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economics

An Economic Analysis of the Impact of Cogongrass among Nonindustrial Private Forest Landowners in Florida

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This study documents and evaluates the economic losses due to controlling cogongrass infestation among nonindustrial private forest (NIPF) landowners in the state of Florida. The analysis is based on information collected through a mail survey that was widely distributed among NIPF landowners in Florida, reaching a final sample of 1,060 landowners. The survey revealed that nearly 30% of respondents have problems with cogongrass in their property. In addition, close to 41% of NIPF owners indicated that cogongrass has reduced the recruitment and/or growth of trees in woodlands, and 54% of them responded that cogongrass has increased the hazard for wildfire in the area of infestation. Data on direct costs associated with chemical or physical control of cogongrass were collected to complete our analysis. An economic input/output analysis revealed that cogongrass control costs resulted in total economic losses of $35 million annually to the forestry industry and related business sectors throughout Florida.

Keywords: nonindustrial private forest landowners, Florida, cogongrass, input/output analysis

Cogongrass (*Imperata cylindrica* [L.] Beauv.) is an invasive rhizomatous perennial grass that negatively affects the agriculture and forestry industry. Some of the intrinsic characteristics that make this grass extremely invasive include the following: it blooms early in the spring and each plant can produce up to 3,000 seeds; it has very light seeds that can be dispersed by the wind for distances up to 15 miles; and it has very strong rhizomes that allow this grass to survive during adverse environmental conditions (e.g., drought, fire, flooding) and also aid its rapid spread within short distances (Onokpise et al. 2007). Once established, this grass may produce more than 7 tons of rhizomes per ha and spread at an exponential rate. Not only do the sheer mass and persistence of rhizomes contribute to the ability of cogongrass to dominate an area but also it has been reported that these rhizomes exude allelopathic substances that inhibit growth of other plants (Hagan et al. 2013). As the density of cogongrass increases, all other vegetation may be excluded, and normal succession of other grasses and shrubs will not occur (Chikoye et al. 2005). Cogongrass grows in a wide range of soils from rich sandy loams to poor sands. Even though this alien species grows best in full sun, it also thrives in deep shade and will persist during severe droughts or through periodic inundations (MacDonald et al. 2006, Onokpise et al. 2007).

More than 500 million ha of land have been infested with cogongrass worldwide (Dozier et al. 1998). In Asia, where an estimated 200 million ha are dominated by cogongrass, infested areas are increasing at a rate of 150,000 ha annually (Dozier et al. 1998). This grass has been reported as a serious economic problem in more than 35 annual and perennial crops, including rubber, coconut, oil palm, coffee, dates, tea, citrus, forests, field crops, and row crops (Waterhouse 1999).

In the United States, more than 100,000 ha are estimated to be infested in the states of Alabama, Florida, and Mississippi (Dickens and Buchanan 1975, Schmitz and Brown 1994). In Florida sandhill communities, cogongrass is threatening the habitat of endangered

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This article uses metric units; the applicable conversion factors are: hectares (ha): 1 ha = 2.47 ac.

species such as gopher tortoises and indigo snakes (Shilling et al. 1997, Lippincott 2000). Cogongrass is also flammable and increases fine-fuel loads. Resultant fires tend to be hotter, taller, and potentially more frequent, even in communities adapted to frequent fire such as longleaf pine and wiregrass. In addition, extensive rhizome reserves of cogongrass enable it to quickly regrow after disturbance events (Onokpise et al. 2007).

Anecdotal evidence suggests that forestland owners in Florida have spent significant amounts of money to control this invasive grass and may have experienced losses in forest production. Thus, from an economic viewpoint, cogongrass can affect the performance of the forestry sector by reducing the productivity of the forest or by increasing its production costs. Measuring the direct impact of cogongrass on forest productivity is not a trivial undertaking. Isolating the impact on productivity of this invasive species from that of other exogenous factors (e.g., climate change, extreme weather, and wild and human-caused fires) is an intricate task that would require an extensive data collection process that tracks forest productivity across forestlands infected with cogongrass as well as across control areas (counterfactual state) free of this invasive grass.[1] At the moment, no such process has been undertaken. However, assessing forest-level losses in revenue due to increased control costs is a feasible task.

Thus, the goal of this study is to document the direct losses in revenue for nonindustrial private forest landowners (NIPF)[2] due to the control of cogongrass infestation in Florida. The forest-level control costs collected from a survey of NIPF owners is then used to estimate the direct, indirect, and induced economic impacts using an input/output regional economic model. In addition, we also document the perceptions of Florida NIPF owners toward cogongrass, the geographic extent of cogongrass infestation in Florida, and some important characteristics of NIPF operations in the state of Florida.

Evaluating and documenting the economic impact of invasive plants on state and regional economies have received little attention in the literature. In one of the few studies on this issue, Hirsch and Leitch (1996) evaluated the impact of knapweed (*Centaurea maculosa*) infestation in Montana. These authors reported that knapweed caused a direct economic loss of $14 million per year in reduced grazing capacity, reduced wildlife-associated recreational spending, and higher rates of soil erosion and surface water runoff. Similarly, Bangsund and Leistritz (1991) documented the direct economic impacts of leafy spurge (*Euphorbia esula* L.) in the Northern Great Plains on grazing land at close to $37 million per year, whereas its direct impacts on other lands totaled $3.4 million per year.

Harris et al. (2006) assessed the economic impacts due to the adverse influence of noxious invasive plants on wildlife-related recreation. Using public lands in Nevada as a case study, these authors estimated the impact of noxious invasive plants on the recreational sector to range from $6 to $12 million per year. In addition, they forecasted the discounted stream of negative economic impact over a 5-year horizon to range between $30 and $40 million.

The economic impact of yellow starthistle (*Centaurea solsitialis* L.) in the rangelands of Idaho was studied by Julia et al. (2007). In this case, the total economic loss was reported to be $12.7 million, of which 64% was attributed to the direct impact of the weed and the remaining was the result of the weed's indirect and induced cost to the region's economy. Using a similar approach, Salaudeen et al. (2013) evaluated the impact of tropical soda apple (*Solanum viarum*) on Florida's cattle production. This study estimated that controlling tropical soda apple resulted in annual economic losses of approximately $15 million throughout the state of Florida. The present article contributes to the literature by documenting the economic costs of cogongrass on the forestry sector in Florida. Given that the optimal strategy for prevention, eradication, or control necessarily depends on the social costs of invasions (Olson 2006), this study offers policymakers and land managers the necessary information to justify future management programs. In addition, the framework developed in this study can be used to study the economic impact of other invasive species on different sectors and geographical areas.

Data Collection and Methods

Data Collection

To assess NIPF owners' perceptions toward cogongrass and measure the direct losses in revenue attributable to the control of this grass, primary data were collected using a mail survey. The survey instrument was designed following Dillman's (2000) tailored design method (TDM) to enhance response rates from survey participants, yield unbiased answers, and minimize measurement error. The TDM is a set of procedures for conducting successful self-administered surveys that produce both high-quality information and high response rates (Dillman 2000). Special attention was focused on developing efficient questions, and graphics software was used in the final layout to give the instrument a professional look. The survey was pretested before being administered to the sample of NIPF owners.[3] Names and addresses of NIPF landowners in Florida were obtained from the Forest Stewardship Program at the University of Florida Institute of Food and Agricultural Sciences (UF/IFAS). The UF/IFAS Stewardship Program manages the most comprehensive list of NIPF landowners in Florida.[4]

A total of 2,832 surveys were mailed to NIPF landowners in Florida on Dec. 24, 2010, followed by reminder postcards 10 days later. Nonrespondents were mailed a second survey in March 2011, and the survey was concluded after 1,150 surveys were completed and returned and 350 surveys were counted as undeliverable. Of the 1,150 returned surveys, 1,060 were completed with no missing relevant data, yielding an adjusted response rate of 42.7%.

Estimating the Statewide Costs of Cogongrass Control

The first step in determining the economic impact of cogongrass is to estimate the direct losses to NIPF landowners as a result of the chemical or physical control of cogongrass patches. To estimate this direct impact at the regional level, our survey results must be extrapolated to the entire state. We estimate this direct impact as a function of total regional nonindustrial forestland owned by private individuals, the level of cogongrass infestation, the proportion of woodland owners attempting to control cogongrass, and the cost of control. For any given region i, the regional cost (RC_i) for cogongrass control can then be expressed as

$$RC_i = I_i \times A_i \times P_i \times C_i$$

where I_i, A_i, P_i, and C_i represent the regional infestation rate, number of acres of NIPF, proportion of NIPF owners controlling cogongrass, and the average cogongrass control cost per acre, respectively. Figure 1 depicts the four geographic areas included in the study (these areas are the same as those used by Brown and Nowak (2010)).

Economic Impact: Input-Output (I/O) Analysis

In this study, we use an I/O analysis to measure the economic impact of cogongrass among NIPF landowners in Florida and the regional economy. I/O analysis derives from the general equilibrium

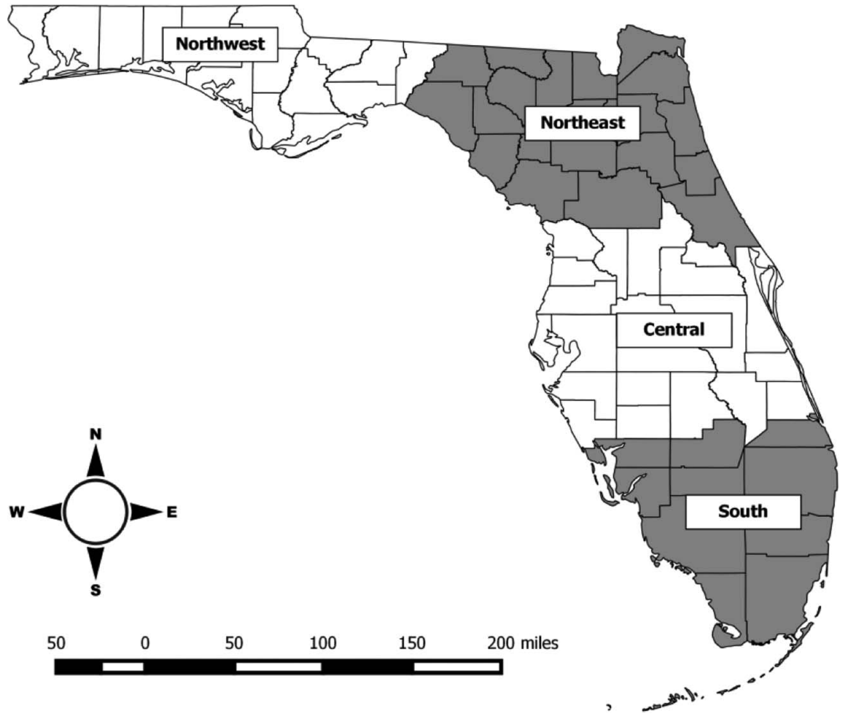

Figure 1. Geographic areas.

model conceptualized by Leontief (1953) and uses an economic framework that links the different sectors of an economy and measures the total regional business activity resulting from a change in one or more particular sectors. I/O models capture not only the direct impact but also the indirect and induced effects that occur throughout the economy due to changes in one or more sectors. Direct effects represent the initial change in expenditures for the industry sectors in question. Indirect effects are the changes in interindustry purchases as supplying industries respond to the increased or decreased demands of the directly affected sectors. Induced effects reflect changes in spending from households as income increases or decreases due to changes in production throughout multiple sectors (Mulkey and Hodges 2000, Watson et al. 2007). Total economic impact is the sum of the direct, indirect, and the induced effects.

In the case of cogongrass affecting NIPF operations, direct economic impacts result from the required increase in production costs to control cogongrass. It is possible to model these direct control costs as either an increase in spending accruing to sectors related to pest control or as an additional cost borne by the NIPF owners. In the former, one could track how the increased expenditures tied to pest control improved the economic condition of these sectors directly and indirectly tied to those mitigating activities. In the latter case, the invasive cogongrass could be considered an unfortunate or accidental act of nature, directly harming NIPF owners by reducing their revenues and, by extension, the various NIPF supporting sectors indirectly. This second approach is similar to that described by the 19th century economist Fredric Bastiat (1848) in his famous essay, "That Which Is Seen and That Which Is Not Seen." In his "broken window fallacy," Bastiat demonstrates that accidental events, such as a shopkeeper's broken window pane, can clearly lead to direct and indirect economic benefits to those mitigating the event; however, it would be wrong to ignore the opportunity cost of those funds used in mitigation. In the case of cogongrass, we follow Bastiat's lead and account for these increases in production costs as losses in the gross revenues of NIPF owners as represented by the forestry sector (forestry, forest products, and timber tract production sector in the impact analysis for planning model [see below]). Hence, these losses to the forestry sector are modeled as the direct economic impact of cogongrass in Florida. In turn, the reduced economic activity in this sector will have secondary or indirect effects on related sectors such as those providing inputs to the forestry sector. Specifically, indirect impacts occur when NIPF owners hire labor, contract services, and purchase inputs or real estate from related sectors. Given that revenues in the forestry sector are reduced as a result of cogongrass infestation, these supporting sectors will experience a reduced demand for their goods or services. Induced or consumption impacts occur when workers and business owners in the forestry, forest products, processing, contracted services, forestry inputs, and real estate sectors purchase goods and services from retailers, restaurants, health care providers, and other sectors. Taken together, the direct and indirect reductions in economic activity will result in an induced effect of lower spending by workers in the affected industries. Given that all these sectors experience decreased revenues as a result of cogongrass infestations, these workers and business owners will experience a decrease in their real incomes and are expected to respond by decreasing their spending.[5]

The reduced economic activity therefore affects employment, income, and expenditures throughout multiple sectors of the regional economy. Because these effects are fully accounted for, I/O modeling is ideally suited for measuring the economic impacts resulting from infestations of noxious invasive species. To implement our I/O analysis, we used the impact analysis for planning (IMPLAN) model (Minnesota IMPLAN Group, Inc. 2009). IMPLAN allows analysis of these effects in terms of industry outputs (sales or revenues), employment (full- and part-time employees), labor income (ratio of output paid as labor expenditure), and added value to the economy (employee compensation, proprietary income or business profits,

Table 1. Descriptive statistics for the sample and population.

Region	Sample		Population*	
	No. of NIPFs	Mean acreage	Total woodland	NIPF woodland
			. . . . (ac)	
Northeastern	544	472.65	6,554,049	1,949,000
Northwestern	474	658.31	5,509,477	1,608,220
Central	111	357.09	2,752,210	779,740
Southern	17	237.78	1,183,455	536,070

* Data from Brown and Nowak (2010).

other types of income, and taxes paid to local, state, and federal governments). For the empirical analysis, we run the I/O models using the 2011 state and county IMPLAN data sets, and the activity year option on all models was modified to year 2010 to ensure that the estimated impacts reflect changes in the regional economy that took place during 2010, the year in which the survey data were collected.[6]

One of the objectives of this study is to document the regional economic impact due to the control of cogongrass infestations by NIPF landowners in Florida. Although we are interested in the statewide economic impact of cogongrass infestations in NIPF operations, there are likely to be large regional variations in economic impact within Florida as a result of differences in infestation rates and control costs. To model the region-by-region and the overall (statewide) impact, we constructed five distinct regional economic models—one for each of the four geographic regions shown in Figure 1 and one statewide model. Similarly, the models were created using social accounting matrix (SAM) multipliers. In our case, SAM takes into consideration the expenditures resulting from changes in forest-level income as well as interinstitutional transfers resulting from the economic activity. Further, we accounted for the increased control costs as a result of cogongrass invasion (Equation 1) as if they were equivalent to a nominal decrease in revenues or a negative industry change to the "forestry, forest products, and timber tract production" sector. In other words, we input the estimated regional control cost (Equation 1) to the regional model as a loss in revenue or direct shock to the "forestry, forest products, and timber tract production (IMPLAN code 15)" sector. Hence, economic impacts are expected to be negative values, or net losses in economic activity. The input to the statewide model is the sum of regional control costs entered as a loss in the same sector. All impacts are expressed in 2010 dollars.

Results and Discussion

Demographic Characteristics and Perception of Invasive Plants

The survey revealed that NIPF property acreage in Florida is highly concentrated in the northwestern and northeastern regions and is lowest in the southern part of state, which is heavily urbanized (Table 1). These results follow the same pattern described in Florida's Forest Inventory and Analysis Factsheet published by the US Department of Agriculture (USDA) Forest Service (Brown and Nowak 2010).

With respect to forest operations, 83% of survey respondents claimed that they manage all or part of their property for timber production. The most commonly used timber management practices are pine production for sawtimber, plylogs, or poles, followed by pine production for paper/pulp. Rapid growth species for carbon sequestration and agro-forestry are the least used management practices (Table 2).

Table 2. Timber management practices used by respondents.

Timber management practices	%
Pine production for sawtimber, plylogs or poles	66.3
Pine production for paper/pulp	60.9
Mixed hardwood and pine	26.1
Hardwood production for pulp/paper	14.8
Cypress or other bottomland	11.9
Agro-forestry	9.0
Rapid growth species for carbon sequestration	1.7

The survey also shows that about 74% of respondents manage their woodland for purposes other than timber production. Among those purposes, wildlife viewing was the most important, followed by hunting and other recreational activities. In addition, the results also showed that ornamental horticulture and agro-forestry were the least important practices for NIPF landowners (Figure 2).

A significant majority of NIPF landowners (83%) received technical advice about woodland or forestland during the last 5 years. The Florida Forest Service was the most common source of this information followed by private consultants and the Florida Fish and Wildlife Conservation Commission. Survey results also revealed that employees of nonprofit groups, paper/timber companies, and the Natural Resource Conservation Service were not very active in the transfer of technical advice (Table 3).

To assess the economic impact of cogongrass control, it is critical to understand the importance of cogongrass as a problem relative to that of other problem plants found on forested lands. Respondents from all four regions reported that cogongrass is a major plant pest on forest property, but responses also yielded some interesting information about other invasive threats to woodlands. Japanese climbing fern, Japanese privet, Chinese tallow (popcorn tree), and blackberry plants are perceived as the biggest problems after cogongrass. The survey also showed that a majority of respondents cannot identify many of these problem plant species. For instance, about 98% of respondents do not know anything about coral ardisia, which is a noxious weed that is toxic to livestock. Hence, survey responses about the distribution of many of these plants may understate their true impact (Table 4).

Respondents were asked specifically about their familiarity with cogongrass and the source of their information about this invasive plant. About 51% of the sample reported some knowledge about cogongrass. The Florida Forest Service was their major source for information about this plant, followed by the Cooperative Extension Service Office. Results also showed that employees of nonprofit groups, logging contractors, paper/timber companies, and the USDA Forest Service were not major sources of information about cogongrass (Figure 3).

Thirty percent of respondents indicated that cogongrass was present on their property and about 33% were not sure. Respondents also reported that they first encountered cogongrass about 7 years ago, but about 34% of our sample cannot recall when they first saw cogongrass on their property.

To document the economic impact of cogongrass on NIPF landowners, the survey asked the targeted population whether they considered cogongrass a problem in their forests, and nearly 25% of the respondents considered this plant as a problem in their woodland. The survey also showed that approximately 5% of the total area of NIPF was covered with cogongrass. Forty-one percent of respondents believed that cogongrass has reduced the recruitment and/or growth of trees in woodlands, and close to 54% of woodland owners

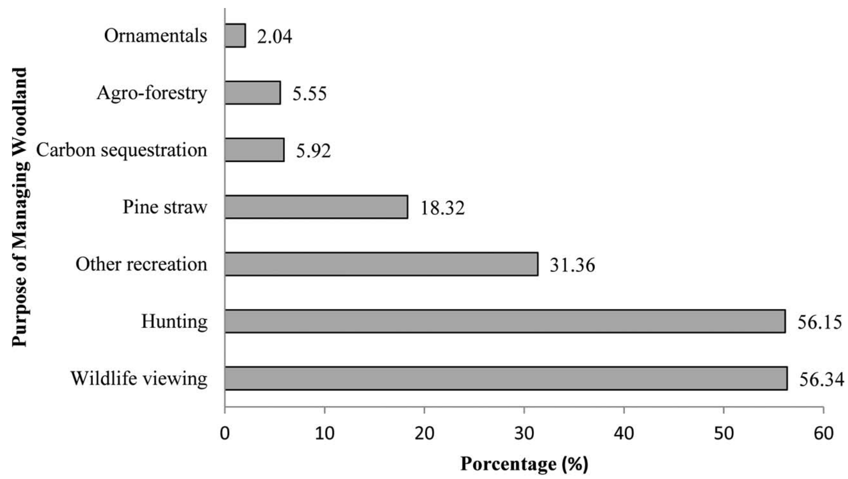

Figure 2. Purpose of managing woodland.

Table 3. Sources of technical advice or information about woodland.

Source of information	%
Florida Forest Service	70.8
Private consultant	34.5
Florida Fish and Wildlife	29.4
Cooperative Extension Service Office	21.5
Other forest landowner, neighbor, or friend	16.9
Logging contractor	12.4
USDA Forest Service	9.2
Natural Resource Conservation Service	8.9
Paper/Timber company	8.7
Employee of a nonprofit group	2.4

Table 4. Relative importance of common weeds found in woodlands.

Common weeds	Mean Likert scale*	% don't know
Cogongrass	1.86	37.3
Japanese climbing fern	1.76	55.8
Japanese privet	1.72	73.1
Chinese tallow (popcorn tree)	1.71	39.2
Blackberry	1.59	17.5
Muscadine grape	1.54	21.8
Tropical soda apple	1.52	52.9
Mimosa	1.50	29.8
Air potato vine	1.39	54.9
Kudzu	1.37	21.5
Japanese honeysuckle	1.33	58.7
Morning glory vine	1.31	34.6
Coral ardisia	1.14	97.9

* Likert scale: 1 (Not a Serious Problem) to 5 (Serious Problem).

responded that cogongrass has increased the hazard for wildfire in the area of infestation (Table 5).

With respect to short-run plans (next 5 years) for their woodlands or forest property in Florida, 43% of the respondents said they would prefer to do the minimum activity necessary to maintain their forest and about 40% would harvest the saw logs or pulpwood. Four percent claimed they would sell their forest property for residential development, and only 1% would convert their forest to commercial development (Table 6).

The survey also revealed some interesting characteristics of NIPF landowners in Florida. Typical respondents have owned their property for 22 years, and about 33% had inherited their woodland. Respondents were asked about the importance of the income derived from their woodland to their household. On average, they derived little of their household income from their forested land (average index value of 1.9 on a scale of 1 to 5). The average household income for the survey respondents was about $104,630, which is much higher than the state median household income ($46,565) and the national median household income ($53,046) (Table 7) (US Census 2016).

Geographic Extent of Cogongrass Infestation

The rates of cogongrass invasion were calculated as regional averages from the collected survey data using Equation 1. Individual woodland owners were asked to estimate the proportion of their woodland infested with cogongrass, and their responses were averaged by region. The mean rates of infestation of cogongrass were then calculated to be 3.89, 5.11, 7.02, 4.33, and 5.01% for Northeast Florida, Northwest Florida, Central Florida, South Florida and the entire state, respectively.

Management and Control Responses and Costs

In terms of control of this invasive plant, nearly 78% of the respondents have tried to control cogongrass using different methods. The most preferred method of control identified is chemical herbicide (80%) followed by mechanical methods (Figure 4). Among all chemicals, Roundup was the leading herbicide used for chemical control, but several NIPF owners had begun using Arsenal and Chopper. Our survey results indicate that NIPF landowners in Florida spent about $81.56 per acre for cogongrass control.

The proportion of NIPF owners who tried to control cogongrass was estimated from the number of respondents who answered positively to the item "tried to control cogongrass." Regional rates of control for cogongrass were 74, 78, 86, 1, and 78% for Northeast Florida, Northwest Florida, Central Florida, South Florida, and the entire state, respectively. Cogongrass control costs were calculated as the average amount spent per acre by a respondent for the control of cogongrass. Average costs for control of cogongrass were $127.62, $115.24, $133.64, $76.25, and $81.56 for Northeast Florida, Northwest Florida, Central Florida, South Florida, and the entire state, respectively. These averages were used to estimate total regional costs of control of $6,693,955, $6,906,136, $5,883,239, and $16,547 in the

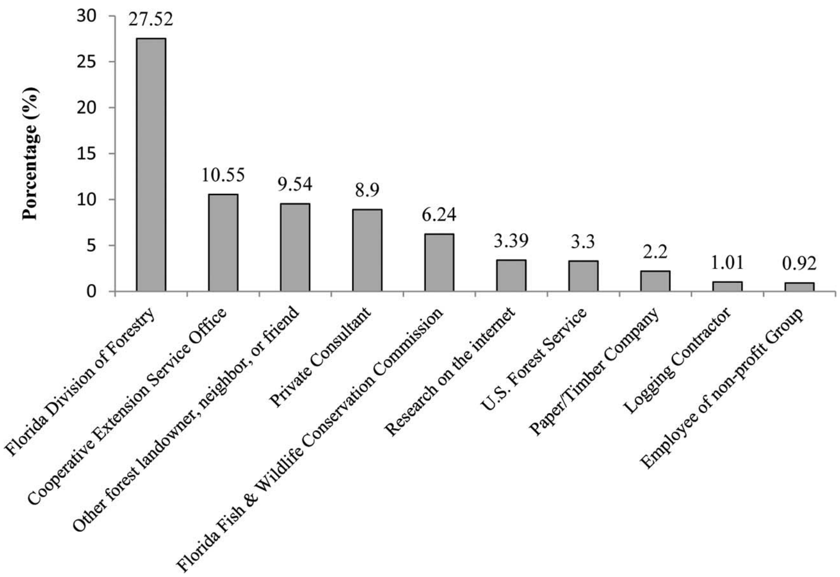

Figure 3. Sources of information about cogongrass.

Table 5. Perceived cogongrass-caused problems in woodlands.

Category	%
Have problem with cogongrass	25
% of cogongrass in woods or forest	5.1
Negative effect of cogongrass on tree growth.	41
Causes wildfire	54

Table 6. Plans for woodland or forest in Florida in the next 5 years.

Plans	%
Minimum activity to maintain	42.6
Harvest saw logs/pulpwood	39.6
Bequest	30.0
Leave it as is—no activity	19.3
Enroll for carbon credit program	13.0
Harvest firewood	11.1
Expansion—buy more forestland	10.6
No plans at this time	9.6
Harvest nontimber forest products	7.8
I don't know	5.4
Sell some or all woodland	5.2
Sell for residential development	4.0
Sell for commercial development	1.4

Table 7. Survey questions, how long owned forest property in Florida, importance of woodland income, and annual income.

Year/income	*n*	Mean
Years owning forest property in Florida	1,073	22.8
Importance of woodland income to household (1–5); 1 = unimportant, 5 = important	1,060	1.9
Annual household income ($)	934	$104,630.6

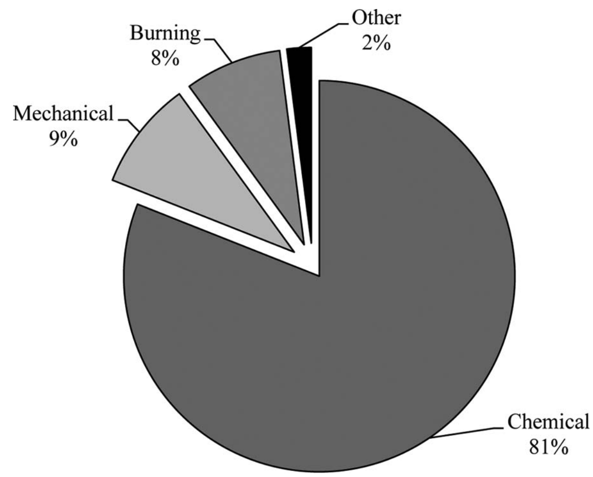

Figure 4. Cogongrass control methods.

northeastern, northwestern, central, and southern regions of the state, respectively. Upper and lower bounds for regional cost estimates were then calculated for a 95% level of confidence (Table 8). These bounds on cost estimates represent direct losses to NIPF landowners due to cogongrass invasion and they serve as input to the regional economic model.

Overall, Northeast Florida was the region most heavily impacted by cogongrass. This may be due to the high infestation rate and proportion of NIPF landowners who control the exotic plant relative to those for other regions.

Impact of Cogongrass on Florida's Economy

We applied an I/O economic model to account for the losses associated with the industries that are directly affected by the infestation of cogongrass as well as industries that are economically linked to them. This model also estimated economic losses to household income. A summary of these economic losses, which are the result of expenses by NIPF landowners for the control of cogongrass infestations in the four regions of Florida (northeastern, northwestern, central, and southern) and statewide is provided in Table 9.

The total average economic impacts associated with cogongrass control are $10,773,611, $9,450,585, $9,959,011, and $35,015 annually for the northeastern, northwestern, central, and southern regions of the state, respectively. These were revenues lost to all supportive business sectors as a result of reduced revenues in the forest products and timber sector, as well as reduced household incomes.

Included in this total cost was the direct cost due to cogongrass control of $6,459,982, $6,396,934, $5,192,824, and

Table 8. Estimation of regional cost for cogongrass control.

Region (no. acres)	Bounds	Infestation rate (%)	Proportion that control (%)	Cost of control/ac ($)	Regional cost of control ($)
Northeastern (1,949,000)	Average	3.89	74.00	127.62	6,459,982
	Lower	2.89	73.88	43.39	1,508,224
	Upper	4.88	74.11	211.85	10,951,489
Northwestern (1,608,220)	Average	5.11	78.00	115.24	6,396,934
	Lower	3.68	77.93	75.30	3,477,890
	Upper	6.54	78.07	155.17	10,731,888
Central (779,740)	Average	7.02	86.00	133.64	5,192,824
	Lower	3.43	85.87	10.20	234,280
	Upper	10.61	86.13	257.08	11,323,596
Southern (536,070)	Average	4.33	1.00	76.25	17,699
	Lower	0.66	1.00	0.00	0
	Upper	8.00	1.00	119.11	51,055
State (4,873,030)	Average	5.09	59.75	113.19	18,067,439
	Lower	2.67	59.67	32.22	10,178,938
	Upper	7.51	59.83	185.80	33,058,028

Table 9. Estimated economic impact of cogongrass control with 95% confidence interval.

Regions	Output	Direct ($)	Indirect ($)	Induced ($)	Total output ($)	Employment
Northeastern	Average	−6,459,982	−2,183,288	−2,130,341	−10,773,611	−95.2
	Lower	−1,508,224	−509,736	−497,375	−2,515,335	−22.2
	Upper	−10,951,489	−3,701,288	−3,611,528	−18,264,305	−161.3
Northwestern	Average	−6,396,934	−1,473,009	−1,580,642	−9,450,585	−76.4
	Lower	−3,477,890	−800,847	−859,365	−5,138,101	−41.5
	Upper	−10,731,888	−2,471,210	−2,651,782	−15,854,880	−128.1
Central	Average	−5,192,8240	−2,837,795	−1,928,391	−9,959,011	−105.7
	Lower	−234,280	−128,030	−87,001	−449,312	−4.6
	Upper	−11,323,596	−6,188,165	−4,205,096	−21,716,857	−230.4
Southern	Average	−17,699	−10,747	−6,568	−35,015	−0.4
	Lower	0	0	0	0	0
	Upper	−51,055	−31,002	−18,948	−101,005	−1.2
State*	Average	−18,067,439	−9,389,618	−7,850,928	−35,307,984	−357.9
	Lower	−10,178,938	−5,289,977	−4,423,101	−19,892,016	−195.7
	Upper	−33,058,027	−17,180,202	−14,364,858	−64,603,087	−654.9

* It is important to note that the state totals are not the sum up of the regional values because of the interactions between regions.

$17,699 in the northeastern, northwestern, central, and southern regions of the state, respectively. This direct loss represents the expenditures to control cogongrass, which are modeled as a reduction in forest products and timber industry revenues. The indirect effects were calculated to be $2,183,288, $1,473,009, $2,837,795, and $10,747 for the northeastern, northwestern, central, and southern regions of the state, respectively. These figures represent revenues lost to the supporting sectors as they respond to the reduced sales of forest products by the directly affected woodland owners who are controlling their cogongrass infestations. The induced effects are changes in spending by households as income decreased due to reduced production of forest products and timber industry support goods and services and were estimated to be $2,130,341, $1,580,642, $1,928,391 and $6,568 for the northeastern, northwestern, central, and southern regions of the state, respectively.

The combined effect of cogongrass control by NIPF landowners in Florida resulted in average direct economic losses of $18,067,439, which represents 51.17% of the total economic impact of cogongrass. These are the total costs of control measures for cogongrass. The remaining losses are the results of indirect and induced effects in the state and include $9,389,618 in indirect cost, which represents 26.59% of the total impact of cogongrass, and $7,850,928 in induced cost, which represents 22.23% of the total impact of cogongrass. The statewide impact or total loss to the economy of Florida as a result of cogongrass infestation in NIPF woodlands is estimated to be $35,307,984.

Generally, the biggest economic impacts from cogongrass infestation were in Northeast Florida. This may be due to the high infestation rate and proportion of NIPF owners that control the exotic plant relative to other regions. The empirical results show that the statewide economic impact of cogongrass infestation is larger than the sum of economic impacts across individual regions. Schmit et al. 2013 explain that in regional economic models the portion of spending that occurs locally drives impacts. Imports or spending on goods and services that are not produced within the local economy are considered leakages, as this type of spending does not result in any indirect or induced impacts within the local economy. However, as the region of interest grows from a small local economy to a large state economy, many of these leakages are internalized and what were considered imports in the smaller model become local purchases in the larger model. Hence, in general, models of larger regions will have fewer leakages in the form of imports, and the same direct effect will bring about larger indirect and induced impacts in a statewide model than in a model that encompasses a subregion of that state.

Summary and Conclusions

This study documented the direct losses to NIPF landowners as a result of cogongrass infestation in the state of Florida. We also implemented a framework to assess the economic losses to the study sample and extrapolate these results to the whole population of NIPF landowners. The empirical analysis uses data collected from 1,060 NIPF owners in Florida. The results showed that close to

25% of the respondents considered cogongrass as a problem in their woodland. In addition, 41% of respondents believed that this invasive grass has reduced the recruitment and/or growth of trees in woodlands, and approximately 54% of woodland owners responded that cogongrass has increased the hazard for wildfire in the area of infestation, illustrating the large negative impact that this invasive grass is having on commercial woodland throughout Florida. The economic I/O analysis revealed that cogongrass control costs resulted in economic losses throughout Florida of $35 million annually to the forestry and supporting business sectors.

The results obtained in this study can be used by policymakers and land managers to justify the implementation of management programs to control this invasive weed. In addition, the framework developed here can be used as an example to study the economic impacts of other invasive exotic species on different sectors and geographical areas. It is important to indicate that our study did not include losses in forest productivity due to cogongrass infestation; therefore, the measures of economic displacement presented here were interpreted as lower bound estimates of the true economic effect on NIPF operations in Florida. This is an area that merits further research.

Endnotes

1. Bravo-Ureta et al. (2012) present a detailed framework to compare production processes across treatment and control groups using cross-sectional data.
2. NIPF landowners are defined as private forest owners who do not own or operate wood-processing facilities and include farmers, miscellaneous individuals, and non-forest industry operations. According to the Forest Inventory and Analysis Factsheet (Brown and Nowak 2010), about 49% of the state of Florida is covered with forests (approximately 6.7 million ha) and 94% of the forested land is classified as available for timber production. NIPF landowners control 63% of these forested lands, making them an interesting case study.
3. The questionnaire is available upon request.
4. More information on this program can be found at www.sfrc.ufl.edu/forest_stewardship.
5. A similar approach can be found in Mhina et al. (2016) and Salaudeen el al. (2013), among others.
6. It is important to indicate that no significant structural changes have been observed during the last decade in the NIPF sector in Florida.

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