Utilizing Russian Olive Trees at the Colorado State Forest Service Nursery: A Case Study

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Abstract

Russian olive (*Elaeagnus angustifolia*) is an invasive tree that is the target of many restoration efforts across the United States. These removals are very expensive and generate large amounts of woody biomass waste that currently goes unused. The attractive grain and color of the wood has motivated some mills to process Russian olive and sell it for artisan uses. Some research exists on Russian olive biomass utilization, but no studies have been done on its use as a solid-sawn wood product. The Colorado State Forest Service nursery has hundreds of Russian olives on its property slated for removal. This presented the opportunity to conduct an economic analysis on the potential for increased utilization of Russian olive wood. An inventory of standing trees was conducted to find the volume of merchantable wood and estimate the potential lumber yield. Additionally, a sample of the trees was removed and milled, with actual costs and lumber yields tracked throughout the process. Findings from the two studies indicate that removal and disposal of merchantable material with no utilization would cost \$30,254.10. Using the estimated 1445.4 ft^3 of merchantable wood and 86.0 yd^3 of mulch could generate revenues of \$16,659.63 and bring net cost down to \$21,544.17, after accounting for additional expenses.

Across the western United States, land managers are conducting restoration projects that involve the removal of Russian olive (*Elaeagnus angustifolia*) trees (Gaddis and Sher 2012). Many large projects have been completed or are under way, particularly in riparian corridors and surrounding reservoirs and irrigation ditches. These projects are very expensive and generate large amounts of woody residue in the form of boles and material such as branches and tops (also referred to as ''slash''). This material is generally chipped or burned (US Department of Agriculture [USDA] Forest Service 2014), with little product recovery other than firewood and mulch. This article explores the economic incentive for producing solid-sawn wood products from Russian olive trees to offset costs of removal. Results and conclusions of this study will be useful to others planning Russian olive removal projects.

A full examination of ecological effects and natural history of Russian olive is outside the scope of this article. Some basic information is presented here to provide context for the study, and more detail is readily available in the literature. Information about the tree's botanical and silvicultural characteristics, as well as the history of its invasion, have been provided by Borell (1976), Christensen (1963), and Little (1961). Some excellent synopses on the tree's general ecological impacts by Katz and Shafroth (2003) and Gaddis and Sher (2012) are available, as well as more specific examinations of its suitability as wildlife habitat by Knopf and Olson (1984), Brown (1990), and Lesica and Miles (2004), and its effect on water yield by Nagler et al. (2010).

Russian olive is an invasive, deciduous perennial, native to southern Europe and western/central Asia (Little 1961). Its form varies from large shrub to small tree, with random and spreading branches that start near the stump (Herman et al. n.d.). It often grows in dense rows, but when open-grown it forms a rounded crown. The tree is also capable of producing prolific sprouts from the root system or root crown (USDA Forest Service 2014). Russian olive was planted extensively for windbreaks and erosion control in the early 20th century because it is a hardy tree that establishes and grows quickly (Christensen 1963). Forest inventory data on the abundance of Russian olive trees does not currently exist (Nagler et al. 2011). However, Friedman et al. (2005) report that the tree is now the fourth most widely distributed woody riparian species in the American west.

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Although the ecological effects of Russian olive are still under debate, the times have changed from its heyday as a preferred species for planting in the western United States. Many of the agencies that once promoted its planting are now spending large amounts of money on removal projects (Stannard et al. 2002, USDA Forest Service 2014). Between 2005 and 2007, the US Bureau of Land Management expended $500,000 on Russian olive removal in riparian areas (Montana Audubon 2010). In 2006, Congress passed the ''Salt Cedar and Russian Olive Control Demonstration Act'' (Salt Cedar and Russian Olive Control Demonstration Act [SROCDA] 2006). This act authorized approval and federal funding of five ''demonstration projects'' that involve large-scale Russian olive and saltcedar removal for ecological restoration. Each demonstration project was eligible for up to $7 million in grants. Currently, many major restoration projects are under way in areas such as the Escalante River in Utah, the Bighorn Basin in Montana, the San Juan Watershed in the Four Corners area of the southwest United States, and the Platte and Republican rivers in Colorado.

Russian olive is now listed as a noxious weed in Colorado, New Mexico, Wyoming, and several counties in Utah and Montana (Montana Audubon 2010). In Colorado it is List B, which means that in areas where the species has established, plans must be put in place to stop its continued spread (Colorado State University [CSU] Extension 2013). Because Russian olive seeds are easily distributed by wildlife (Shafroth et al. 1995), the existence of the trees on the Colorado State Forest Service (CSFS) nursery property helps to promote the spread of the species. Therefore, the nursery has placed a priority on Russian olive removal to help prevent further spread.

There are several different approaches for the control of Russian olive (USDA Forest Service 2014). Because much literature is available about Russian olive suppression and management, this article will not go into detail on these topics. However, in order to understand how Russian olive removals may yield merchantable logs, a basic understanding of control methods is necessary. It is worth noting that, in addition to the mechanical or manual methods discussed, monitoring and follow-up treatments may be necessary to prevent sprouting from the stumps or root system.

Russian olive removals are typically achieved by either mechanical or manual means (USDA Forest Service 2014). Mechanical removal projects use excavators to extract the tree and root ball. This can be an efficient method of managing large acreages and can be less costly than manual removals. However, heavy machinery is only justified if enough trees need to be removed and if site conditions allow the equipment to operate with an acceptable level of environmental impact. Mechanical removals have a greater chance of damaging timber and of triggering root sprouting. Mechanical removal costs have been estimated at between $800 and $1,820 per acre (O'Meara et al. 2010).

An alternative to heavy machinery is employing hand crews with chainsaws. Hand crews can fell trees with greater care in preserving merchantable logs. Slash is generally burned or chipped, and logs are either left on site or hauled away for disposal. By painting the stump with an herbicide (Imazapyr or Triclopyr, for example) within 10 minutes of felling, sprouting can be reduced, though generally not eliminated (USDA Forest Service 2014). The downside of manual removals is their greater cost and labor requirements. Manual removals with chainsaws (including herbicide application) can cost between $1,800 and $4,530 per acre (O'Meara et al. 2010).

The crooked form of Russian olives makes milling the tree difficult, so mill owners avoid the high costs and low yields of processing the tree into a solid-sawn product. However, the attractive, moderately dark wood is occasionally used by woodworkers (Dykstra 2010, Herman et al. n.d.). The visual qualities of the wood make it highly suitable for woodworking, furniture, and potentially other uses. Using urban trees for wood products is a relatively new idea, but it has gained traction in the 21st century (Plumb et al. 1999, Bratkovich et al. 2008). Given the potential value of Russian olive wood and the amount of it currently going to waste, an economic analysis is justified to determine whether increased utilization can be achieved.

Utilization and Marketing of Russian Olive

The Salt Cedar and Russian Olive Control Demonstration Act of 2006 identified the need ''to assess economic means to dispose of biomass created as a result of removal of salt cedar and Russian olive trees'' (SROCDA 2006). Some research pertaining to using Russian olive biomass exists (Miles 2012, Nackley et al. 2013), but almost none has been done on its solid-sawn potential. Several mills in Northern Colorado have successfully milled and sold wood from Russian olive trees. Logs from urban removals are often available free of charge from arborists and city foresters. By donating to mills, these entities can save on disposal costs that may be charged by landfills or wood recycling yards. TC Woods, in Fort Lupton, Colorado, is an urban hardwood mill that has developed a market for Russian olive wood. They currently sell Russian olive slabs and flitches for $5 to $8 per board foot, depending on size. If landowners have Russian olive logs they wish to dispose of, they may contact local hardwood mill operators in their area.

Properties of Russian olive wood

Russian olive wood has many attributes that make it a good candidate for solid-sawn use. The visual qualities of the wood make it highly desirable for artisans. The golden brown wood exhibits strong contrast between the light springwood and the dark summerwood. The specific gravity of 0.52 (Miles and Smith 2009) means that it has a similar density to species such as western larch (*Larix occidentalis*), red maple (*Acer rubrum*), and sweetgum (*Liquidambar styraciflua*). On a structural level, the wood is ring porous with rays visible to the naked eye (Wood Database, n.d.). In this respect it is similar to species such as oak (*Quercus* spp.), hickory (*Carya* spp.), and white ash (*Fraxinus americana*). Little is known about mechanical properties like strength and stiffness. This information would be interesting but is not critical because the wood is unlikely to be used in structural applications. More useful tests would be working properties such as nail withdrawal, ease of bonding, and shrink and swell. Little scientific testing has been done on the properties of the species, but reportedly it has good working qualities. One project that used Russian olive wood to manufacture flooring and cabinetry reported the wood to have ''acceptable dimensional stability and resistance to excessive warping'' (La Calandria Associates, Inc. 2006).

Product markets available

Use of Russian olive has generally been focused on commodity products such as bioenergy and wood–plastic composites. However, as stated by Dykstra (2010), ''Russian olive wood is moderately dark with an attractive grain figure, especially around knots. It is often confused with olive wood by woodworkers.'' This suggests that the wood could be used in aesthetic applications in ways similar to blue-stained softwoods as well as hardwoods such as walnut (*Juglans* spp.), ash (*Fraxinus* spp.), and oak (*Quercus* spp.) harvested from urban settings. Wood from these species is often used by artisans for furniture, flooring, and turning stock (Cesa et al. 2003) and frequently procured in small volumes on spot markets, sometimes directly by artisans themselves. Three potential markets for Russian olive are introduced here: rough cut lumber, slabs, and turning stock.

Rough cut lumber.—Rough cut lumber is sold in varying lengths and widths with thickness in 1/4-inch increments. It is typically kiln-dried to a moisture content of below 10 percent, but in dry climates such as Colorado, this can potentially be achieved by 8 months of air-drying. Russian olive rough cut lumber is marketed toward woodworkers and sold directly to consumers for specific project needs. It is often sold as flitches, defined as larger pieces of wood that have been sawn on two or more sides and can be further sawn or sliced for veneer. Kiln-dried Russian olive flitches have been sold in the Front Range of Colorado for $5 to $8 per board foot.

Slabs.—A growing use for material from urban tree removals is for producing wood slabs (Cesa et al. 2003, MacVean 2012). Slabs are defined as full-length log cuts of varying thickness, where unique grain patterns, burl, and shape add to the quality of the piece. End uses for slabs include tabletops, countertops, and clocks (Cesa et al. 2003). Slabs can either be sold unfinished to do-it-yourself consumers or they can be planed, finished, and sold in a ready-to-use state. The Russian olive growth form has traits that lend itself very well to slab production. Sweep, crook, and branch crotches all add to the character of the piece and can add value rather than being considered a defect. One potential issue with Russian olive slabs is finding logs of sufficient size to be useful. However, this study's inventory revealed logs with small-end diameters of up to 18 inches. Many boutique shops now stock finished wood slabs, so they could potentially be sold either through a retail outlet or directly to the consumer.

Turning stock.—Russian olive can be processed into turning stock such as pen blanks, bowl blanks, or turning blanks. All of these products are designed to be turned on a lathe and vary principally in their size. Pen blanks measure around 3/4 inch wide, 3/4 inch thick, and 6 inches long; turning blanks are 1 to 2 inches wide, 1 to 2 inches thick, and of various lengths; bowl blanks are larger with various dimensions. Russian olive is readily available on eBay in all of these sizes. A principal risk involved in this market is that the species has not been tested for properties relevant to performance on a lathe. Some of the most common turning defects include fuzzy grain, roughness, and torn grain (Educo International Ltd. 1989). Also, moisture content control is very important in turning stock, and the blanks would likely require kiln-drying to fit this end use.

Challenges for niche wood products

Many buyers may be understandably reluctant to purchase Russian olive logs or lumber. Wood products from species such as oak and walnut have established markets and processing them is less of a financial risk. However, as stated by Hacker (2006), ''Niche markets can arise, or be created, in a number of ways. Perhaps the most common is due to ever expanding customer preferences and desires for greater product choices.'' There are many resources available for small business owners to build their networks and develop markets for niche wood products. University extension services and state and federal programs exist to lend direct technical assistance or specialized research and marketing assistance (Hacker 2006). Specific opportunities to businesses may include loans or grants for equipment, marketing training sessions, workshops on niche wood utilization, and networking opportunities.

According to Gold et al. (2004), lack of market information, institutions, and established grading practices often discourages entrants from producing and selling specialty wood products. The ''five forces'' model provided by Gold et al. (2004) and Porter (1980) is useful to help understand marketing factors that affect niche wood products throughout their distribution channels. Some of the factors from this model that are relevant to Russian olive include barriers to entry, suppliers, buyers, industry competitors, and government policy. Currently there is much government support for the removal of Russian olive, which will guarantee a steady supply of logs.

From a sawmill's perspective, supply conditions are favorable. A sawmill's profit is affected by the cost of raw materials, and because Russian olive trees generally represent a waste product with disposal costs for landowners, mills may be able to procure these logs at a lower price than commercial species that are more widely used and more highly valued, or even at zero cost in the case of urban removals. If the price of Russian olive lumber is competitive with other species, it may be more profitable to saw this species when it is available. To keep buyers engaged, it is necessary for producers to continually seek new products and markets for their raw materials (Gold et al. 2004). Russian olive has many potential end uses. Additional property testing and creative innovations could lead to development of other utilization opportunities.

The biggest barrier to entry in the Russian olive market may be product differentiation. Advertising campaigns could be used to bring consumer awareness to the quality of the wood. As described above, marketing assistance is available to help implement this. Competition is unlikely to be a factor in the Russian olive market, as there are currently few participants. In fact, participants may wish to work together in order to bring awareness to the product and increase demand, as is being done with hazelnuts (*Corylus avelana*) and chestnuts (*Castanea* spp.) in the Pacific Northwest (Gold et al. 2004). Hacker (2006) advocates a ''cluster based development'' approach, where businesses offering similar niche products band together to share infrastructure, labor markets, and services.

CSFS Nursery Case Study: Methods

The opportunity for this study arose with a Russian olive removal project at the Colorado State Forest Service (CSFS) nursery in Fort Collins, Colorado. Originally planted as

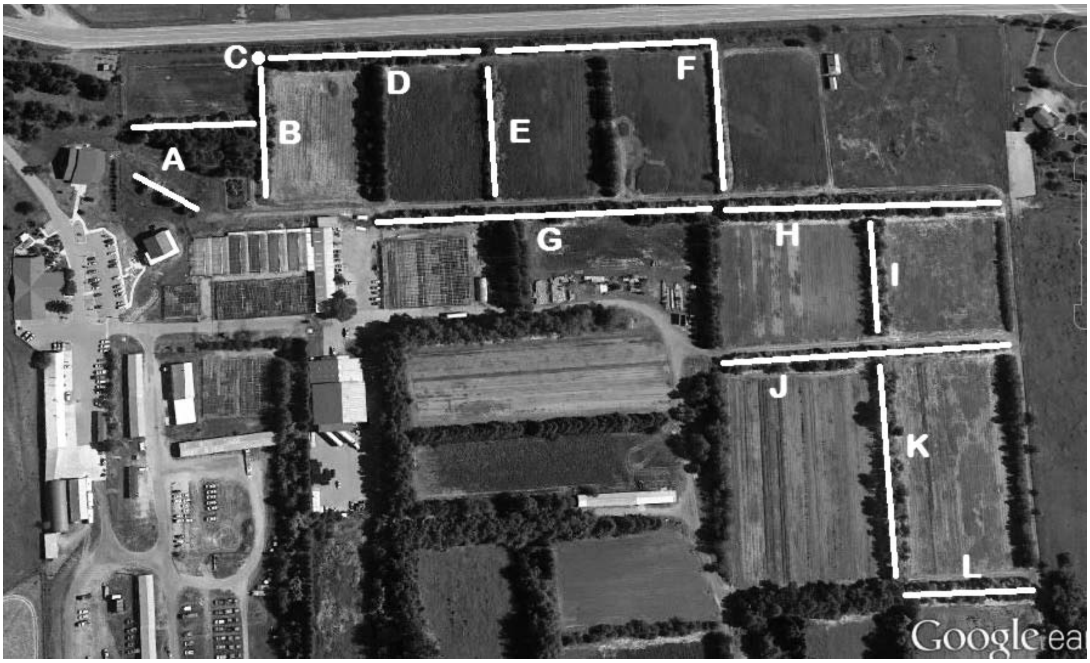

Figure 1.—Map of the Colorado State Forest Service (CSFS) nursery with section labels for the inventory. All labeled sections consist of rows of Russian olive trees, with the exception of "C," which is a log deck.

windbreaks, the trees border several of the nursery's fields in dense rows. Although many trees were removed by volunteers during 2 work days that occurred in February 2014, the vast majority of them remain standing, and the nursery is left with a decision on how to proceed with the remaining removals. Many of the trees are quite large, but prior to this study it was not known how many larger trees existed or what the potential value of the wood could be. To determine potential wood volume, an inventory was conducted to count the trees and estimate how much merchantable wood could be recovered from the removal projects. This information was used, along with estimated costs for the removals, to determine whether an economic benefit would result from use.

Inventory

To gain an idea of the number and size of Russian olives on the property, it was necessary to conduct an inventory. Data from the inventory were used to estimate the volume and value of available wood as well as the costs for removals. The Russian olives grow in rows surrounding fields in the northeast corner of the CSFS nursery. For the purposes of this inventory, the site was divided into 12 distinct sections, lettered A through L (Fig. 1). All sections consist of Russian olive rows, with the exception of C, which is a log deck from previous removals.

In determining the merchantable volume, logs with negligible sweep that met minimum dimension specifications were included. The minimum dimensions were 4 1/2-foot lengths and 8-inch top-end diameter (specifications provided by local mills as the smallest size they would work with). When possible, log length and diameters were measured by hand with a logger's tape. If merchantable, the bottom log was always measured in this fashion. For logs higher in the tree not reachable from the ground, a relascope was used. The relascope provides a rough estimation because the upper limbs rarely grow vertically; consequently the accuracy of the clinometer function of the instrument is limited. Rather than deducting for defects during the inventory, gross log volumes were taken. To estimate the cubic foot volume of logs, Smalian's formula was used. Smalian's formula was chosen rather than Bruce's Butt Swell formula because there is relatively little taper in the trees except in the case where they branch very low, and in that case the butt log is not merchantable. Additionally, stumps were left high in the pilot study of this project (see ''Pilot study'' below) so Bruce's formula does not apply.

Smalian's formula:

$$V = \frac{(d^2 + D^2) \times 0.005454}{2} \times L \tag{1}$$

where

$V =$ volume (ft^3),
$d =$ small-end diameter (in.),
$D =$ large-end diameter (in.), and
$L =$ length (ft).

Pilot study

A pilot study was conducted that consisted of the removal and processing of all 37 trees in Row B. Figure 1 shows the location of Row B, which is a linear row of Russian olives bordered to the west by Row A, which runs perpendicular, and a mixed stand of Austrian pine (*Pinus nigra*) and ponderosa pine (*Pinus ponderosa*) south of Row A. Row B was selected because it was identified as the highest priority for removal in the nursery's management plan. All harvesting was done by CSFS employees. As requested by the nursery, stumps were left approximately 2 feet high so that they could be cut again to expose a fresh surface on which to apply the herbicide treatment. Removals took approximately 2 weeks, during which time logs were left on site. After completion of the row, logs were skidded by hand with a cant hook and loaded into a pick-up bed. Logs were then transported approximately 5 miles to a local mill, where a portable Wood-mizer bandsaw mill was used to process them into 8/4 flitches. Therefore, logs had up to 2 1/2 weeks to dry before being milled. Flitches were stored under a shelter at the CSFS property, stacked, and stickered with heavy weights on top to prevent warp. A selection of flitches was sold to a local urban hardwood retailer 51 miles away after 1 week of storage. Those that were not sold were air-dried for 8 months and observed for drying defects.

This study did not target merchantable trees; rather, all trees in the row were removed, and merchantable wood was separated for processing. It would be difficult, if not impossible, to target merchantable trees for removals while leaving the other material. The interlocking branches of the trees prevent this selective cutting; generally a logger must remove all neighboring trees in order to access a particular one. This greatly increases the costs involved in removals but succeeds in achieving the ecological objectives.

Yield and value.—In traditional timber sales, the price paid to the landowner for the right to harvest timber (i.e., stumpage) can be estimated by subtracting all harvest, transport, and processing costs from the value of the lumber that will eventually be produced, leaving the theoretical maximum value of the timber before it is cut. In reality, the cost structure of a particular manufacturer is unknown to foresters and landowners, so the stumpage price is generally estimated based on market transactions (e.g., previous stumpage sales) and published stumpage prices. These are useful benchmarks when a landowner is selling standing trees, but because Russian olive is rarely bought and sold, and for the most part is treated as a waste product, there are limited market data that can be used for its valuation. Rather than focus on stumpage, in this study the cost of production from stump to wholesale product is evaluated against potential revenues. The wholesale products produced are green rough sawn flitches, to which further value can be added through drying, surfacing, and/or edging.

To establish conversion factors, it was first necessary to measure the logs prior to milling. Small-end diameter, large-end diameter, and length were measured, and Smalian's formula was used to calculate gross volume. Measurements were taken of outside bark to remain consistent with those in the inventory. After milling, the flitches were measured to calculate board foot yield. However, because the flitches had two live edges and often suffered from sweep or crook, reliable measurements were difficult to take. To address this, measurements were taken in the following way:

1. The flitch was laid so that the narrowest side faced up.
2. A straight edge that included no wane was marked by fixing a string on one end and stretching it across the flitch lengthwise.
3. The narrowest portion of wood was measured and multiplied by the length and thickness to calculate cubic inches.
4. Cubic inches were divided by 144 in^2 to calculate board footage.

It is important to note that this method underestimates the yield but can be used to determine the size of the board that would remain if the piece were edged. The measured yields will not be further reduced by loss of trim or saw kerf because only clear wood is measured. If pieces were custom cut for specific projects, or if flitches were sold whole as slabs, the yield could be significantly increased. In this study, flitches were milled to 8/4 because that was requested by the retailer. However, two additional factors may reduce recovery from these flitches: shrinkage and planing. Little is known about the shrinkage value for Russian olive. Because the flitches are sold rough sawn at retail, thickness loss through planing is not taken into account.

The above measurements were used to develop conversions from various log measurements to board footage. A lumber recovery factor (LRF) was calculated for each log by dividing its board foot yield by the gross cubic foot log volume. Additionally, a regression equation was developed in Microsoft Excel 2013 to predict board foot yield from log cubic foot volume and small-end diameter measurements.

Costs and revenues.—Cost estimations were important because the data from the O'Meara et al. (2010) report are not directly relevant to this project. The data in that report are given on a per-acre basis rather than the dense linear rows that the nursery has. Other factors are unknown, such as the amount of undergrowth, size of trees, and what was done with the material. Cost analysis methods developed by Miyata (1980) were used to track costs in the pilot study. Miyata also provides models to estimate total costs from raw data. Elements tracked in the study are fixed costs (machine depreciation, insurance, and taxes), machine operating costs (consumable supplies, maintenance, and repair), labor costs (payroll, unemployment insurance, worker's compensation, and social security), and contract services (milling). Additional costs are a 20 percent nursery administrative cost for mulch sales, or \$2/yd^3. Cost assumptions are shown in Table 1.

The cost and value results from the pilot study were used to estimate potential net costs for nursery-wide removals. This was done by taking total cost and revenue from the

Table 1.—Cost assumptions for the pilot study.

Category	Cost
Fixed costs	
Chainsaw depreciation[a] (\$/mo)	33.50
Chainsaw insurance and taxes (\$/mo)	6.42
Machine operating costs	
Chainsaw maintenance and repair[a] (\$/mo)	33.50
Fuel (\$/gal)	3
50:1 oil mix (\$/bottle)	3
Bar oil (\$/gal)	12
Vehicle mileage (\$/mi)	0.54
Vehicle mileage (\$/d)	0.50
Labor	
Hourly rate (\$/h)	16.67[b]
Social security contribution (% of payroll)	6[c]
State unemployment insurance (% of payroll)	2
Federal unemployment insurance (% of payroll)	6
Worker's compensation (% of payroll)	18
Mulch sale administration (\$/yd^3)	2
Contract services	
Specialty milling (\$/h)	95

[a] Stihl MS440: manufacturer's suggested retail price \$2,145, salvage value \$536.26, economic life 4 years.

[b] Bureau of Labor Statistics average hourly wage for a logger (Bureau of Labor Statistics 2013).

[c] Payroll calculated by multiplying hourly rate by total man-hours.

Table 2.—Select results from the inventory organized by section.

Section	Total no. of trees (merchantable trees)	Merchantable vol (ft^3)	Merchantable log count	Small-end log diam. Range (in.)	Mean (in.)	SD
A	42 (18)	146.9	26	8.0–15.0	9.5	1.8
B	37 (19)	142.6	24	8.0–14.0	9.5	2.0
C	NA[a]	50.5	15	8.0–13.3	9.9	1.6
D	NA	33.4	8	8.0–14.8	9.9	2.1
E	36 (11)	94.1	19	8.0–14.0	10.1	1.8
F	47 (10)	30.5	10	8.0–10.5	8.9	0.8
G	86 (32)	272.5	47	8.0–18.0	10.4	2.2
H	137 (24)	151.9	33	8.0–14.3	9.7	1.6
I	22 (10)	99.9	17	8.0–17.0	10.2	2.8
J	132 (24)	153.2	27	8.0–13.5	9.9	1.5
K	69 (25)	189.2	33	8.0–14.6	10.6	1.8
L	29 (8)	80.7	10	8.0–12.9	9.6	1.7
Total	637 (187)	1445.4	269	8.0–18.0	10.0	2.0

[a] NA = not applicable.

pilot study, arriving at a per-unit value, and using results from the inventory to apply this to the entire nursery. The per-unit value is either per tree or per cubic foot, depending on which is more appropriate. The average LRF from the pilot study was used to project merchantable cubic foot measurements from the inventory to potential revenue.

A value of $2.50/board foot was used to calculate revenue from flitches. This reflects the wholesale rate that the flitches produced in this study were sold for. Revenue from mulch sales was calculated by applying an $8/yd^3 rate, which incorporates the $2/yd administrative fee. In order to compare utilization methods to nonutilization methods, it was necessary to account for traditional disposal costs. Disposal costs, $6.50/yd^3 ($0.24/ft^3), were based on the rate charged by a local wood recycling yard.

Results and Discussion

Inventory

The inventory showed that 187 merchantable trees currently stand on the CSFS nursery grounds, which comprises 29.4 percent of the total number of standing Russian olive trees. Additionally, a log deck exists from the volunteer removals of trees in Rows D and F. The volume of merchantable wood from all trees and logs on the property is estimated at 1445.4 ft^3. Table 2 displays statistics about the trees and logs on the property (see Fig. 1 for section locations).

Lumber recovery

Row B removals produced 26 merchantable logs, totaling 107.5 ft^3, and 475.5 board feet of 8/4 flitches (Table 3). Very few drying defects were observed for the flitches that remained in storage. The only notable problem was checking on the ends of some of the flitches. Most were free of checks, and only in rare cases did the check extend more than 2 inches into the length of the flitch. End-checking can be prevented by applying a wood sealer such as Anchorseal to logs within 24 to 36 hours of felling.

The following regression equation was found to predict board foot yield from log measurements with an adjusted R^2 value of 0.84 (see Table 4 for regression statistics):

$$y = 2.4591x_1 + 2.0393x_2 - 14.2471 \tag{2}$$

where

y = board foot yield,
x_1 = cubic foot volume (ft^3), and
x_2 = small-end diameter (in.).

The average LRF obtained was 4.42 board feet per ft^3 (standard deviation 1.07).

Generally, LRF is strongly correlated with small-end log diameter (Steele 1984). However, that was not the case in this study. Figure 2 shows a scatterplot of the LRF versus

Table 3.—Log measurements, board foot yields, and lumber recovery factors for sawlogs from Row B.

Log	Small-end diam. (in.)	Cubic foot measurement	Board foot measurement	Lumber recovery factor
1	8.8	3.41	9.86	2.89
2	10.1	3.19	7.70	2.41
3	9.2	2.09	8.21	3.93
4	8.3	2.19	11.39	5.20
5	8.7	2.46	10.21	4.15
6	10.7	3.82	14.80	3.88
7	9.9	3.41	11.71	3.43
8	9.0	2.15	8.13	3.79
9	13.0	5.94	29.65	5.00
10	12.4	4.18	21.49	5.14
11	17.3	7.65	41.06	5.37
12	8.5	2.79	7.67	2.75
13	10.8	3.12	18.04	5.78
14	12.3	3.67	23.59	6.43
15	8.3	2.46	9.09	3.69
16	8.2	2.81	8.14	2.90
17	15.3	7.53	31.80	4.22
18	14.7	9.21	31.49	3.42
19	11.8	4.63	22.45	4.85
20	8.3	1.96	7.27	3.72
21	12.2	3.57	10.12	2.83
22	10.5	5.59	25.59	4.58
23	11.2	4.57	23.74	5.19
24	11.0	4.84	25.24	5.22
25	14.2	6.00	35.56	5.93
26	10.5	4.22	21.46	5.08

Table 4.—Regression statistics for Equation 2.

	df	Mean squared error	*F* value	*P* value
Regression	2	1084.48	66.39	2.79162E−10
Residual	23	16.33		

small-end diameter relationship ($R^2 = 0.18$). A possible explanation for this poor correlation is that, because of the Russian olive growth form, longer logs are more likely to have crooks that significantly decrease lumber yield and consequently LRF. Despite small-end diameter being a poor predictor of LRF, it remains an accurate predictor of board foot yield. This is because in measuring board foot yield, length was often sacrificed in order to obtain a higher yield. For example, if the board suffered from a crook near an end, that section may have been excluded from the measurement; otherwise the edged board would have a narrower width. However, the crook would have still been included in the log's measurements before milling. The LRF and Equation 2 are sensitive to product mix. In this case, the desired product was the largest possible flitch, which does not necessarily maximize the LRF. If a mill were interested in producing cut stock material or boards with smaller width, a higher proportion of the log would be used, and the LRF would increase.

As mentioned in the ''Methods'' section, conversions are based on gross log volume measurements rather than a net volume that is deducted for defect. The logs had very little heart rot, so most yield losses were due to their unpredictable shape. The low productivity requirements of specialty milling allowed for an individual approach to milling each log. Rather than being cut into cants, the logs were flat-sawn after being intentionally positioned on the mill in a way that maximizes yield. This allowed volume loss from each log to be reduced.

Data from Row B removals differed from inventory predictions (Table 2) in two ways: cubic foot yield was 24.6 percent less than predicted, and sawlog count was two logs higher. One explanation for the error in volume is the yield lost in the remaining stumps (see ''Pilot study''). On seven of the removals, this resulted in a significant loss of yield. Another explanation is that some longer logs were sectioned into shorter ones to eliminate defects such as sweep or crook and improve board foot yield. This explains the extra sawlogs and the loss in overall yield.

Nursery-wide cost projections

An important comparison can be made here between net costs of a removal project that seeks utilization versus a traditional approach. Both approaches are net losses, but if a traditional removal project were conducted, logs would still need to be removed and disposed of without recovering any value. Cost information such as man-hours and fuel used were tracked during the pilot study and are shown in Table 5. Table 6 shows nursery-wide costs and potential revenues from flitches and mulch both for a utilization approach and a traditional approach to removals. Net costs for the project are estimated at $30,254.10, but if all yields are sold at market value, net cost could be reduced to $21,544.17.

To estimate this, per-tree cost and value is relied upon (see ''Costs and revenues''). Removal costs and wood values of individual trees are in reality highly variable, depending on a number of factors such as tree size, structure, and volume of merchantable wood. The per-tree values are used here out of necessity to extrapolate findings from the pilot study to the larger nursery. Because this study's trees were planted together and raised under similar growing conditions, it is assumed that Row B is representative of the entire nursery. However, the per-tree values reported here may not be applicable to other operations.

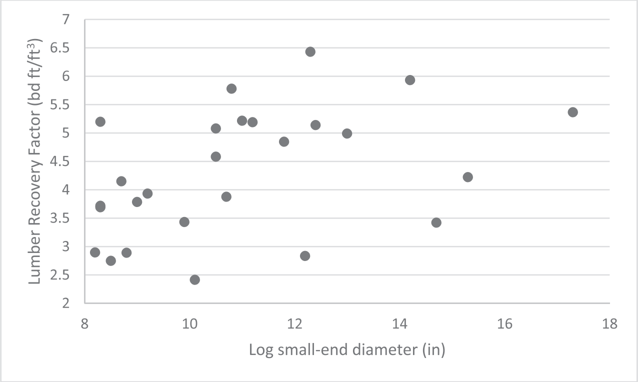

Figure 2.—Scatterplot showing lumber recovery factor versus log small-end diameter.

Implications: Increasing Russian olive demand and utilization

A selection of flitches from this study was sold to a local retailer. The wholesale price was $2.50/board foot, and the eventual retail price was $5 to $8 per board foot, depending on size of the piece. This mark-up reflects the drying process, storage facilities, and retail base. Because of current market conditions, the retailer could only use 300 board feet of the 475.5 produced. However, there is potential for markets to improve.

Russian olive has desirable qualities, both aesthetic and physical, and can be used to produce lumber that has market value. Despite this, consumer preference is lacking for Russian olive wood and demand is low. An article by Luppold and Bumgardner (2007) identifies three major factors that influence the price of hardwood lumber: fashion influences, manufacturing influences, and availability of timber. Russian olive is well suited to take advantage of these factors and gain an increase in product value, helping the species go from a waste product with disposal costs to a commercial species that may offset treatment costs.

Table 5.—Total costs of pilot project by category.[a]

Cost category	Total cost ($)	Inputs
Fixed	39.93	1 mo of chainsaw use
Machine operating	196.10	2.5 gal of chainsaw fuel; 12 gal of chipper fuel; vehicle use (101 mi and 3 d); $35.25 in various chainsaw repair parts
Labor	1501.00	67.25 man-hours (harvest, chip, transport, skid), mulch sale administration for 5 yd^3
Contract services	617.50	6.5 h of specialty milling
Total	2,354.53	

[a] Reference Table 1 for information on cost assumptions.

Table 6.—Projected costs of tree removal and value of harvested material.[a]

	Unit avg.	No. of units	Total cost ($)	Total value ($)	Applies to[a]
Milling costs	$5.74/ft^3	1445.4	8296.60		Utilization
Lumber value	$11.05/ft^3	1445.4		15,971.67	Utilization
Removal and transport costs	$46.95/tree	637	29,907.20		Both
Mulch value	$1.08/tree	637		687.96	Both
Disposal costs	$0.24/ft^3	1445.4	346.90		Traditional

[a] The data is segregated into the type of project: one that attempts to utilize the logs, a traditional approach, and activities that apply to both approaches.

Because consumer preference in hardwood lumber is closely tied to marketing (Luppold and Bumgardner 2007), target marketing and product differentiation may be used to increase consumer demand for Russian olive. Product differentiation is necessary to set the species apart from lower value species such as ash or elm and convince consumers that it is as desirable as species such as oak or maple. The target market for Russian olive is artisans who purchase the product on spot markets and use it for furniture or woodworking projects. Increased consumer demand could lead to higher value for the product and allow a greater cost offset than that which the CSFS achieved in this study. One barrier to this is that mills are not very familiar with processing Russian olive logs. However, this research has shown that it is possible to process Russian olive logs with a band-mill. Additional research and technical assistance may be necessary to convince mills to work with Russian olive on a larger scale.

The hardwood industry is capable of reacting to increased demand for Russian olive sawlogs. Because the species is likely to be sold directly to consumers rather than furniture manufacturers, demand is not subject to manufacturer constraints such as fixed proportion production and fixed market strategies that prevent substituting of species. Timber availability is another constraint that often prevents a species from taking advantage of potential increases in value (Luppold and Bumgardner 2007). Because of the volume of Russian olive logs currently going to waste and the policy incentives for continued removal, timber availability does not appear to be a major concern in the near future.

Conclusions

Russian olive removal projects may differ in specifics such as site conditions, access to trees, and local infrastructure. These variables may significantly affect the practical and economic feasibility of use. Many Russian olive removal projects are in riparian areas that are difficult to access, where logs are often left on site. This research is more likely to apply to easily accessed trees such as those in urban landscaping and in windbreaks. However, utilization should still be considered for riparian removal projects, and its potential has been demonstrated (La Calandria Associates, Inc. 2006).

This research has shown that (1) it is possible to harvest commercial Russian olive sawlogs and process them into a product that consumers will pay for, and thus (2) the CSFS nursery, and potentially other landowners, could realize a cost offset by selling Russian olive sawlogs from removal projects. When faced with high costs for removal projects, one would have difficulty finding a reason not to seek out some profit and use for the wood. Currently there is not a high demand for Russian olive wood, nor is there an excess of mills that are familiar with milling the logs. This study proposes that such an arrangement is economically feasible, with the hope that increased Russian olive utilization can result. Raising awareness for the value of Russian olive wood could not only provide interesting new wood to the market but could provide a means to an end for those wishing to remove the invasive species and restore their properties.

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