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Effect of conserving habitat for biodiversity on optimal management of non-industrial private forests in Florida ☆

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Abstract

Healthy forests and enhanced habitat for wildlife is a growing concern among public and policy makers. These concerns have led to substantial interest in promoting various regulatory and voluntary compliance policies to further biodiversity on private forests. These policies, however, might result in additional cost to forestland owners. In this paper, we estimate the opportunity cost of adopting various biodiversity-friendly forest practices. We do this in the context of slash pine, a dominant commercial tree plantation species in Florida. Results suggest that prescribed burning, invasive species control, maintaining streamside buffer zones, and extending timber harvest beyond the optimal rotation age would significantly decrease the profitability of slash pine forestry. If the major objective of landowners is to maximize profits, results indicate that they are less likely to adopt these practices at socially desirable levels without a policy support. More specifically, results suggest that an annual payment of $38–83 per hectare is required for landowners to adopt these practices. The paper further argues that

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application of mere command-and-control approaches to implement these practices may result in conversion of private forests to other competitive land uses.

JEL classification: Q23

Keyword: Biodiversity conservation; Sustainable forestry; Profitability; Land expectation value

Introduction

Concerns for healthy forests, enhanced wildlife habitat, and improved water quality in recent times have made sustainable forestry a major societal objective the world over. In particular, the growing recognition of the role of private forests in furthering biodiversity has led to the promotion of several regulatory and voluntary compliance policies to augment habitat for conservation on these lands (Kline et al., 2000a, b). For example, in the United States (US), federal laws such as the Endangered Species Act and state regulations such as the Oregon Forest Practices Act impose restrictions on timber harvesting, including stipulations on set-aside and streamside zone requirements. In addition, most states require forest landowners to voluntarily comply with silvicultural best management practices (BMPs). Both regulatory and voluntary compliance measures, however, could significantly increase forest management costs and thus a decrease in the profitability. Efforts to conserve habitat for biodiversity on non-industrial private forests (NIPF) are particularly challenging because, often, the costs of such measures accrue to landowners while benefits are spread to the entire society. In the face of internal costs and external benefits, landowners whose objective is to maximize profits, are less likely to undertake efforts to further biodiversity at a socially desirable level (Alavalapati et al., 2004). Despite the critical role of these costs, few studies have systematically analyzed the financial implications of integrating habitat conservation with private forest management (Brockett and Gebhard, 1999; Gullison, 2003).

NIPF lands account for about half of the total timber supply in the US. It is expected to increase to about 60% by the year 2030 (Haines, 1995). In the US South, out of 86 million forested hectares, NIPF landowners – sometimes called family forests, own 60%. These family forests provide us with a myriad of socioeconomic and environmental benefits such as wood products, recreation and scenic beauty, cultural and spiritual values, erosion control and clean water, carbon sequestration and clean air, biodiversity, and rural employment. Therefore, sustainable management of NIPF is not only critical for US timber supply but also meeting the environmental needs of US citizens.

In this paper, we assess the financial implications of adopting forest practices that are perceived to promote biodiversity conservation on NIPF, taking the example of slash pine (*Pinus elliottii*) management in Florida. We apply a modified Faustmann Model to achieve the task.

NIPF and forest practices for biodiversity conservation in Florida

Forests in Florida comprise over 6.5 million hectares or 47% of the total land cover and contribute over $7 billion annually to the state's economy (Carter and Jokela, 2002). Besides providing several economic, social, recreational, and environmental services, these forests are also home to several threatened and endangered species such as the Red-cockaded Woodpecker, Flatwoods Salamander, and Gopher Tortoise. As such, sustainable management of these forestlands is of paramount importance to Florida's economy and environment. While there are compelling reasons to conserve these areas, the risk they currently face from habitat degradation, conversion to other uses, and unsustainable management is extreme. Florida is one of the fastest growing states in the country, and consequently, natural areas are in great demand for conversion to residential and commercial uses (DeCoster, 2000). For example, between 1980 and 2000, Florida's population grew on average about 39 persons per hour. While population density has increased 29% since 1982, the amount of developed land rose by 35%. More than 50% of all types of pre-settlement wetlands have been lost (Dahl, 1990).

Critical to restoration of habitat for biodiversity conservation in Florida is sustainable management of strategic habitat conservation areas (SHCA). These are the areas specifically identified after a thorough assessment of the state's conservation needs and priorities by the Florida Fish and Wildlife Conservation Commission. Of the 1.95 million hectares of private lands identified as SHCAs, over 50% are private forests, which signify their importance for biodiversity conservation. Pineland (39%), Cypress Swamp (28%), Mixed Hardwood Swamp (20%), and Upland Hardwoods (10%) constitute their general composition.

In the course of their forestland management, NIPF landowners pursue various management practices. While the effect of land use options such as forest conversion, fragmentation, and parcelization on wildlife habitat are known, the relative influences of silvicultural practices on forest biodiversity are very complex (see Hanson et al., 1991; Fredericksen et al., 2000). This complexity often makes it difficult to recommend specific practices that are compatible with biodiversity conservation on private forests. Despite such challenges, a variety of management practices are often recommended to promote forest health and habitat for biodiversity on NIPF. Prominent among these practices are periodic controlled burning, invasive species control (FF&WCC, 2004), delaying timber harvest beyond the optimal rotation age (Kline et al., 2000a), and creation and/or maintenance of streamside/wetland buffer zones to protect riparian buffers (Kline et al., 2000b).

Past studies on the prevalence of these practices indicate that very few landowners actually pursue them. For example, Wear and Greis (2002) reported that only about 14% of the landowners in the US South use fire to control undesirable vegetation and about 11% of them undertake practices that improve wildlife habitat. Specifically in regard to NIPF in Florida, English et al. (1997) noted less than a third of large (40+ ha) landowners implement practices designed to enhance timber growth, improve wildlife habitat, protect water quality, and/or enhance scenic values. Protection of wetlands was also cited as the least frequently used

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conservation practice by these landowners. Further, Jacobson (1998) observed that about 47% of NIPF owners in Florida were not actively managing their lands. One of the reasons for leaving the lands as such was the investment cost needed for their active management (Jacobson, 1998). For example, in a forest with a good network of streams, set-aside buffers could take as much as 20–50% of land out of production; and this could have a devastating effect on the operation of a small family forest. In fact, Wear and Greis (2002) observe that doing nothing is considered as both a practical and cost-effective approach for many landowners. Thus, the choice to follow these practices has a strong bearing on the economic implications entailed.

The thrust for fostering the adoption of these practices among NIPF owners mostly emanates from the societal benefits they produce. Some management practices such as prescribed burning and invasive species control may help landowners reduce the risk of damage to their plantations due to wildfires and alien species infestation. However, following such practices also renders several benefits to the society, such as avoided losses to life and structures in the wildland–urban interface (Weible et al., 2005). For example, the 1998 wildfires in Florida are estimated to have resulted in fire suppression costs of about $100 million, property losses of about $10–12 million, and unmeasured but significant costs related to human health, in addition to damages worth about $350 million to pine timber (Butry et al., 2001). Similarly, invasion of alien plant and animal species is widely recognized as a major threat to the ecological integrity of native ecosystems. Although there is uncertainty about the true value, the environmental damage and other losses from these species in the US range from tens to hundreds of billions of dollars per year (Eiswerth and vanKooten, 2002). As such, tremendous emphasis has been placed on eradication of invasive species by various conservation organizations and government agencies in recent years.

Practices such as delaying timber harvest and protecting riparian habitat, while benefiting overall society, entail significant negative financial implications to the landowners. Several studies have recognized these private costs and recommended positive incentives for landowners to adopt these practices (Shogren et al., 1999). Although owners' willingness to accept economic incentives to adopt conservation-enhancing practices varies by their forest ownership objectives (Kline et al., 2000a, b), these incentives seem to play a major role in promoting non-timber services from NIPF lands. While some studies have predicted a gradual decline in tree planting on NIPF lands in the US South due to rising costs and lower levels of government cost-share assistance (Kline et al., 2002), systematic analysis of costs entailed in adopting these conservation-enhancing forest practices on NIPF is limited.

In this paper, we assess the impact of extending timber rotation age, expanding riparian buffer strips, undertaking periodic prescribed burning, and controlling invasive species on slash pine stand management and profitability. Slash pine is the predominant species, making up 68% of all the softwood forest types in the state (Carter and Jokela, 2002) and thus provides an important rationale to study the economic implications of biodiversity conservation on its management. A stand level

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optimization model that allows incorporating various levels of these practices is employed to achieve this task. This study is of particular significance to the US South where private forestry is significant. Of the South's 87 million hectares of forestlands, private holdings constitute 89% of the timberland acreage. And NIPF owners alone control 79% of this area (Wear and Greis, 2002). Intensive management of pines for timber supply in this area is dominant. Thus, the use and management of the South's private forests in the face of various costs imposed by regulations and voluntary compliance will have important impacts on future supplies of forest resource goods, services, and benefits in the US.

Model specification

For the purpose of our study, we used a growth and yield model developed by the Plantation Management Research Cooperative at the University of Georgia. This model was used by Yin et al. (1998) to predict the total outside bark stem volume, $v(t)$, sawtimber volume over time (t), $v(t)_{\text{saw}}$, and pulpwood volume, $v(t)_{\text{pulp}}$. In order to ensure flexible mathematical properties for economic analysis, Stainback and Alavalapati (2002) developed the following functional form:

$$v(t)_{\text{pulp}} \text{ or } v(t)_{\text{saw}} = wt^{y}\mathrm{e}^{-zt} \quad (1)$$

Using data from economically relevant portion of the growth and yield function, they also estimated the parameters w, y, and z.[1] The model assumes a slash pine stand with a tree density of 1482 trees per hectare (ha) at age two on a site index of 21.3 m (base age 25 years).[2] Following Stainback and Alavalapati (2002), we specify merchantable value, val(t), as

$$\text{val}(t) = p_{\text{s}}v(t)_{\text{saw}} + p_{\text{p}}v(t)_{\text{pulp}} \quad (2)$$

where p_{s} and p_{p} are the prices of sawtimber and pulpwood per cubic meter, respectively. The present value of timber benefits of one rotation can be calculated from

$$\text{pvt}(t) = \text{val}(t)\mathrm{e}^{-rt} - g \quad (3)$$

where g represents the planting and management cost expressed in present value and r, the rate of discount. If the land is used for timber production in perpetuity, the land expectation value (LEV) can be calculated from

$$\text{LEV}(t) = \text{pvt}(t)/1 - \mathrm{e}^{-rt}) \quad (4)$$

The above formula can be maximized with respect to t to obtain the optimal rotation age. In our analysis, this Faustmann formula is simulated to assess the

[1]Parameter values of w, y, and z for pulpwood and sawtimber volume, respectively, are, 0.05, 2.95, 0.08 and 0.02, 3.02, and 0.01.

[2]Data on site index was originally obtained in American units but was converted to metric units to be consistent with other unit expressions in the paper and international norms (1 m = 3.28 ft).

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variation in LEV in response to the adoption of biodiversity conservation practices. Specifically, we compare the land value under standard (S) plantation management, which entails a single pass with a rolling drum chopper and a broadcast burn just before planting, with those derived under proposed practices – (a) prescribed burning, (b) invasive species control, (c) maintenance of a streamside buffer zone, and (d) delaying harvest beyond the optimal harvest age.

Modeling costs

The present value of the cost of undertaking prescribed burning (pvpb) is calculated by

$$\text{pvpb} = \text{cpb}(e^{-r(y1)})/1 - e^{-r(y1)} \tag{5}$$

where cpb is the per hectare cost of prescribed burning and $y1$ is the frequency with which this practice is repeated. Similar formula can be applied to the estimation of present value of the costs related to invasive species control (pvis)

$$\text{pvis} = \text{cis}(e^{-r(y2)})/1 - e^{-r(y2)} \tag{6}$$

Here cis refers to the per hectare cost of invasive species control and $y2$, to the frequency of its implementation. Restricting harvesting on either side of a stream serves as a buffer that will reduce timber benefits that are proportional to the extent of streams in a forest. The buffer zone impacts revenues and no other costs are involved with this practice. Thus, the costs related to maintaining a buffer zone (cbz) is modeled as the percent loss in the total merchantable value. This is represented as

$$\text{cbz} = \text{val}(t)(z/100) \tag{7}$$

where z denotes the % area removed from timber production due to buffer zone maintenance.

The costs related to extending rotation age beyond the optimum are obtained by calculating the difference between the optimum LEV and the LEV derived at a specified extended period.

Modeling benefits

The benefits of undertaking silvicultural practices such as prescribed burning and invasive species could be modeled as future losses avoided. For example, Routledge (1980) indicates that ignoring risk and managing forests assuming no risk leads to a reduction of up to over 10% in LEV. Forest fires are very common in Florida. Typically in a year, wildfires burn about 80,000 ha, which amounts to roughly 1.2% of Florida's forestland area (Stainback and Alavalapati, 2004). While some are low-intensity ground fires that result in very little harm to the over-story trees, a few, especially the ones occurring after prolonged dry spells, however, do cause catastrophic damage.

Similarly, invasive species outbreak such as cogon grass (*Imperata cylindrica*) infestation could result in significant losses to the landowner. Jose et al. (2002)

indicate that intense competition for resources in a cogon grass-infested pine plantation, besides creating a severe fire hazard, reduced the vigor and growth of trees. So the benefits undertaking periodic controlled burns and invasive species control are reducing the risk of wildfires and avoiding the loss of productivity.

In estimating potential losses due catastrophes such as fire or invasive outbreak, we followed model of Reed (1984). According to Reed, under the assumption that none of the stand is salvageable after catastrophic fire, fire risk simply has the same effect of increasing the discount rate by the same amount as the average frequency of fires. If some portion of the stand is salvageable after a fire, then the inclusion of fire risk into the analysis has the effect of not only increasing the discount rate but also changing the effective stumpage value curve. Since situations such as invasive species infestation may not result in total damage, in our model, we have investigated two scenarios: catastrophic-entire stand is destroyed; and less catastrophic – 70% of the stand is salvageable.

As discussed in "NIPF and forest practices for biodiversity conservation in Florida", adopting these conservation-enhancing practices by NIPF landowners also provide environmental benefits at the societal level. To include these benefits, we assume an annual payment system similar to the one landowners receive through Conservation Reserve Program. The present value ($\mathrm{pv_a}$) of such annual payment could be modeled as

$$\mathrm{pv_a} = \mathrm{sub}/r$$

where sub is the annual payment received from a conservation organization or government agency for undertaking the above management practices.

For the purpose of our analysis, the prices of sawtimber P_s, and pulpwood, P_p, respectively, are \$38.49 and 7.06 per cubic meter (Timber Mart-South, 2001). The standard (S) planting and management cost, g, is \$301 per ha and the discount rate, r, is 4%. There is a high variation in terms of costs incurred toward practicing prescribed burning and invasive species control. For prescribed burning, they range from \$12.5 to 62.5 per ha (Butry et al., 2001; Stewart, 2005). Florida's Fish and Wildlife Conservation Commission extends an amount of \$20 per ha to private landowners for undertaking this operation under the Landowner Incentive Program (FF&WCC, 2004). Similarly, the Landowner Incentive Program (LIP) provides \$62.5–150 per ha, depending on the method of eradication involved, for invasive species control. However, eradication of species such as cogon grass can cost landowners as high as \$235 per ha toward the cost of chemicals alone (see Ramsey et al., 2003).

Results and discussion

According to the model, under standard management (S), the optimum rotation age is 25.9 years and the corresponding LEV is \$1952 per ha. As can be expected, when harvesting timber is delayed beyond the optimal rotation age, the LEV drops

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at an increasing rate (Fig. 1), clearly indicating that such an option will have significant negative financial implications for the landowner.

Fig. 2 below indicates the effect of prescribed burning and invasive species control on LEV. As can be seen from the figure, in all cases, additional cost involved in undertaking these practices is causing a drop in the LEV. The drop is particularly steep if the cost of undertaking this practice is high.

For example, if prescribed burning or invasive species control is carried out once in 5 years at a cost of \$12.5 per ha, the LEV is \$1896. If either of these practices is undertaken every alternate year at the same cost (\$12.5/ha), the LEV drops to \$1802, a difference of only \$94. On the other hand, if an amount of \$75 per ha is spent, the corresponding LEV values are \$1614 (repeated every 5 years) and \$1052 (repeated every 2 years) indicating a difference of \$562.

Similarly, maintaining a buffer zone of certain width shifts the production function downward and accordingly lowers the LEV. Fig. 3 below indicates the effect of maintaining a buffer zone of various extents on LEV.

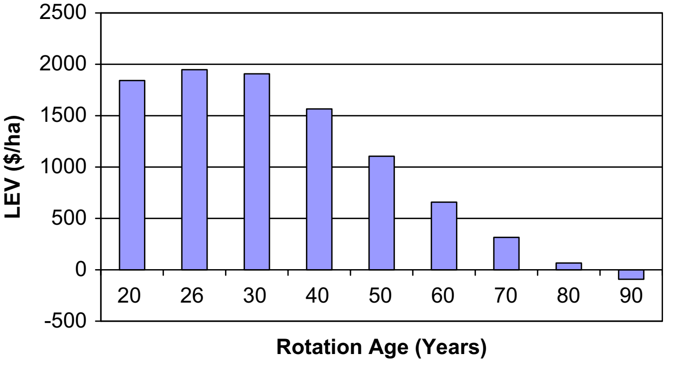

Fig. 1. Effect of delaying timber harvest on LEV.

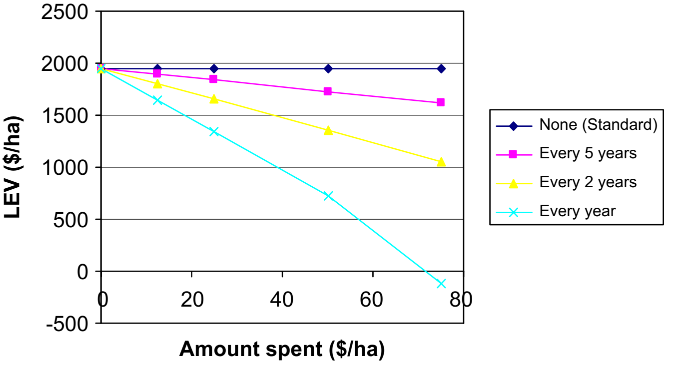

Fig. 2. Effect of prescribed burning or invasive species control on LEV.

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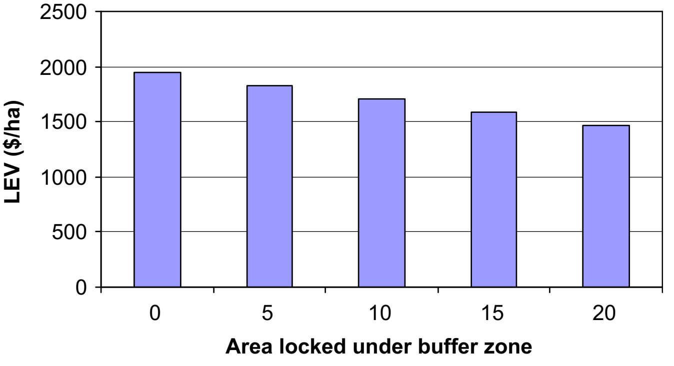

Fig. 3. Effect of buffer zone maintenance on LEV.

Cumulative effect of costs of conservation-enhancing practices

As expected, when the management includes all the suggested practices, i.e., delaying harvest beyond optimal rotation age, prescribed burning, invasive species control, and buffer zone maintenance, the LEV falls drastically. For example, with buffer zone occupying 10% of the area, practicing prescribed burning at $75/ha every 2 years and conducting invasive species control at $25/ha every 4 years, the LEV is reduced to $666. Delaying timber harvesting till the age of 50 under this scenario will further reduce the LEV to $87/ha. Other combinations of management options are given in Table 1.

Incorporating plausible benefits to the landowners

As detailed in ''Modeling benefits'', the benefits of undertaking silvicultural practices such as prescribed burning and invasive species could be considered as future losses avoided. Fig. 4 indicates the effect of a catastrophic event on LEV under various intensities of risk of its occurrence. The land value decreases with increasing risk, particularly when the salvageable portion of the stand is lower. For example, when 70% of the stand is salvageable, the LEV at 1% risk of a catastrophic event occurring is $1685. Under no salvage scenario, the value of LEV at this risk level is $1497, a difference of only $188. However, at 5% risk level, the difference in LEV between a scenario where 70% of the stand could be salvaged and a scenario where nothing could be salvaged is $556 ($696−140).

This analysis of the risk of a catastrophic event suggests that NIPF landowners follow periodic prescribed burning and invasive species control to reduce the risk of such events occurring on their lands and thus avoid potential losses. A critical examination of the cost and benefits entailed, however, indicates that often the cost of following such preventive measures may outweigh the potential benefits to the landowner. For example, even if a landowner does not undertake any preventive measures, at 2% level of risk and 70% of the stand salvageable, the reduction in LEV

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Table 1. The cumulative impact of conservation practices on LEV

Buffer zone (% area)	Prescribed burning = \$0 Invasive species = \$0	Prescribed burning = \$0 Invasive species = \$25	Prescribed burning = \$75 Invasive species = \$0	Prescribed burning = \$75 Invasive species = \$25
0	\$1952.29 (\$1103.05)	\$1808.21 (\$959.00)	\$1051.90 (\$202.69)	\$907.85 (\$58.61)
5	\$1831.33 (\$1030.48)	\$1687.26 (\$886.41)	\$930.97 (\$130.12)	\$786.89 (−\$13.96)
10	\$1710.43 (\$957.89)	\$1566.38 (\$813.84)	\$810.06 (\$57.53)	\$666.01 (−\$86.52)
15	\$1589.59 (\$885.32)	\$1445.54 (\$741.27)	\$689.23 (−\$15.04)	\$545.18 (−\$159.12)
20	\$1468.83 (\$812.75)	\$1324.78 (\$668.68)	\$568.47 (−\$87.64)	\$424.42 (−\$231.69)

Table 1 shows the cumulative impact on LEV per hectare (\$/ha) of various biodiversity conservation measures. The buffer zone column indicates the percentage of land set aside for the buffer zone. Prescribed burning takes place every 2 years and invasive species control takes place every 4 years. The numbers in parentheses indicate LEV with the rotation fixed at 50 years.

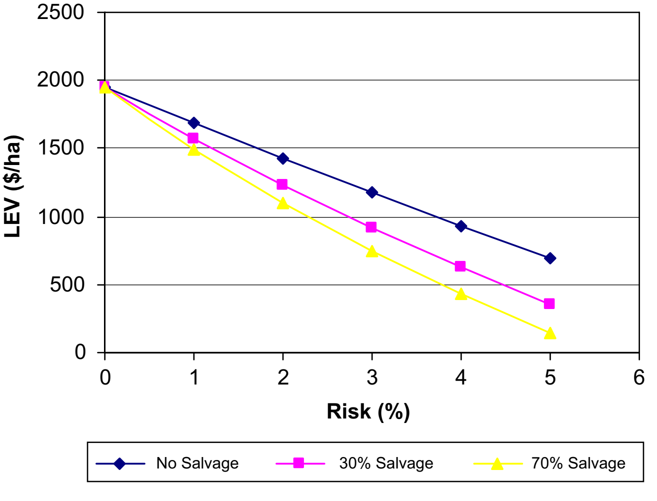

Fig. 4. Effect of a catastrophic event risk on LEV.

would be just \$526 (\$1952−1426). On the other hand, spending \$75/ha on either prescribed burning or invasive species control once in 2 years would bring down the LEV from \$1952 to 1052, a loss of \$900. As demonstrated earlier, the negative financial implication of incurring these costs will be much more if some land is under streamside or wetland buffer zone or if timber harvesting is delayed beyond the optimal rotation age.

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These financial implications may perhaps better explain why there is reluctance on the part of some landowners to undertake these practices. They also provide an empirical basis or justification for extending incentives to landowners to adopt these practices on their lands. Incorporating such incentive payments into the model indicates an annual payment of $38–83 per ha, to make adoption of these practices financially viable to the landowners. The payment amount varies depending upon the nature and extent of the practices followed and the level of risk and magnitude of wildfire and other catastrophic events these lands are exposed to.

Conclusions

As society's demand for environmental services has increased over the years, there has been a steady pressure on private landowners to protect and enhance ecological resources through regulatory and voluntary compliance. Particularly, in recent years, habitat degradation and forest fragmentation have led to the development of comprehensive plans aimed at protecting fragile habitats on private forestlands, such as SHCAs in Florida. Sustainable management of these forestlands requires efforts aimed at not only meeting the economic and environmental needs of Floridians but also ensuring the financial viability of private forestry enterprise. In this study, we have analyzed the effect of habitat conservation on optimal management of NIPF forests, taking the example of slash pine plantation management in Florida. Our results indicate that adoption of these conservation-enhancing practices imposes significant costs on landowners. While practices such as prescribed burning and invasive species control have some potential benefits to the landowners, in areas where risks of such catastrophic events are low, the costs of undertaking them outweigh their potential benefits to the landowners. On the other hand, societal benefits of these practices seem to be high. Further, management practices such as delaying timber harvesting and maintaining riparian buffer strips render several environmental services such as wildlife habitat protection, water quality improvement, carbon sequestration, and aesthetics, which are largely public goods. Given the costs are internal and benefits are external, NIPF landowners have little incentive to adopt these practices at optimum levels. An annual payment of $38–83 per ha for landowners to internalize the costs associated with adoption of these four practices would motivate them to adopt these practices. This amount is comparable to other incentive programs prevailing in the state such as the Conservation Reserve Program where about $94 per ha is being paid to landowners for enrolling their lands under the program (USDA, 2005). As stated earlier, several authors have underscored the importance of such incentive support for the sustainability of private forestry in the face of competing land uses (Kline et al., 2000a, b; Parkhurst and Shogren, 2003). In fact Kline et al. (2002) in their seminal work on private forest management project a significant decline in NIPF tree planting in the US South in the next 50 years owing to increasing plantation costs and lower levels of external cost-share assistance. Added to this impediment on the production side, the prices for pulpwood and sawtimber are showing a downward trend. As such, any regulatory or voluntary efforts to enhance habitat for conservation on NIPF without appropriately compensating the landowners for the costs entailed may further contribute to such declines in NIPF and may even take significant areas of it out of forestry altogether. This should be a cause for concern as well as action for all those interested in ensuring the success and sustainability of forestry in the US South, which is often referred to as the nation's ''wood basket''.

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