be feasible for saltcedar because of the salt content of the bark.

Figure 6. Natural weathering test rack with extruded composite boards manufactured from saltcedar-, juniper-, and pine-wood flours. Saltcedar boards are those with the darkest coloring. From Stark and Clemons (2008); U.S. Forest Service photograph.

Bio Oil

Saltcedar and Russian olive biomass might be used to produce "bio oil," which can be burned in boilers, turbines, and diesel generators to produce heat and power. Recently, a Canadian company, Advanced BioRefinery, Inc. (Ottawa, Ont., Canada; see company website at *http://www.advbiorefineryinc.ca/*, accessed 6 May 2009), has reported developing a transportable unit that can be taken to a job site, loaded with wood residues (including limbs and bark), and operated to produce bio oil. The transportable unit can reportedly process 55 dry tons of slash per day, producing 60 percent bio oil and 40 percent charcoal, ash, and synthetic gas. Production units are currently being tested.

Charcoal

It is not clear how the high salt content of saltcedar might affect its utility for firewood or charcoal, although it has a good reputation as firewood (National Park Service, 2005b). Laboratory tests of charcoal made from saltcedar indicate that its properties are similar or superior to those of several common sources of charcoal (Taylor, 2005).

During a symposium on saltcedar control organized by Colorado State University, Taylor (2005) reported on the only known study involving conversion of saltcedar wood into charcoal. The report has subsequently been updated on the sponsoring organization's website (Sustainable Communities, Inc., 2008) with comparative information from laboratory tests on charcoal made from saltcedar and five native tree species plus four types of commercially available charcoal.

Charcoal was produced from saltcedar in the field (fig. 7), near a site from which saltcedar trees and beetle-killed piñon pine (*Pinus edulis*) were being removed and juniper trees (*Juniperus* spp.) were being thinned to reduce fire hazards. Three different charcoal kilns were evaluated. The qA kiln (fig. 8), with a charge capacity of 635 kg, had greater production efficiency, but a medium-sized kiln, with a charge capacity of 200 kg (fig. 7), could be transported by pickup truck and moved easily from site to site.

A very small kiln shown in figure 7 was used for short pieces and to provide exhaust gases for a small wood-preservation chamber. The two wood-preservation chambers shown in figure 7 were designed to preserve wood for fence posts and similar applications. The exhaust gases from charcoal production were used as the preservation medium. A charge of wood was converted to charcoal in 2 days, after which the kiln was allowed to cool for 24 hours and then opened to remove the charcoal. It was then refilled and the process repeated. The auxiliary preservation of wood with exhaust gases from the kilns was a slower process, requiring at least 20 days of continuous exposure to the gases.

Samples of charcoal produced from six different tree species, including saltcedar, were sent to Huffman Laboratories, Inc., a fuel-testing facility in Golden, Colo. Four commercial charcoal products were also tested to provide

Figure 7. Field setup for charcoal production in the project described by Taylor (2005). At left is a solar panel used to power a water pump for the wood-preservation chambers. The pickup-truck-transportable charcoal kiln is located in the pit, with exhaust gases piped to a tall wood-preservation chamber to the left of and behind the kiln. At right rear are a smaller charcoal kiln and preservation chamber for short wood pieces. Photograph copyrighted by Lynda Taylor, used with permission.

Figure 8. The large kiln being charged. Several species of wood were included in each charge but segregated within the kiln to facilitate testing. Photograph copyrighted by Lynda Taylor, used with permission.

reference data. The results for three important charcoal attributes are summarized in figure 9. In general, a higher value for fixed carbon suggests that charcoal will burn better, with more even, consistent heat. Higher heating value is a measure of the amount of heat energy generated from combustion, and higher values are generally superior because they indicate that smaller amounts of charcoal can be used to generate a given quantity of heat energy. Ash represents the amount of unburned residues left over after burning, and therefore lower values are better. On the basis of these tests, saltcedar appears to show promise for use as charcoal, with the fourth-best fixed-carbon value, a good higher heating value, and relatively low ash content.

As confirmation that the saltcedar charcoal is a marketable product, it is currently being sold in farmer's markets in New Mexico.

Data Gaps and Future Research Needs

Demonstration projects are needed to determine the comparative effectiveness of various ways to use saltcedar and Russian olive biomass. Such projects would provide the most information if they included the following:

1. **Site comparisons.** Sites should be selected that include both saltcedar and Russian olive or provide a good representative sample of each species. It is desirable to know what harvesting, processing, and utilization problems might be unique to each species and what problems may arise when both species are present in a given location.

2. **Large scale.** Test sites should be located in areas where large quantities of the invasive species are available. Although the distribution of these species is vast, the quantities of biomass available for use may not be sufficient in many areas to generate/encourage industrial participation.

3. **Bioenergy.** If possible, one or more sites should be located within economical transportation distance of a bioenergy facility. This could be an electrical power generation facility or a biomass heating facility such as those now being developed in parts of Montana and Colorado. It is unlikely that investors could be induced to develop new facilities for short-term demonstration projects. Because of the potentially corrosive effects of high salt content in saltcedar biomass, it would be important to determine whether maintenance issues arise if the saltcedar fraction of biomass processed at a facility is relatively high.

4. **Commercial and community scales.** Both commercial-scale operations and community-scale operations should be examined.

   a. *Commercial-scale operations* will probably be necessary if biomass is to be used for composite products such as particleboard or wood-plastic composites, or as a feedstock for bioenergy or biofuels operations. However, these are likely to be practical only if the proper manufacturing or conversion facilities already exist within economical transportation distance of the demonstration site.

   b. *Community-scale operations* would likely have a somewhat different perspective than commercial-scale operations. Many rural communities are interested in providing employment and at the same time thinning forest and woodland areas to reduce fire hazard. Removal of saltcedar and Russian olive would be of most interest to them in the context of thinning programs that involve other species as well. They likely also would be interested in projects that provide local employment opportunities and that offer the possibility of producing saleable products such as charcoal or other value-added wood products.

5. **Machinery.** A range of felling and extraction machines and techniques should be tested and time-study data collected so that the economic feasibility of the different techniques can be evaluated. Some of the important questions include the following:

   a. In the context of biomass extraction, what are the relative costs, organizational issues, and environmental impacts associated with chainsaw felling as compared to machine felling of the two species, both separately and in combination?

   b. What are the relative costs and benefits of using bulldozers, hydraulic excavators, or chaining to uproot the trees in preparation for extraction to roadside?

   c. Is it feasible to use self-propelled chippers in combination with one or more of the systems in questions (a) and (b) to reduce the biomass to small particles that can be more efficiently transported to a facility?

   d. Can balers or slash bundlers be used to reduce the cost of extracting the biomass to roadside and then transporting it to a facility?

6. **Comprehensive tests.** Tests on the wood properties of both saltcedar and Russian olive are needed. The only such tests known for saltcedar date from the late 1930s when testing equipment, procedures, and sample sizes were much different from those used today. The FPL would be a logical place to do this testing, although some universities located near the project sites might also have the necessary equipment and technical skills. In addition to evaluation of the wood properties, tests should also be undertaken on the potentially corrosive effects of products derived from saltcedar wood. For instance, fasteners may have to be used that resist corrosion.

7. **Additional development and testing.** Additional testing of composite products made from the two species would be useful. Thus far, only a small quantity of material has been tested, and only from one species of saltcedar. Comprehensive demonstration projects could justify much more extensive testing. Such testing may identify special applications or types of composite products for which these invasive species might be well suited.

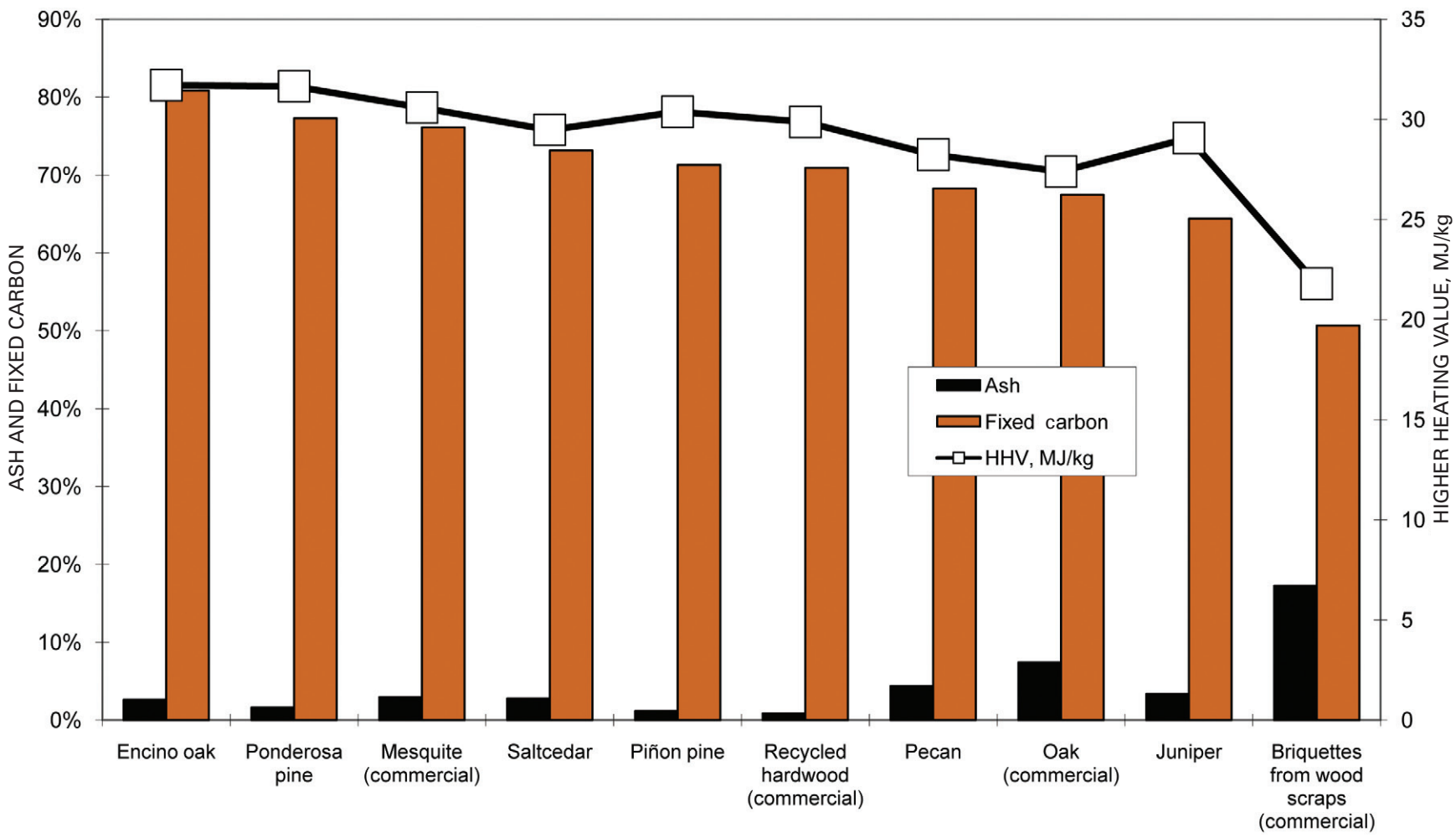

Figure 9. Results of laboratory tests on samples of charcoal made from six tree species from New Mexico as compared to four samples of commercial charcoal. Two samples of ponderosa pine that were charcoal tested were averaged. Ash and fixed carbon (vertical bars) are expressed as percentages of total sample weight and are measured on the left y-axis. Higher heating values (squares connected by a solid line) are measured on the right y-axis. All samples except the one commercial briquette sample at far right were lump charcoal. From Sustainable Communities, Inc. (2008). (HHV, higher heating value; MJ/kg, megajoules of energy available per kilogram of mass.)

8. **Testing the wood's potential.** Testing for use in the production of wood pellets would be useful. Wood pellets can be used at any scale to produce heat or generate electricity, and because of their density, they offer a significant economic advantage for long-distance transport.

9. **Tests of slash-processing units.** Slash-processing units such as Advanced BioRefinery's transportable units for producing bio oil might be considered as an option for using the wood from eradication projects.

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