Carbon Stocks on Forest Stewardship Program and Adjacent Lands[1]

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Nonindustrial private forestlands (NIPF) in Florida are important because they provide many environmental benefits and services, including the storage of carbon. Forests have the ability to sequester and store carbon dioxide in biomass such as trees and plants (US EPA 2005). Carbon sequestration is not only important for mitigating the effects of climate change, but it is also valued in the market place as an essential ecosystem service (Stern 2007; Tallis et al. 2010). For example, in 2005 the United Nations' Kyoto Protocol to the Framework Convention on Climate Change began allowing for the sale of carbon credits, providing a direct monetary value for sequestered carbon (Andreu et al. 2009). In 2008, recognizing the important role that forests play in providing environmental services, the UN added financial incentives specifically targeting forests to the framework to "reduce emissions from deforestation and degradation" or REDD (Mulkey et al. 2008).

The State of Florida also recognizes the important role that forests play for our economy and environment through its support of NIPF and, in particular, the Florida Forest Stewardship Program (FSP). FSP is an opportunity for forest landowners to manage their forests for multiple uses (FSP 2012). The program promotes forest conservation and encourages landowners to promote and maintain the "ecosystem services" derived from their land. Ecosystem services are "the components of forests that are directly enjoyed, consumed, or used to produce specific, measurable human benefits" (Escobedo et al. 2012). In 2012, there were approximately 2,700 private forests enrolled in the FSP.

Raising awareness about the value of carbon stored in Florida's NIPF, and programs like REDD that provide incentives to store carbon, may help landowners preserve their forests and demonstrate the value of programs like FSP to policy makers and the general public. In this fact sheet, we present the results of a study that quantified the carbon stored in properties enrolled in FSP and estimated its economic value.

Methods

FSP properties were identified using management plans and property boundary spatial data provided by the Florida Forest Service. Analyses were based on the 99,800 acres of FSP lands that have boundary data available. Carbon stocks in all lands classified as "forests" in Florida were analyzed using data from the US Department of Agriculture's (USDA) Forest Inventory and Analysis (FIA). This land was classified as accessible forest land. Since data are collected from a different 20% of the plots within Florida each year, this study used data collected between 2002 and 2007, which completed a full cycle of annual plot measurements.

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While specific FIA plot locations for the FSP properties in this study could not be identified, the USDA's Forest Service provided maps of FSP properties that had FIA plots within their boundaries and a one mile buffer around each FSP with FIA plots (Lambert 2012). This information resulted in 532 FIA plots on or within one mile of FSP properties. A total of 43 plots were within FSP properties and 489 were within the one-mile buffer.

The FIA data include information on carbon stocks in various types of pools, or the carbon that accumulates in trees, plants, soil, and the forest floor (Haile et al. 2008). This information included tree aboveground carbon, tree belowground carbon, understory aboveground, understory belowground, carbon down dead, carbon litter, and soil organic carbon (Table 1).

From the carbon pools provided by the FIA data, four carbon pools were calculated for this analysis: aboveground, belowground, carbon dead, soil organic carbon. These four pools were then summed into total Mg C/ha (metric tons of carbon per hectare; Table 2).

The carbon stocks for the four carbon pools on FSP properties and the one mile of forested buffer were calculated. Carbon stocks were calculated separately for the four FIA regions in Florida: northeastern, northwestern, central, and southern Florida. We then grouped plots by forest type and calculated carbon stocks by type in each region (Table 3).

The total economic value of carbon was based on the carbon prices provided by PointCarbon (Charnley et al. 2010). The value of carbon is expected to be between $5 and $40 per metric ton of carbon (Mg C) (or $1.36 to $10.19 per ton of carbon dioxide equivalent [CO2e]) on average through 2020 (Point Carbon 2010; for a complete discussion of the methods for this analysis, see Escobedo et al. 2012).

Northwestern Florida

The average total carbon stock for FSP properties in northwestern Florida was 166 Mg C/ha, while the average total carbon stock for the one-mile buffer around these properties was 138 Mg C/ha (17% lower). A t-test was used to compare the four carbon pools and the total carbon for the FSP properties and their one-mile buffers. The properties enrolled in FSP had higher carbon stock for all the carbon pools as compared to their one-mile buffers, but results were not significant at the 95% level of confidence, likely due to the insufficient sample size of FSP properties (Table 4).

We also found that carbon stocks differ by forest type in northwest Florida, with mixed upland hardwood forest having the highest aboveground carbon stock, followed by slash pine. The total carbon stock and soil organic carbon was higher for oak gum cypress forest. Results in the one mile of forested buffer demonstrate the difference in carbon stocks by forest type between FSP and buffer properties. In the buffer, oak gum cypress forest had the highest aboveground, soil organic, and total carbon stock (Table 5).

Northeastern Florida

The average total carbon stock for FSP properties in northeastern Florida was 143 Mg C/ha, compared to 102 Mg C/ha for adjacent one-mile buffer properties. Carbon stock was generally higher in FSP properties than in the one-mile buffer, with the exception of aboveground and belowground carbon stock (although these differences were not statistically significant) (Figure 1).

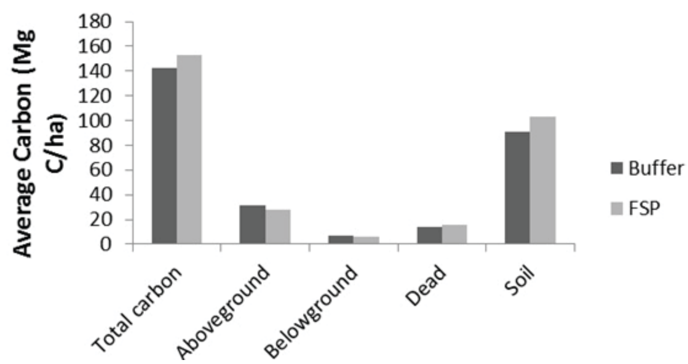

Figure 1. Carbon stocks for forest stewardship properties (FSP) and forested areas within one mile (buffer) of forest stewardship properties in northeastern Florida.
Credits: Escobedo et al. (2012 p. 74)

In northeastern Florida FSP properties, slash pine forest had the highest aboveground, belowground, dead, and total carbon stock. However, soil organic carbon stock was the highest for the oak gum cypress forest. In the one mile of forested buffer, oak gum cypress forest had the highest aboveground, belowground, soil, and total carbon stock (Table 6).

Central Florida

In central Florida, the average total carbon stock for FSP and buffer properties was 163 Mg C/ha and 167 Mg C/ha, respectively. Unlike in northeast and northwest Florida, all of the carbon pools, including the total carbon, were higher in the one-mile buffer than in FSP properties, although we were not able to directly compare forest types due to insufficient observations (Figure 2). Note that central

Florida FIA plots within FSP properties had only longleaf pine forest (Table 7).

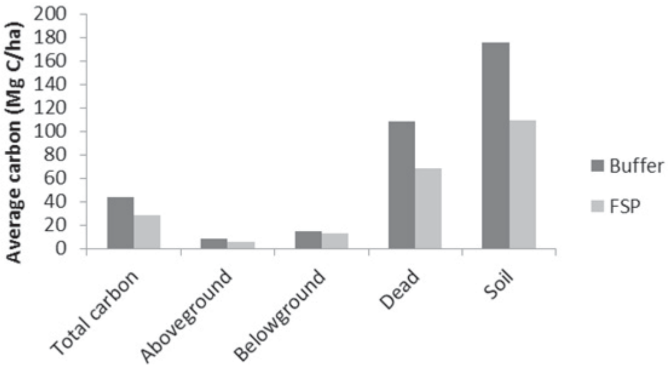

Figure 2. Carbon stocks for forest stewardship properties (FSP) and forested areas within one mile (buffer) of forest stewardship properties in central Florida.
Credits: Escobedo et al. (2012 p. 74)

In the mile buffer from FSP properties, mixed upland hardwood forest had the highest aboveground carbon. The total carbon stock was higher in oak gum cypress forest (Table 8).

Southern Florida

In southern Florida, there were no FIA plots within FSP properties, so carbon stock was calculated only for forested areas within one mile of FSP properties (Table 9), and FIA plots only had the mixed upland hardwood forest type represented (Table 10).

Economic Valuation of Carbon

Based on an assumed value of $19 per Mg C, the average dollar value per hectare of stored carbon was $3154 for northwestern Florida, $2907 for northeastern Florida, $3097 for central Florida, and $3610 for southern Florida. The values were calculated based on the minimum, mean, and maximum value for price and the total carbon per hectare (Table 11).

The total value of geographically weighted carbon stored in FSP properties is around $300 million dollars. The value was estimated by multiplying the average economic value (dollars per hectare, assuming $19 per Mg C) times the total of current and active (2010) FSP hectares in each FIA region (Table 12).

Key Forest Management Implications

As national carbon markets are being developed, it is important to assess the value of carbon stored in FSP properties in Florida. These results can inform landowners about the value of carbon sequestration, which is an important consideration when managing forests for multiple uses or when considering participation in carbon markets. In addition, policy makers can use these results to assess the worth of forest conservation programs such as FSP and guide decisions about forest conservation and management.

The average total carbon stock estimates for FSP properties and the one-mile buffers in the different FIA regions range from 143 to 190 Mg C/ha, which is within the range reported for the southeastern United States (Heath et al. 2011), as well as within the range reported for tropical forests (Lal 2005). In general, the FSP properties in the northeastern and northwestern regions had higher values in all of the carbon pools, including total carbon, than the one-mile buffers (although this difference was not statistically significant). For these areas in Florida, NIPF forestland in FSP is likely being managed in a way that increases carbon sequestration.

Oak gum cypress forest, mixed upland hardwood forest, and slash pine forest had higher amounts of carbon than other forest types. This is consistent with prior studies that have shown that hardwood forests have higher amounts of carbon stocks and wood production (Brown et al. 1999). In addition, most of the plantations in Florida are slash pine, which has to be intensively managed to increase growth. This management approach results in higher amounts of carbon, which is consistent with our results. These results suggest an important tradeoff between forest type and carbon sequestration that may inform policy and land use decisions.

The expected dollar value per hectare of carbon for a property with an average total carbon figure ranged from $2,907 to $3,610. These values are higher than the ~$1,000 average value reported by Moore et al. (2011) for private forests in Georgia. The total value of carbon stored in FSP properties was $300 million, which is approximately four times the average value of carbon credits that landowners will receive per year if all the pine plantations in Florida are managed with moderate intensity (Mulkey et al. 2008). This indicates the important role that multiple use forests play in providing a key ecosystem service—carbon sequestration—and hints at the benefits provided by programs like FSP.

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Table 1. Carbon Stocks by Pool Identified in USDA Forest Service Forest Inventory and Analysis Data.

Carbon Pools	Description
Tree aboveground	Carbon in bole, crown, branches, and stump of live trees (> 2.5 cm) and dead trees (>12.5 cm)
Tree belowground	Carbon in coarse roots (>2.5 mm) for live (>12.5 cm) and dead (>12.5 cm) trees
Understory aboveground	Carbon in aboveground portion of seedlings, shrubs, and bushes
Understory belowground	Carbon in belowground portion of seedlings, shrubs, and bushes
Carbon down dead	Carbon in dead woody material (>7.5 cm) and their stumps and roots (> 7.5 cm)
Carbon litter	Carbon in fine woody debris, fine roots, and organic forest floor above the mineral soil
Soil organic carbon	Soil organic carbon to a depth of 1 meter

Table 2. Carbon Stocks Identified by Pool in the USDA Forest Service Forest Inventory and Analysis Data.

Carbon Pools	Description
Aboveground (Mg C/ha)	Sum of tree aboveground and understory aboveground
Belowground (Mg C/ha)	Sum of tree belowground and understory belowground
Carbon dead (Mg C/ha)	Sum of down dead, litter, and standing dead
Soil organic carbon (Mg C/ha)	Soil organic carbon to a depth of 1 meter
Total carbon	Sum of aboveground, belowground, carbon dead, and soil organic carbon
Note: Mg C/ha = Metric tons of carbon per hectare	

Table 3. Forest Types Used in the Current Study after Combining the Forest Types Described in the USDA Forest Service Forest Inventory and Analysis Data.

Forest Types	FIA Forest Types
Longleaf pine	longleaf pine, longleaf pine/oak
Slash pine	slash pine, slash pine/hardwood
Other pine hardwood	loblolly pine, sand pine, pond pine, shortleaf pine, loblolly pine/hardwood, other pine/hardwood
Oak hickory	post oak/black jack oak, white oak/red oak/hickory, sassafras/persimmon, yellow poplar, southern scrub oak, red maple/oak
Oak gum cypress	sweetgum/nuttall oak/willow oak, overcup oak/water hickory, bald cypress/water tupelo, sweetbay/swamp tupelo/red maple, bald cypress/pond cypress.
Mixed upland hardwood	mixed upland hardwood/tropical hardwood/exotic hardwood

Table 4. Carbon Stock (Mg C/ ha) for Different Carbon Pools for Forest Stewardship Property and a Mile Buffer from Forest Stewardship Property in Northwestern Florida.

Carbon Pools	Forest Stewardship Property			Buffer		
	Min	***Mean***	***Max***	***Min***	***Mean***	***Max***
Aboveground	8	33	100	1.14	28	133
Belowground	1.3	6.8	23	0.2	5.6	28
Carbon dead	9.3	15.5	22	1.9	13.7	29
Soil organic carbon	67	111	175	25	90	174
Total carbon	104	166	266	32	138	362
Note: Mg C/ha = Metric tons of carbon per hectare; Min=Minimum, Max=Maximum, n/d=not determined						

Table 5. Average Carbon Stock (Mg C/ha) for Different Forest Types within Forest Stewardship Properties (FSP) and non-FSP Properties in Northwestern Florida.

Forest Types	Above-ground		Below-ground		Carbon Dead		Soil Organic Carbon		Total Carbon	
	FSP	*Non-FSP*	*FSP*	*Non-FSP*	*FSP*	*Non-FSP*	*FSP*	*Non-FSP*	*FSP*	*Non-FSP*
Longleaf Pine	n/a	29	n/a	6	n/a	18	n/a	102	n/a	154
Mixed upland hardwood	40	18	8	3.3	9	9	77	47	135	78
Oak gum cypress	22	46	4.2	9	16	19	174	171	216	246
Oak hickory	n/a	12	n/a	2	n/a	10	n/a	50	n/a	73
Other pine hardwood	25	16	5.1	3	17	15	76	78	124	113
Slash pine	35	28	7.5	6	18	17	111	109	172	160
Note: Mg C/ha = Metric tons of carbon per hectare; n/a=not applicable										

Table 6. Average Carbon Stock (Mg C/ha) for Different Forest Types within Forest Stewardship Properties (FSP) and Non-FSP Properties in Northeastern Florida.

Forest Types	Above-ground		Below-ground		Carbon Dead		Soil Organic Carbon		Total Carbon	
	FSP	*Non-FSP*	*FSP*	*Non-FSP*	*FSP*	*Non-FSP*	*FSP*	*Non-FSP*	*FSP*	*Non-FSP*
Longleaf pine	4.5	15	0.5	3	13	17	12	94	139	129
Mixed upland hardwood	14.6	25	2.6	4.7	25	9.3	77	48	120	87
Oak gum cypress	15	58	2.8	12	11.5	18	174	174	203	263
Oak hickory	6.2	11	1	1.8	7	11	50	50	64	74
Other pine hardwood	16	19	3.2	4	16	18.5	80	78	116	120
Slash pine	67	31	14	7	18	17	121	113	221	168
Note: Mg C/ha = Metric tons of carbon per hectare										

Table 7. Average Carbon Stock (Mg C/ha) for Longleaf Pine Forest Type within Forest Stewardship Properties in Central Florida.

Forest Types	Above-ground	Below-ground	Carbon Dead	Soil Organic Carbon	Total Carbon
Longleaf pine	42	8.5	19	94	163
Note: Mg C/ha = Metric tons of carbon per hectare					

Table 8. Average Carbon Stock (Mg C/ha) for Different Forest Types within One Mile of Forest Stewardship Properties in Central Florida.

Forest Types	Above-ground	Below-ground	Carbon Dead	Soil Organic Carbon	Total Carbon
Mixed upland hardwood	51	10	13	68	142
Oak gum cypress	47	10	22	174	253
Oak hickory	63	11.8	16.5	50	141
Note: Mg C/ha = Metric tons of carbon per hectare					

Table 9. Average Carbon Stock (Mg C/ha) for Different Carbon Pools within One Mile of Forest Stewardship Properties in Southern Florida.

Carbon Pools	One-Mile Buffer		
	Min	**Mean**	**Max**
Aboveground	6	24.5	43
Belowground	0.89	4.6	8.3
Carbon Dead	3.7	14	27
Soil Organic Carbon	105	147	190
Total Carbon	115	190	265
Note: Mg C/ha = Metric tons of carbon per hectare; Min=Minimum, Max=Maximum, n/d=not determined			

Table 10. Average Carbon Stock (Mg C/ha) for Mixed Upland Hardwood Forest Type within a One-Mile Buffer of Forest Stewardship Properties in Southern Florida.

Forest Types	Above-ground	Below-ground	Carbon Dead	Soil Organic Carbon	Total Carbon
Mixed Upland Hardwood	25	4.5	14	148	191
Note: Mg C/ha = Metric tons of carbon per hectare					

Table 11. Economic Value (Dollars per Hectare) of Total Carbon Stored (Mg C/ha) in Forest Stewardship Properties and Forests within One-Mile of Forest Stewardship Properties.

FIA Region	Price Range	FSP Total Carbon Value (Dollars per Hectare)			Buffer Total Carbon Value (Dollars per Hectare)		
Northeastern	Min	580	765	1,225	85	715	1,890
	Mean	2,204	2,907	4,655	323	2,717	7,182
	Max	4,640	6,120	9,800	680	5,720	15,120
Central	Min	445	815	1,185	190	880	1,540
	Mean	1,691	3,097	4,503	722	3,344	5,852
	Max	3,560	6,520	9,480	1,520	7,040	12,320
Southern	Min	575	950	1,325	n/d	n/d	n/d
	Mean	2,185	3,610	5,035	n/d	n/d	n/d
	Max	4,600	7,600	10,600	n/d	n/d	n/d
Notes: Mg C/ha = Metric tons of carbon per hectare; Min=Minimum, Max=Maximum, n/d=not determined							

Table 12. Total Economic Value of Carbon Stored in Forest Stewardship Program (FSP) Lands in Each Florida Forest Inventory and Analysis (FIA) Region.

FIA Region	Total FSP Area (in hectares)	Average Value ($ per hectare)	Total Value
Northeastern	55,695	2,907	$161,905,365
Northwestern	32,562	3,154	$102,700,548
Central	8,985	3,097	$27,826,545
Southern	2,572	3,610	$9,284,920
State-wide			$301,717,378
Note: Only FSP properties with available spatial data were analyzed.			