PRELIMINARY FINANCIAL EVALUATION OF MANAGEMENT REGIMES CONTROLLING CHINESE PRIVET IN LOBLOLLY PINE STANDS

Fabio J. Benez-Secanho, Donald L. Grebner, Andrew W. Ezell, and Robert K. Grala

Abstract—Chinese privet (*Ligustrum sinense* Lour.) is the most common invasive shrub species in the Southern United States, causing biodiversity and economic losses. This study evaluated several treatments found in the literature and conducted a financial analysis to identify the most cost-effective management regimes for controlling this species in loblolly pine (*Pinus taeda* L.) stands. Simulated scenarios were created to assess these management regimes. Three components were used: infestation levels, herbicide application methods, and herbicides. For each simulated scenario, the financial impact on land expectation values (LEV) was analyzed. Results indicated that the most cost-effective management regime controlling Chinese privet in loblolly pine stands is to aerial spray with Arsenal AC, followed by a backpack spray 2 years later with the same herbicide. Chinese privet control is economically feasible, and a positive LEV could be achieved for all scenarios. Further research of the same nature with more components and variables is being conducted.

INTRODUCTION

Components of the Earth's biodiversity are being altered by humans' activities, leading to an increase in species invasions and extinction of endemic species. These changes in composition of communities and ecosystems can affect the provision of ecosystem services, which are essential for society (Estrada and Flory 2014, Hooper and others 2005). Competition among plants can cause environmental changes, especially when an exotic species spreads over a nonnative range, competes with native species, and becomes an invasive species (Brooker 2006). About 50,000 species were introduced in the United States for many reasons, such as landscaping, biological control, packing materials, and food production. Currently, exotic species account for more than 98 percent of the U.S. whole food system, and are responsible for an estimated annual value of US$800 billion (Pimentel and others 2005). However, due to favorable conditions some of these species escaped from cultivation and became invasive species, spreading over 133 million acres in the United States and causing an estimated annual loss of US$120 billion (Pimentel and others 2005).

Chinese privet (*Ligustrum sinense* Lour.) is a shrub native to China, and was introduced in the United States in 1852 for landscaping purposes (Dirr 1998, Maddox and others 2010). Due to its ability to grow and reproduce rapidly, it spread over the Southern United States and became the most common invasive shrub species in this region (Oswalt and Oswalt 2011, Urbatsch and Skinner 2000). Other invasive species belonging to the same genus, such as European privet (*Ligustrum vulgare* L.), mostly found in the Northeastern United States (BONAP 2015), and Japanese privet (*Ligustrum japonicum* Thunb.), mostly occurring in the Southern United States, are less abundant than Chinese privet (BONAP 2015, Maddox and others 2010). Chinese privet is an effective colonizer, growing by seed dispersal and vegetatively, and is normally introduced into new areas carried by wildlife, especially birds (Maddox and others 2010). Chinese privet can grow in the understory and suppress growth of tree seedlings, compromising overstory regeneration and causing a shift within the ecosystem from forest to shrub land (Loewenstein and Loewenstein 2005).

Although some species have potential to harm or feed on Chinese privet, there is no widespread use of any biological control (Maddox and others 2010). Chinese privet can sprout vigorously after burning, so fire is not recommended as a stand-alone treatment (Urbatsch and Skinner 2000). Mechanical removal is more effective if combined with herbicide applications because Chinese privet can vegetatively spread (Hanula and others 2009, Klepac and others 2007). Finally, herbicide applications alone can effectively control privet (Maddox and others 2010, Miller 2003).

Author information: Fabio J. Benez-Secanho, Graduate Research Assistant, Mississippi State University, Mississippi State, MS 39762-9681; Donald L. Grebner, George L. Switzer Professor of Forestry, Mississippi State University, Mississippi State, MS 39762-9681; Andrew W. Ezell, Department Head, George L. Switzer Professor of Forestry, Mississippi State University, Mississippi State, MS 39762-9681; Robert K. Grala, Associate Professor, Mississippi State University, Mississippi State, MS 39762-9681.

Kirschman, Julia E., comp. 2018. Proceedings of the 19th biennial southern silvicultural research conference. e-Gen. Tech. Rep. SRS-234. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 444 p.

Only a few studies in the literature evaluated the financial tradeoffs of invasive species control measures. A common financial criteria land expectation value (LEV) can be used to compare alternative forest investments (Bettinger and others 2009). Grebner and others (2011) utilized LEV to analyze alternative management regimes controlling kudzu [*Pueraria montana* var. lobata (Willd.)], and Prevost and others (2007) assessed financial tradeoffs controlling cogongrass [*Imperata cylindrica*, (L.) P. Beauv.] by using LEV. Therefore, the objective of this study was to compare the financial effectiveness of common silvicultural treatments used to control different levels of Chinese privet infestations in loblolly pine stands.

MATERIALS AND METHODS

Area Conditions

This study evaluated Chinese privet treatments in loblolly pine (*Pinus taeda* L.) stands. These stands were assumed to be 20 years old and having 251 trees per acre at this age. Growth and yield were simulated using the software acquired from the U.S. Department of Agriculture Forest Service's Forest Vegetation Simulator (FVS). An initial planting density of 538 seedlings per acre (9 feet x 9 feet) was used in this simulation, and a rotation length of 33 years was adopted. First thinning was to occur at age 13 and a second thinning at age 21. This rotation length and thinning intervals were consistent with previous literature (Davis 2013). This study also assumed that the area will be artificially regenerated after harvesting and the same regime adopted.

Chinese privet can grow dense thickets even in the understory of forests, which can adversely impact operational efficiency of ground-based herbicide applications (Klepac and others 2007, Maddox and others 2010). Therefore, three different Chinese privet infestation levels were evaluated. Each level was defined by the number of Chinese privet stems per acre and was adapted from Hanula and others (2009), Hart and Holmes (2013), and Merriam and Feil (2002): low density (<3,496 stems per acre), medium density (ranging between 3,497 and 8,742 stems per acre), and high density (>8,743 stems per acre).

Management Regimes

Some of the most effective treatments for Chinese privet were collected, reviewed, and used to calculate costs under different levels of Chinese privet density and herbicide control options. These treatments were herbicide-based, and had a minimum effectiveness of 90 percent when controlling for this species to decrease the chance of recolonization after treatment (Miller 2005). This study evaluated two different herbicide application methods: aerial (helicopter) and skidder equipped with broadcast sprayer. In addition, two herbicide brands were included in this evaluation: Arsenal AC (imazapyr) and Accord XRT II (glyphosate). Aerial applications are recommended to be conducted during the winter to limit native species damage, and herbicides containing glyphosate should be avoided even during the winter due to their potential for harming pine trees (Dow AgroSciences 2012). Rates of active ingredient per acre were estimated based on studies from the literature, and they varied according to the Chinese privet infestation level. Table 1 provides the quantity of each herbicide per acre based on rates of active ingredient and their respective concentration. Chinese privet is not properly controlled with one single herbicide application (Johnson and others 2010, Klepac and others 2007, Miller 2005). Therefore, all management regimes include a second application 2 years later, using a backpack to spray on resprouts. This second application used the same herbicide of the first application and the same rate used in low infestation level treatments.

Financial Analysis

Land expectation value was the method chosen to compare economic impact of controlling Chinese privet in loblolly pine stands, and cash flows were discounted at a rate of 6 percent. Net present value (NPV) of current stands was first calculated using revenues from thinning and final harvesting,

Table 1—Rate of herbicide per acre used in the management regimes for controlling Chinese privet (*Ligustrum sinense* Lour.)

				Herbicides (product/ac)[a]		
				Chinese privet infestation levels		
Commercial name	Active ingredient	Concentration (active ingredient/gal)	Unit	Low	Medium	High
Accord XRTII	Glyphosate	5.07 lb/gal	gal/ac	0.592	0.888	1.183
Arsenal AC	Imazapyr	4.9 lb/gal	gal/ac	0.128	0.153	0.179

[a] Rates are calculated based on the concentration of active ingredient and rate of active ingredient per acre.

and costs of management regimes controlling Chinese privet. In addition, LEV for a loblolly pine reforestation was calculated using revenues from thinning and final harvesting and costs of reforestation. This LEV calculation did not include costs for controlling Chinese privet because it was assumed that this species population was effectively controlled at this point (Hudson and others 2013). Finally, this study merged NPV of current stands and LEV of future reforestation to calculate the combined LEV. Therefore, this combined LEV accounts for costs and revenues from current and future stands. Since this study assumed that current stands are 20 and 22 years old when Chinese privet treatments occur, these are years 0 and 2 for financial analysis purpose. LEV for an area free of Chinese privet was also calculated for comparison purpose.

Costs and revenues

Costs used in this study represent an average of southern States (Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia), and were obtained from vendors, literature, and personal communication. Table 2 displays costs for herbicides and surfactant. Costs related to herbicide application are reported in table 3, and they vary according to Chinese privet infestation level. An average cost of US$144.89 per acre for loblolly pine regeneration in the Southern United States was calculated by accounting for chemical site preparation, planting stock, and hand planting.[1] Revenues from timber harvesting were calculated using prices from TimberMart-South. The average price for pulpwood used in this study was US$10.23 per short ton, US$17.31 per short ton for chip-n-saw, and US$25.39 per short ton for sawtimber (TimberMart-South 2016).

Table 2—Average costs of herbicides and surfactant used in the management regimes for controlling Chinese privet (*Ligustrum sinense* Lour.)

Product	Unit	Cost/unit (US$)
Accord XRT II (herbicide)	Gallon	32.64
Arsenal AC (herbicide)	Gallon	182.38
Cide-Kick II (surfactant)	Gallon	36.95

Source: Local and online vendors.

Table 3—Costs[a] for herbicide application for controlling Chinese privet (*Ligustrum sinense* Lour.)

Application method	Chinese privet infestation level		
	Low (US$/ac)	Medium (US$/ac)	High (US$/ac)
Aerial	30.00	30.00	30.00
Skidder	55.00	65.00	70.00
Backpack	80.00	-	-

Sources: Aerial: Personal communication. Michael McCool. 2016. Provine Helicopter Service, 308 Airport Road, Greenwood, MS 38930.

Skidder and backpack: Costs were estimated based on Miller (1988) and personal communication, Gueth Braddock. 2016. Silviculturist, 524 Natchez Dr. NE, Brookhaven, MS 39601.

[a] Costs for herbicide and surfactant are not included.

RESULTS AND DISCUSSION

A land expectation value of US$895.18 per acre, with a rate of return of 12.35 percent, was first calculated for a loblolly pine stand free of Chinese privet. This LEV was incorporated with the NPVs of all simulated area conditions, generating a combined LEV for each management regime. The maximum possible combined LEV that can be obtained for this loblolly pine stand was US$3,238.41 per acre when no Chinese privet is present. Table 4 reports the results for all area conditions, displaying the maximum possible LEV for this loblolly pine stand, total cost per acre for each management regime (this cost includes a first and second application), regime effectiveness, LEV when regime costs are included, and the percentage that these LEVs represent when compared to the maximum LEV for this area.

Results depicted in table 4 suggested that aerial application with Arsenal AC followed by a second application using the same herbicide, but spraying with backpack sprayer, was the most cost-effective management regime when controlling for Chinese privet when the infestation level is low, and has a cost of US$151.21 per acre. This regime has an effectiveness rate of 94 percent, and yielded a LEV of US$3,087.20 per acre, which represents 95.33 percent of the maximum LEV. The most cost-effective management regime for controlling a medium infestation of Chinese privet is aerial spray with Arsenal AC followed by an application with the same herbicide using backpack sprayer two years later (table 4). This regime has a cost of US$155.88 per acre, and yielded a LEV of US$3,082.53 per acre.

[1] Personal communication. Randall J. Rousseau. 2016. Associate Extension/Research Professor, Room: 369 Thompson Hall, Department of Forestry, Mississippi State, MS 39762-9681.

Table 4—Results for controlling low, medium, and high infestation levels of Chinese privet (*Ligustrum sinense* Lour.) in a loblolly pine (*Pinus taeda* L.) stand

		Chinese privet control			
		Total cost[b]	Effectiveness	Financial analysis	
Infestation level	Code[a]	US$/acre	%	LEV[c] (US$/acre)	%[d]
No Chinese privet	No control	0.00	-	3,238.41	100
Low	A-Ar	151.21	94	3,087.20	95.33
	S-Ar	177.13	94	3,061.28	94.53
	S-Ac	162.70	99	3,075.71	94.98
Medium	A-Ar	155.88	94	3,082.53	95.19
	S-Ar	192.72	94	3,045.68	94.05
	S-Ac	182.36	99	3,056.05	94.37
High	A-Ar	160.53	94	3,077.88	95.04
	S-Ar	194.36	94	3,044.05	94.00
	S-Ac	197.01	99	3,041.39	93.92

[a] Codes depict characteristics of management regimes. No control = no management regime is used. Application method: A = aerial; S = skidder. Herbicide: Ar = Arsenal AC; Ac = Accord XRTII.

[b] Total cost includes two applications.

[c] LEV (land expectation value) when control costs are included.

[d] Percentage this LEV represents of the maximum possible LEV for each area.

When the infestation level is high, table 4 shows that spraying aerially with Arsenal AC followed by a second application using backpack sprayers with the same herbicide was also the most cost-effective management regime. However, under this condition, costs of controlling Chinese privet were higher due to higher rates of herbicides, and this treatment costs US$160.53 per acre. The LEV of this regime is US$3,077.88 per acre, and represents 95.04 percent of the maximum LEV.

Overall within treatments, costs for controlling Chinese privet increased as the infestation level increased. Due to a higher number of plants per unit area, ground-based herbicide application operations were more expensive for higher infestation levels. Aerial applications were less costly when compared to ground-based, and for this reason the most cost-effective management regimes in this study used aerial applications. Even though aerial application costs were constant, regardless of the infestation level, higher herbicide rates were necessary to control higher infestation levels of this species, which made these applications more costly under these conditions. When determining whether aerial applications are feasible or not, an important consideration is target area size. Normally, contractors only spray areas larger than 20 acres. However, some contractors offer their services for a group of landowners of small areas from the same region, making these applications economically feasible.[2] Although aerial applications had better financial performance, due to site restrictions, landowner preferences, or other reasons, these applications sometimes cannot be used. For these cases, this study included ground-based applications conducted by a skidder as possible management regimes. Controlling invasive species can aid in recapturing underutilized or degraded sites, which provides wildlife habitat and can generate extra revenues for landowners (Grebner and others 2011).

CONCLUSIONS

The study objective was to evaluate and examine the financial tradeoffs of controlling Chinese privet in loblolly pine stands with different levels of infestation. Regardless of the infestation level, an aerial application and followup backpack spray with Arsenal AC was the most cost-effective control method for Chinese privet. Results indicated that controlling any level of Chinese privet infestation in a loblolly pine stand with these specific characteristics

[2] Personal communication. Michael McCool. 2016. Provine Helicopter Service, 308 Airport Road, Greenwood, MS 38930.

was economically feasible. Revenues generated by this stand were sufficient to offset management regime costs, and the financial impact of these regimes on LEVs was relatively small. Further economic analysis is being conducted to evaluate management regimes controlling for Chinese privet in other forest types, accounting for stand density and including a greater number of control methods.

ACKNOWLEDGMENTS

We acknowledge the Forest & Wildlife Research Center at the College of Forest Resources, Mississippi State University, for providing funds for this research, and Gueth Braddock, Michael McCool, and Dr. Randall J. Rousseau for their assistance in estimating costs of various silvicultural activities in the Southern United States. Finally, we acknowledge Dr. John L. Willis and Dr. Stephen C. Grado for their time and knowledge involved with reviewing this article.

LITERATURE CITED

Bettinger, P.; Boston, K.; Siry, J.P.; Grebner, D.L. 2009. Forest management and planning. Amsterdam: Academic Press. 331 p.

Biota of North America Program [BONAP]. 2015. *Ligustrum sinense*. http://bonap.net/MapGallery/County/Ligustrum%20sinense.png. [Date accessed: September 12, 2015].

Brooker, R.W. 2006. Plant-plant interactions and environmental change. New Phytologist. 171(2): 271–284.

Davis, P.B. 2013. Economic tradeoffs of managing pine plantations for timber production or wildlife habitat. Starkville, MS: Mississippi State University. 53 p. M.S. thesis.

Dirr, M.A. 1998. Manual of woody landscape plants: their identification, ornamental characteristics, culture, propagation, and uses. 5th ed. Champaign, IL: Stipes Publishing Company. 1250 p.

Dow AgroSciences. 2012. Accord XRT II product label. Dow AgroSciences: Indianapolis, IN. 12 p.

Estrada, J.A.; Flory, S.L. 2014. Cogongrass (*Imperata cylindrica*) invasions in the US: mechanisms, impacts, and threats to biodiversity. Global Ecology and Conservation. 3: 1–10.

Grebner, D.L.; Ezell, A.W.; Prevost, J.D.; Gaddis, D.A. 2011. Kudzu control and impact on monetary returns to non-industrial private forest landowners in Mississippi. Journal of Sustainable Forestry. 30(3): 204–223.

Hanula, J.L.; Horn, S.; Taylor, J.W. 2009. Chinese privet (*Ligustrum sinense*) removal and its effect on native plant communities of riparian forests. Invasive Plant Science and Management. 2(4): 292–300.

Hart, J.L.; Holmes, B.N. 2013. Relationships between *Ligustrum sinense* invasion, biodiversity, and development in a mixed bottomland forest. Invasive Plant Science and Management. 6(1): 175–186.

Hooper, D.U.; Chapin Iii, F.S.; Ewel, J.J. [and others]. 2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. Ecological Monographs. 75(1): 3–35.

Hudson, J.R.; Hanula, J.L.; Horn, S. 2013. Removing Chinese privet from riparian forests still benefits pollinators five years later. Biological Conservation. 167: 355–362.

Johnson, J.; Griffin, S.; Taylor, J. 2010. Aerial glyphosate application to control privet in mature hardwood stands. Georgia Forestry Commission report. 8 p.

Klepac, J.; Rummer, R.B.; Hanula, J.L.; Horn, S. 2007. Mechanical removal of Chinese privet. Res. Pap. SRS-43. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 16 p.

Loewenstein, N.J.; Loewenstein, E.F. 2005. Non-native plants in the understory of riparian forests across a land use gradient in the Southeast. Urban Ecosystems. 8(1): 79–91.

Maddox, V.; Byrd, Jr., J.; Serviss, B. 2010. Identification and control of invasive privets (*Ligustrum* spp.) in the middle Southern United States. Invasive Plant Science and Management. 3(4): 482–488.

Merriam, R.W.; Feil, E. 2002. The potential impact of an introduced shrub on native plant diversity and forest regeneration. Biological Invasions. 4(4): 369–373.

Miller, J.H. 1988. Herbicide technology: its present and future role in re-establishing southern plantations. In: Proceedings of the second rotation plantation establishment workshop. Georgetown, SC: Baruch Foundation: 26–38.

Miller, J.H. 2003. Nonnative invasive plants of southern forests: a field guide for identification and control. Res. Pap. SRS-62. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 93 p.

Miller, J.H. 2005. Chinese privet control with herbicide foliar sprays. Wildland Weeds. Summer: 8(3): 5–8.

Oswalt, S.N.; Oswalt, C.M. 2011. The extent of selected nonnative invasive plants on southern forest lands. In: Proceedings of the 17th central hardwood forest conference. Gen. Tech. Rep. NRS-P-78. Lexington, KY: U.S. Department of Agriculture Forest Service, Northern Research Station: 447–459.

Pimentel, D.; Zuniga, R.; Morrison, D. 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics. 52(3): 273–288.

Prevost, J.D.; Grebner, D.L.; Jones, J.C. [and others]. 2007. Evaluation of cogongrass control techniques for nonindustrial private landowners in Mississippi. In: Proceedings of the 2007 southern forest economics workshop. San Antonio, TX: Texas A&M University: 188–193.

TimberMart-South. 2016. Timber Mart-South: annual summary. Athens, GA: Daniel B. Warnell School of Forest Resources, University of Georgia. 2nd quarter 2016.

Urbatsch, L.; Skinner, M. 2000. Chinese privet Ligustrum sinense Lour. Plant guide. U.S. Department of Agriculture, Natural Resources Conservation Service. 5 p.