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Economics of Cogongrass Control in Slash Pine Forests

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Cogongrass (*Imperata cylindrica*), an invasive weed, is a threat to slash pine forests. Using a dynamic optimization model, we estimated the impact of cogongrass on the profitability of slash pine forestry under four scenarios: no threat of cogongrass infestation; infestation is uncertain, and no control measures are taken; infestation is uncertain, but control measures are undertaken by one landowner but not the neighbors; and infestation is uncertain, and control measures are undertaken by everyone. Results indicate that annual net returns per acre under each scenario, respectively, are $25.30, $16.97, $13.89, and $17.38. Results suggest fostering a cooperative behavior among landowners is desirable.

Key Words: cogongrass, infestation, invasive species, productivity, profitability

JEL Classifications: Q0, Q2

Cogongrass (*Imperata cylindrica*), a perennial grass native to Southeast Asia, has been identified as the seventh worst weed species in the world (Dozier et al.; Holm et al.). This nonnative weed is spreading across forests in the southeastern United States at an alarming rate. Although nine *Imperata* species have been reported worldwide, only two closely related species, *I. cylindrica* and *I. brasiliensis* (Brazilian satintail), are seen in the United States. An ornamental variety of cogongrass, known as "Japanese Blood Grass," is sold for landscaping in the United States. Although this reddish grass is not an aggressive invader, it has the potential to revert to the green, invasive form (Greenlee).

Understanding the habitat of cogongrass will help to realize the potential threat this species poses to managed and unmanaged forest ecosystems of the Southeast (Jose et al.). This weed usually grows in warm areas. However, it has been widely distributed between 45° latitudes in the northern and southern hemispheres at altitudes ranging from sea level to 2,700 m (Holm et al.; Hubbard et al.). It can grow on a wide range of soils from nutrient-poor, coarse sands to nutrient-rich, sandy loam soils. Cogongrass grows in full sun and in deep shade (down to 2% of full sun) and tolerates extreme drought as well as water logging. It thrives in disturbed areas, such as cutover sites, minimum tillage cropping systems, reclaimed mined areas, and

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Figure 1. Current Distribution of Cogongrass (*Imperata cylindrica*) on Natural and Planted Forests in U.S. Southeast

roadsides, as well as in less disturbed areas, such as pine and hardwood forests, grasslands, and recreational areas (King and Grace; Willard, Gaffney, and Shilling; Willard et al.). Thus, cogongrass can potentially invade any piece of land and turn into an "alien nightmare" for the landowner (Jose et al.).

History

Literature suggests that cogongrass was introduced accidentally as packing material in Alabama in 1912 from Japan (Jose et al.). In the 1920's, cogongrass was intentionally brought to the United States as a potential forage crop. Forage trials were carried out at university experiment stations in Texas, Mississippi, Alabama, and Florida. Anxious cattle ranchers planted cogongrass to improve pastureland and thus helped spread the species throughout the Southeast. Although it has a short-term forage value while leaves are young and tender, mature leaves are unpalatable because of high silica content (Dozier et al.). As a result, cogongrass lost its appeal as a forage crop very quickly. However, its use for soil reclamation by the Soil Conservation Service and for soil stabilization along roadways by state departments of transportation continued until recently. Further spread throughout the Southeast occurred when soil contaminated with cogongrass rhizomes was used for highway and railroad construction and maintenance work. Most recently, natural and planted forests in the South have become the greener pastures for cogongrass invasions (Ramsey et al.). Today, cogongrass is sparsely spread throughout the southeastern United States from Texas to Virginia, threatening the ecological and economic integrity of our natural and planted forestlands (Figure 1).

Spread and its Impacts

The spread of an exotic invasive species depends partially upon its ability to multiply and establish rapidly in new habitats. Cogongrass can reproduce by both sexual and asexual means. Cogongrass is a prolific seed producer, with as many as 3,000 seeds per plant. Wind dispersal of seeds as far as 15 mi. is possible (Hubbard et al.). However, low seed germination rates (Shilling et al.) and low viability (Dozier et al.) have been reported as limitations to cogongrass sexual reproduction. Once a plant is established from a seed, its local spread is facilitated mainly through rhizomes. Rhizomes can give rise to shoots at every node (0.5–1.5 in. apart), and each node can produce as many as 350 shoots in 6 weeks covering an area of 43 ft^2 in 11 weeks (Eussen). Rhizomes give cogongrass its competitive edge as an aggressive invader. In general, burning, mowing, or even some herbicide applications will not control cogongrass. It can regrow and spread aggressively from the buried rhizomes.

Recent studies in a Florida sandhill savanna have shown that cogongrass can displace most of the sandhill vegetation, except for large trees (Lippincott). Preliminary studies conducted at a northwest Florida longleaf pine forest revealed similar trends (Collins et al.; Jose et al.). Cogongrass can alter the soil chemistry, nutrient cycling, hydrology, and disturbance regimes of the infested site.[1] As a result, natural and artificial regeneration of forest stands infested with cogongrass is very problematic. Cogongrass can also create a severe fire hazard in pine plantations and natural habitats. Biomass accumulation of cogongrass can be higher than that of native ground vegetation, and this invader burns hotter because of high silica content. Temperatures as high as 450°C at heights ranging from 0 to 5 ft (Lippincott), if persistent for more than a few seconds, can kill not only tree seedlings, but also juvenile trees in plantations and natural areas (Jose et al.). In sum, the impact of cogongrass on timber and nontimber productivity can be severe (Daneshgar et al.).

Control Measures

Extensive herbicide trials with cogongrass have been carried out all over the world. Of all the herbicides evaluated, imazapyr and glyphosate seem to be the most effective (Ramsey et al.; Shilling et al.; Willard et al.). Cultural treatments such as disking or burning do not effectively control cogongrass (Gaffney; Willard et al.); however, they may be used to eliminate or greatly reduce seed formation. An integrated management approach that uses all available methods, such as burning, disking, mowing, applying herbicides, and revegetating the area, is recommended as the key to achieving long-lasting cogongrass control (Dozier et al.; Johnson, Gaffney, and Shilling; Jose et al.). Burning or mowing cogongrass foliage forces the rhizomes to produce new aboveground shoot growth, thus depleting more carbohydrate reserves and weakening the rhizomes. After regrowth occurs, the site can be disked as deeply as possible. Herbicide application can be done following sufficient regrowth of the aboveground shoots. From a landowner's viewpoint, all these control measures increase the marginal cost of timber and nontimber product production.

This paper investigates the impact of cogongrass on the profitability of slash pine forestry, a dominant forest business activity in the southeastern United States. In particular, profitability will be estimated under four scenarios: no threat of cogongrass infestation; cogongrass infestation is uncertain and no control measures; undertake control measures by one landowner but not his/her neighbors; undertake control measures by a landowner and his/her neighbors. A dynamic optimization model is applied to estimate the profitability under the specified scenarios.

The paper is organized as follows. In the next section, details of the model specification and cogongrass control scenarios are provided. The discussion about data and parameter values is provided in section 3. Results are presented and discussed in section 4. Conclusions are provided in the last section, along with limitations of the study and suggestions for future research.

Model Specification and Scenarios

The Faustmann model provides a convenient framework to assess the profitability of forestry operations in perpetuity and to

[1] For example, the soil water content in the 8- to 16-in. soil layer was reduced by as much as 50% by cogongrass compared with sandhill vegetation in Florida (Jose et al.).

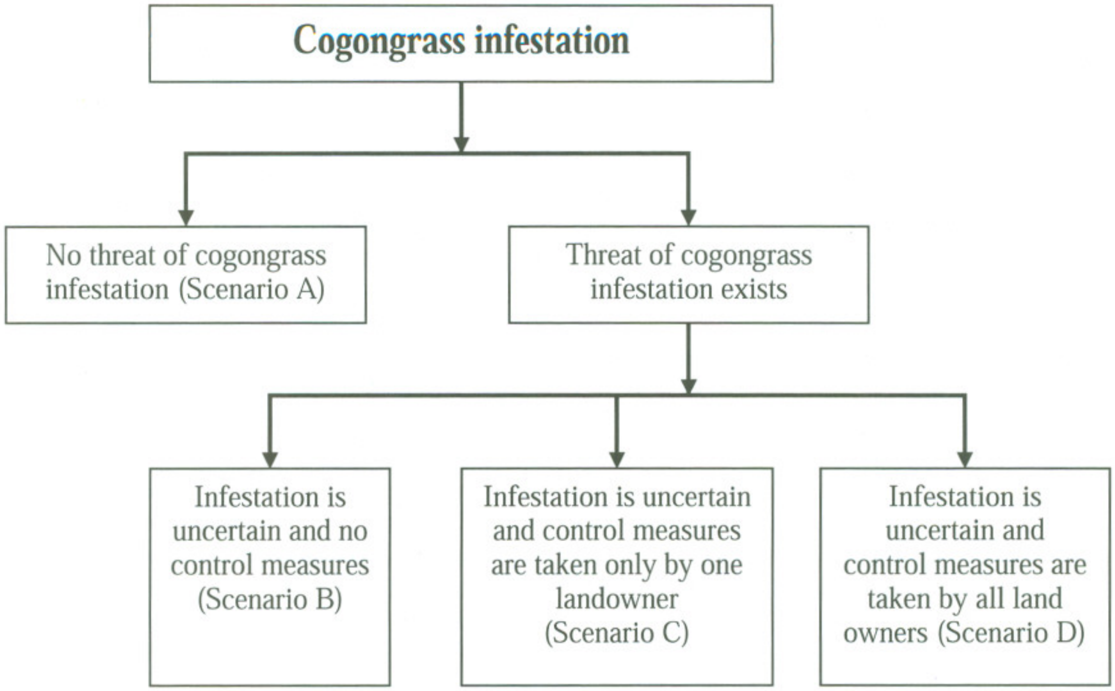

Figure 2. Plausible Scenarios of Cogongrass Infestation

express them in terms of land expectation value (LEV) (or land value) under the assumption that the land was put to its best use, forestry in this case. The LEV under forestry can be calculated as[2]

$$(1) \qquad \text{LEV} = \frac{[PV(t) - g]e^{-rt}}{1 - e^{-rt}}$$

where P is the price of forest products; $V(t)$ is volume of forest biomass or timber over time t; r is the discount rate; and g is the cost of regeneration and other management costs. The above model can be solved for the optimum rotation age (t^*) that maximizes LEV. This model can be expanded to include additional revenue and costs, such as non-timber products and periodic costs of management (i.e., control measures of invasive species).[3]

[2] The numerator in this following equation defines the net present value or profit from one forest rotation. With the denominator, the equation defines the profit associated with forestry in perpetuity or an infinite number of rotations.

[3] See Hartman, for instance, for more details on the inclusion of nontimber values into the Faustmann model.

The above specified model is applied to assess plausible scenarios of cogongrass invasion that a typical slash pine forestland owner could face (see Figure 2). In the best-case scenario, the landowner may not have any threat of cogongrass invasion. As such, he/she will grow slash pine forests and produce sawtimber and pulpwood with an objective of maximizing profit. In this scenario (A), he/she will not incur any additional costs to control cogongrass. In the Southeast, however, there is always a chance that forests will be infested with cogongrass. Whatever the risks of cogongrass infestation, some landowners may not want to undertake any control measures (scenario B). In addition, it is possible that one landowner will undertake necessary control measures by incurring additional costs, but his/her neighbors may not choose to undertake any measures. Thus, the threat of cogongrass invasion might vary, depending on whether a single landowner or all landowners in a region undertake control measures. Therefore, we specified two additional scenarios (C and D) to reflect these situations.

Data, Parameter Values, and Model Calibration

Following Stainback and Alavalapati, we use a growth and yield model developed by Pienaar and Rheney for intensely managed unthinned slash pine (*Pinus elliottii*) plantations with even-aged harvest cycles. To ensure the desired mathematical properties of the model, amenable for integration, for example, Stainback and Alavalapati fitted the output from the original model from years 0 to 55. Their model uses the following functional form for $V(t)$:

$$(2) \quad V(t) = \alpha t^{\beta} e^{-\alpha t}$$

where $V(t)$ is the merchantable wood volume outside bark in cubic feet per acre, t is the age of the stand in years, and a, β, and α are parameters to be estimated. By nonlinear least-squares regression, a, β, and α were determined to be 0.015, 3.85, and 0.05. The growth function assumes tree density to be 600 trees per acre at age 2 and the site index to be 60 ft at a base age of 25 years. Following Stainback and Alavalapati, the forest stand is assumed to produce two products—sawtimber and pulpwood—and was modeled as

$$(3) \quad M = exp\left[-0.52(\frac{h}{q})^{3.84-0.28n^{-0.12\left(\frac{w}{q}\right)^{5.72}}}\right]$$

where M is volume expressed in cubic feet of trees with a diameter at breast height equal to or greater than w *inches* to a top h *inches* outside bark, q is the quadratic mean diameter at breast height in inches, and n is the number of trees per acre at stand age t. Sawtimber is determined by setting h to be 6.1 in. and w to be 12.3 in. Pulpwood volume is determined by letting h be 2.03 in. and w be 4.06 in. Because sawtimber yields a higher price, we assume that the landowner sells all merchantable timber volume that is suitable for sawtimber as sawtimber and the remainder of the merchantable timber volume as pulpwood.

The net present value (NPVf) of timber benefits per acre over a single rotation can be represented as

$$(4) \quad \text{NPV}_f = [P_p M_p(t) + P_s M_s(t) - g(t)]e^{-rt}$$

where P_p and P_s are prices of a cubic foot of pulpwood and sawtimber, respectively, and $M_p(t)$ and $M_s(t)$ are the cubic foot volumes for pulpwood and sawtimber, respectively. The variable g is the regeneration, management, and treatment costs of the stand in dollars per acre. This equation simply states that the present value of timber benefits is the discounted value of sawtimber and pulpwood produced from the stand minus the regeneration cost. If the land is used to produce slash pine in perpetuity, the bare land value or LEV in dollars per acre of timber benefits over an infinite number of rotations can be represented as

$$(5) \quad \text{LEV} = \frac{\text{NPV}_f}{1 - e^{-rt_f}}$$

It should be noted that NPV_f is equal to the numerator in the first equation. To obtain the optimal rotation age that represents the highest obtainable LEV, the above equation is maximized with respect to t.[4]

It is assumed that the price of pulpwood is \$0.20 per ft^3, the price of sawtimber is \$1.09 per ft^3, the real discount rate is 5%, and replanting costs are approximately \$121 per acre (Timber Mart-South; Yin, Pienaar, and Aronow). In addition to the above parameter values used in the model, the following assumptions are made:

1. The effect of cogongrass infestation would cause a 25% decrease in timber productivity. Although the authors are aware of the instances in which the productivity loss due to infestation ranges from 5 to 90%, based on the discussion with forestland owners and forest managers, we chose a conservative value of 25%.
2. In the absence of accurate data on the probability of cogongrass infestation and based on our knowledge and experience in forestry practices in the U.S. South, we

[4] See Klemperer for a detailed mathematical treatment of LEV derivation.

Table 1. Optimum Rotation Age and Corresponding Land Expectation Values of Slash Pine Forestry for Possible Scenarios of Cogongrass Infestation

Scenario	Optimum rotation age (yrs.)	Land expectation value ($ per acre)	Annual rental value ($ per acre)
A. No threat of cogongrass infestation	23.40	510.64	25.53
B. Infestation is uncertain, but no control measures are undertaken	24.06	339.45	16.97
C. Infestation is uncertain, and control measures are taken only by one landowner	25.87	277.80	13.89
D. Infestation is uncertain, and control measures are taken by all landowners	25.17	347.61	17.38

believe that the probability of cogongrass infestation in slash pine forest will be 5%.

3. Based on discussions with silviculturists and cogongrass researchers, the cost of cogongrass control measures per acre is specified as follows: $100 in year 1; $50 in year 2; $10 in year 3; and $5 in years 4 and 5. The values would enter as "g" in the NPV equation.

Results and Discussion

Table 1 presents the optimum rotation age and corresponding LEV of slash pine forestry under various scenarios of cogongrass infestation. Results suggest that rotation age in the absence of any threat of cogongrass is shorter than those of scenarios where some threat exists. There are two possible explanations for this. First, the threat of infestation is likely when the forest crop is young. This might serve as a disincentive to landowners to harvest mature trees quickly and undertake regeneration. Second, control measures of cogongrass infestation are largely in the early phase of plantation. As such, the costs associated with control measures would influence landowners to wait longer and then undertake tree harvesting and regeneration. This result is consistent with findings of previous studies in which regeneration costs increased rotation age.

Results suggest, not surprisingly, that the land value under no threat of cogongrass infestation (scenario A) is much higher than those scenarios where infestation occurs. When infestation is certain and landowners do not choose to undertake any control measures, the annual per acre rental value is approximately $17, and this is $8.50 lower than that of scenario A.[5] Results derived under scenarios C and D are more interesting. In the face of a risk of infestation, if a landowner undertakes control measures and if his/her neighbors in the region do not, the land value and annual rental value, respectively, are $277.80 and $13.89. On the other hand, when all landowners undertake control measures, the corresponding land and annual rental values are $347.61 and $17.38.

Two important conclusions can be drawn from these results. First, it is economically desirable for landowners to undertake cogongrass control measures. If ecological benefits are considered, such as forest health and biodiversity, for example, it would be even more beneficial to control cogongrass infestation. Second, it is critical for all landowners to undertake control measures in order to realize optimum economic and environmental benefits. If one undertakes control measures and

[5] Land rental values are calculated as follows. Land expectation value is considered an asset value, and multiplying it with the interest rate will give us the annual rental value. In other words, the present value of perpetual annual rents is the asset value.

others do not, the person who undertakes control measures will be worse off relative to the situation in which infestation is certain but no one undertakes control measures. This suggests that cooperative behavior among forestland owners is a requirement to address cogongrass infestation. State and federal agencies and nongovernmental organizations could play a key role in promoting cooperative behavior through selective incentives and educational programs.

Future Research

Several extensions are possible to this study. First, the quality and quantitative data on the probability of cogongrass infestation, impact of productivity loss, and environmental or ecological damage are very weak. Future research efforts can help generate long-term data on these variables. Second, we did not account for the impacts of additional wildfire risk and associated productivity and wildlife impacts due to cogongrass. Accounting for these impacts is a challenge but a very important one. Third, our model did not include the ecological benefits of cogongrass control. For example, control measures might improve wildlife habitat and thus increase hunting revenues. With appropriate data, it is straightforward to model these benefits. Finally, it would be useful to conduct a sensitivity analysis to gain insights about the effect of variations in discount rates, probability of infestation, and expected productivity loss due to infestations.

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