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Terrestrial carbon pools in southeast and south-central United States

Fengxiang X. Han · M. John Plodinec · Yi Su · David L. Monts · Zhongpei Li

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Abstract Analyses of regional carbon sources and sinks are essential to assess the economical feasibility of various carbon sequestration technologies for mitigating atmospheric CO_2 accumulation and for preventing global warming. Such an inventory is a prerequisite for regional trading of CO_2 emissions. As a U.S. Department of Energy Southeast Regional Carbon Sequestration Partner, we have estimated the state-level terrestrial carbon pools in the southeast and south-central US. This region includes: Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia. We have also projected the potential for terrestrial carbon sequestration in the region. Texas is the largest contributor (34%) to greenhouse gas emission in the region. The total terrestrial carbon storage (forest biomass and soils) in the southeast and south-central US is estimated to be 130 Tg C/year. An annual forest carbon sink (estimated as 76 Tg C/year) could compensate for 13% of the regional total annual greenhouse gas emission (505 Tg C, 1990 estimate). Through proper policies and the best land management practices, 54 Tg C/year could be sequestered in soils. Thus, terrestrial sinks can capture 23% of the regional total greenhouse emission and hence are one of the most cost-effective options for mitigating greenhouse emission in the region.

1 Introduction

Detailed regional inventories of carbon sources and sinks are essential to assess the potential roles of various carbon sequestration pools for mitigating atmospheric CO_2 accumulation and

F. X. Han (✉) · M. J. Plodinec · Y. Su · D. L. Monts
Institute for Clean Energy Technology (ICET), Mississippi State University, 205 Research Blvd, Starkville, MS 39759, USA
e-mail: han@icet.msstate.edu

F. X. Han
Department of Plant and Soil Sciences, Mississippi State University, Mississippi State, MS 39762, USA

Y. Su · D. L. Monts
Department of Physics and Astronomy, Mississippi State University, Mississippi State, MS 39762, USA

Z. Li
Institute of Soil Science, the Chinese Academy of Sciences, P. O. Box 821, Nanjing 210008, China

hence for preventing global warming. Such information is necessary for examining the economical feasibility of a particular technology. Moreover, it is a prerequisite for development of systems/markets for regional and national carbon emission trading (North East State Foresters Association 2002; Idaho Soil Conservation Commission 2003).

Current global terrestrial carbon storage has been estimated to be around 2,500,000 Tg C (2.50×10^6 teragrams of carbon) (Eswaran et al. 2000). The current terrestrial biomass is 560,000 Tg C (Schlesinger 1995). Soil carbon storage is the largest terrestrial sink. Global soil carbon (0–100 cm) has been estimated to be 2,157,000–2,296,000 Tg C with 1,462,000–1,550,000 Tg C of soil organic carbon and 695,000–748,000 Tg C of soil carbonate carbon (Batjes 1996; Lal and Kimble 2000). The North American continent has 346,700 Tg C of total stored soil organic carbon, of which the US has 72,900 Tg C of soil organic carbon stored (Waltman and Bliss 1997). Bliss et al. (1995) estimated soil organic carbon storage in the southeast and south central US. However, there are no details available on the state-level distributions and on other major terrestrial carbon pools, including biomass carbon storage in regional forests, crops, and grasslands. This information will serve as the baseline for regional trading of CO_2 emissions.

Terrestrial ecosystems in the Northern Hemisphere are believed to sequester significant amounts of atmospheric CO_2 (Fan et al. 1998; Houghton et al. 1999; Schimel et al. 2000). Both land- and atmosphere-based approaches yield a consistent conclusion that the U.S. terrestrial ecosystem is a relatively stable net sink for carbon (Schimel et al. 2000; Pacala et al. 2001). Terrestrial carbon sequestration with proper land management can offset 10 to 30% of US fossil fuel emission (Houghton et al. 1999; Holland et al. 1999). Bruce et al. (1999) and Lal et al. (1999) noted that soil carbon sequestration may achieve about 15% of the total annual mitigation targets for the United States and Canada under the Kyoto Protocol. Moreover, they believe that U.S. cropland could sequester 123–295 Tg C/year by adoption of proper management practices. Unfortunately, current annual rates of the various terrestrial carbon pools are poorly understood and are not well documented at state and regional levels. Furthermore, the potential for enhancing terrestrial carbon sequestration in the southeast and south-central US has not been studied in detail.

This study seeks to answer the following questions: (1) What are the current annual rates of terrestrial carbon sequestration in each state of the Southeast and South-Central U.S.? (2) In each state, what is the overall contribution of terrestrial carbon sequestration to mitigating its total greenhouse gas emission? (3) What is the current baseline in the region for possible carbon trading? and (4) What is the potential for enhancing terrestrial carbon sequestration? Since the states of the Southeast and South-Central United State are mostly characterized by a humid climate, soil organic carbon is the most important dynamic terrestrial carbon pool. Soil carbonate carbon becomes an important carbon sink only in the soils of Texas. Furthermore, the carbonate pool is not as dynamic as the organic carbon pool with regard to the effects of agricultural management. Thus this study focuses on terrestrial organic carbon pools in the region. The distribution of carbonate carbon pool in the region requires further study.

2 Materials and methods

2.1 Estimates of the current total terrestrial carbon storage

The total terrestrial carbon pools in the region were estimated for the following major components: soil organic carbon pool, forest biomass carbon pool, agricultural crop biomass carbon pool, and pasture biomass carbon pool. Soil organic carbon pools in Alabama (AL), Arkansas (AR), Florida (FL), Georgia (GA), Mississippi (MS), North Carolina (NC), South Carolina (SC), Tennessee (TN), Texas (TX), and Virginia (VA) were directly taken from the detailed work of Bliss et al. (1995). Soil organic carbon was calculated from each layer of the soils collected in the National Soil Geographic Data base (NATSGO), that was developed by the Soil Conservation Service (Bliss et al. 1995). The midpoint of the range of organic matter content and of bulk density were used to represent the organic matter content and the bulk density, respectively, of the layer of each soil. Soil organic carbon content was the product of the midpoint organic matter, the midpoint bulk density, the rock fragment conversion factor, the thickness of the layer, and the organic carbon factor. A statewide average of soil organic carbon per unit area was computed by dividing the total carbon content by the reported area. The details of estimating the soil organic carbon pools at the state level were presented by Bliss et al. (1995). Soil organic carbon pools include soil organic carbon in all forest, pasture and agricultural soils. Soil organic carbon storage in Louisiana (LA) was estimated from the regional carbon density and land area.

Forest biomass carbon pools were assessed from the total biomass on timberland (Smith et al. 2001). We used the total biomass on timberland to estimate the total biomass for the rest of the forestland by assuming that forestlands have the same biomass density as does timberland. The average carbon content in dried forest biomass was assumed to be 50% (Birdsey 1996).

Annual agricultural crop and pasture biomass carbon pools were estimated from annual yields of major crops and pasture in the region. Crops include rice (*Oryza sativa*), corn (*Zea mays*), soybean (*Glycine spp.*), cotton (*Gossypium spp.*), barley (*Hordeum spp.*), wheat (*Triticum spp.*), oats (*Avena spp.*), sorghum (*Sorghum bicolor*), peanuts (*Arachis spp.*) and tobacco (*Nicotiana spp.*). Yields of these crops were those cited by the USDA National Agricultural Statistics Service (2003). Biological yields, i.e., the biomass aboveground, were calculated from grain yields and harvest index (aboveground biomass of each crop = grain yield × harvest index). The harvest index is defined as the ratio of the yield (grain weight) to the aboveground total biological yield. The underground biomass of each crop was calculated from aboveground biomass and crop specific ratio of roots/shoots (underground biomass of each crop = aboveground biomass × crop-specific ratio of roots/shoots). Overall biomass for each crop was estimated from its aboveground and underground biomass. Literature values of the average harvest index and of the ratios of roots/shoots for major crops were used in this study (Stoskopf 1981; Klepper 1991; Arnold et al. 1995; Pettigrew 2003). The total state-level crop/grass biomass is the sum of biomass of all major crops/grasses grown. The state-specific total biomass is the sum of all biomasses in each state. An average of 45% of the carbon content was used for assessing total biomass carbon pools for both agricultural crop biomass carbon pools and pasture biomass carbon pools (Kucharik and Brye 2003).

2.2 Estimate of current and potential annual terrestrial carbon storage

The annual state-specific increases in forest biomass carbon pools were estimated from the net annual forest growth on timberland during 1996 (Smith et al. 2001). The total annual net forest growth for the rest of the forestland was extrapolated from that on timberland by assuming similar growth rates for the other forestlands. Actually for most states in this region, non-timberland forestland accounts for 0 to 2–3% of the total forestland. On the other hand, non-timberland in Florida and Texas account for 11.3% and 56% of the total forestlands, respectively. Therefore, we believe that this extrapolation gives reasonable estimates for most states of this region. However, the annual forest growth component of the net biomass in Florida and Texas may be overestimated by such extrapolation. We have not considered the contribution of the forest trees' roots. The average carbon content in dried forest biomass is assumed to be 50% (Birdsey 1996). Estimation of annual crop and pasture biomasses were discussed above.

The potentials for terrestrial carbon sequestration were estimated by using the average rates of potential carbon gain in each category (forestland, cropland, and grassland), assuming proper policies and sound management practices (Bruce et al. 1999). The potential rate of carbon gain per km^2 was taken as the long-term average (20 years) soil C gain in the United States and Canada, utilizing the best possible carbon-conserving practices. We used a potential soil C gain of 4×10^{-7} Tg C/km^2/year for cropland and woodland, and a potential C gain of 2×10^{-7} Tg /km^2/year for grasslands (Bruce et al. 1999; Lal et al. 1999).

The potentials for forestland, grassland, and cropland are the estimated carbon gains of soil carbon. These were obtained by simply multiplying the land area by the potential rate for carbon gain per km^2 in each category. The state-level total potential is the sum of the potential carbon gains for forestland, cropland, and grassland, while the total potential carbon gain for this region is the sum of state-level potential increases.

These estimates assume that the best possible practices are adopted in all land categories at the beginning of the next two decades. This assumption could clearly lead to overestimation of achievable carbon gains. The actual adoption of these practices in the future is uncertain. The actual carbon gains depend upon the policies adopted and upon changing economic and political factors. Also since reduced tillage and other C-conserving practices have already been in use on some lands, the total additional carbon gain may be lower than the estimates.

2.3 Total greenhouse gas emission

Total greenhouse gas emission values for Alabama, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Tennessee, Texas, and Virginia in 1990 or 1992 were taken from the USEPA (2003a, b). Arkansas and South Carolina do not have complete data on greenhouse gas emission, due to lack of information on the waste, agriculture, and industry sectors.

3 Results and discussion

3.1 Total terrestrial carbon storage

The total terrestrial carbon storage in the southeast and south-central U.S. (11 states) is estimated to be 21,102 Tg C (Table 1). Texas has the highest total terrestrial carbon storage (5,619 Tg C), accounting for 26.6% of the total terrestrial carbon storage in the region (Table 1). Florida (3,757 Tg C or 17.8%) is the second largest contributor. Tennessee and Mississippi have the lowest terrestrial carbon storage (800–900 Tg C or 4% of the regional total terrestrial carbon storage).

We divided the terrestrial carbon storage into four major carbon pools: soil organic carbon, forest biomass, crop biomass, and grass biomass. Among these categories, soil organic matter is the largest terrestrial carbon pool, totaling 16,535 Tg C (78% of the overall regional terrestrial carbon pool), followed by the forest biomass carbon pool

Table 1 Total terrestrial carbon storage in southeast and south-central US

State	Soil organic C	Biomass C			Total terrestrial C
		Forest	Crop[a]	Pasture[a]	
	(Tg C)	(Tg C)	(Tg C)	(Tg C)	(Tg C)
AL	535	489	1.3	1.3	1,027
AR	814	482	22	2.9	1,321
FL	3,504	252	0.3	0.7	3,757
GA	1,232	514	3.7	1.6	1,751
LA	1,100	376	8.7	0.7	1,485
MS	457	450	7	1.3	915
NC	1,761	517	7.4	1.8	2,287
SC	888	262	1.9	0.7	1,153
TN	408	389	5.2	4.7	807
TX	5,320	269	21	8.9	5,619
VA	516	455	6.3	3.2	980
Sum	16,535	4454	85	28	21,102

[a] On an annual basis

(4,454 Tg C or 21%). Carbon storage in agricultural crops and grass biomass is relatively small, totaling 113 Tg C (0.53% of the total terrestrial carbon storage). Due to the short life cycle of carbon in crop and pasture biomass, these categories are not considered to be efficient terrestrial carbon sequestration sinks for mitigating greenhouse gas.

Terrestrial carbon (soil organic carbon and forest carbon) in the U.S. has been estimated to be 110,900 Tg (72,900 Tg for soil organic carbon in soils of 1-m depth, 38,000 Tg for forest carbon) (Waltman and Bliss 1997; Washington Advisory Group LLC 2002). Terrestrial carbon storage in this region accounts for 18.9% of the total terrestrial carbon storage in the US. This estimate is in agreement with the percentage (20.6%) of the land area in the region relative to the total land area in the US, indicating that terrestrial carbon density in the region is in the range of the average US terrestrial carbon density.

In addition, Texas has the highest soil organic carbon pool in the region (5,320 Tg C) and Florida (3,504 Tg C) the second highest. Tennessee and Mississippi have the lowest soil organic carbon pool (from 400 to 500 g C). However, Florida has the highest soil organic carbon density (25.7 kg C/m^2), followed by North Carolina (14.3 kg C/m^2). Alabama, Arkansas, Mississippi, Tennessee, and Virginia have lower soil organic carbon density (around 3.8–6.1 kg C/m^2). The soil organic carbon pool is, in general, the largest component of terrestrial carbon storage in the region. It accounts for 93–95% of the total terrestrial carbon storage in Florida and Texas, while it represents about 50% of the total terrestrial carbon pools in Alabama, Mississippi, Tennessee, and Virginia.

Most of the southeast and south-central states have similar forest biomass carbon storage (around 450–520 Tg C). Florida, South Carolina, and Texas have relatively low forest biomass carbon storage (around 250 Tg C for each state) (Table 1). Forest biomass carbon accounts for 40–50% of the total terrestrial carbon storage in Alabama, Mississippi, Tennessee, and Virginia, but only 4.8–6.7% of the total terrestrial carbon storage in Florida and Texas.

3.2 Current annual terrestrial carbon sinks

The total annual terrestrial carbon sink for the region was estimated to be 189 Tg C/year (Table 2). Texas is the leading state (38 Tg C/year), accounting for 20.1% of the total annual terrestrial carbon sink. Arkansas (31 Tg C/year or 16.6%) is the second largest (Table 2). South Carolina and Florida have the smallest total annual terrestrial carbon sinks (6.4 Tg C/year or 3.4% for each state). Most states have a total annual terrestrial carbon sink of between 16 and 20 Tg C/year (Table 2).

The annual carbon sink in forests was estimated to be 76 Tg C/year (Table 2), accounting for 40.2% of the total regional annual carbon sink and 27% of the total annual carbon accumulation in US forests. The total annual US forest carbon accumulation from 1952 to 1992 was 281 Tg C/year (US Department of Energy 1999). The contribution of the regional forest carbon accumulation to the overall US forest carbon accumulation is in proportion to the forestland. Forestland in the region totals 784,700 km^2 representing 30% of the total forestland in the US (total forestland in the US is 2,598,220 km^2) (USDA National Agricultural Statistics Service 2003). Katul et al. (1999) reported that forests in the southeast US are a dominant carbon sink, accounting for 50% of the carbon sequestered in North America.

Georgia has the highest absolute annual carbon sink in forest biomass (11 Tg C/year, representing 14.5% of the total carbon sink in forests of the region). South Carolina has the smallest (3.8 Tg C/year or 4.9% of total annual carbon sink in forests of the region) (Table 2). Compared to other sinks, Alabama has the highest percentage of its total annual biomass carbon sink in forest (77%) and Georgia (68%) the second highest. Texas and Arkansas have the smallest percentage (20%). The current value (76 Tg C/year) of annual carbon accumulation as forest biomass in this region is in agreement with other estimates: Delcourt and Harris (1980) reported that forests in the southeastern US have served as a sink for 70 Tg C/year in biomass and soils.

Total annual carbon storage in crop biomass (including roots and shoots) was estimated to be 85 Tg C/year (Table 2), accounting for 45.1% of the total annual terrestrial carbon sink in the region. Total carbon in grass biomass is around 28 Tg C/year (14.7% of the annual sink). The regional total carbon storage in crop and grass biomass pools is 113 Tg C. Arkansas and Texas have the highest carbon storage in crop biomass (21–22 Tg C/year). Florida (0.3 Tg C/year), Alabama (1.3 Tg C/year) and South Carolina (1.9 Tg C/year) have the lowest C storage in crop biomass (Table 2). It should be noted that grassland and rice paddies are the dominant land-uses in Texas and Arkansas (USDA National Agricultural Statistics Service 2003).

Table 2 Current annual terrestrial biomass C pools in southeast and south-central US

State	Biomass C (Tg C/year)			Total terrestrial C as biomass (Tg C/year)
	Forest	Crop	Pasture	
AL	8.7	1.3	1.3	11.3
AR	6.5	22	2.9	31.4
FL	5.4	0.3	0.7	6.4
GA	11	3.7	1.6	16.3
LA	5.9	8.7	0.7	15.3
MS	7.8	7.0	1.3	16.1
NC	8.5	7.4	1.8	17.8
SC	3.7	1.9	0.7	6.4
TN	4.3	5.2	4.7	14.3
TX	7.8	21	8.9	38.0
VA	6.3	6.3	3.2	15.8
Sum	76.0	85.3	27.8	189.1

Due to lack of data on annual soil organic matter accumulation in the region, we used the rate of soil organic carbon sequestration suggested by Schlesinger (1990). Consequently, we estimated the annual soil organic carbon accumulation to be around 3.8 Tg C/year, accounting for 1.9% of the regional total terrestrial annual carbon sink. The actual state-level annual soil organic carbon storage requires further study.

3.3 Total greenhouse gas emission

Since complete state-specific data on greenhouse gas emission in 2000 from energy, waste, agriculture, and industry sectors in the region are not available, the total greenhouse gas emission in 1990 (504 Tg C/year, Table 3) was used in this study. The 1990 total annual greenhouse gas emissions account for 30.1% of the U.S. total emission (1,674 Tg C; USEPA 2003b) This computation excluded Arkansas and South Carolina due to lack of greenhouse gas emission data from waste, agriculture, and industry sectors for those states.

Texas has the highest greenhouse gas emission (173 Tg C/year), representing 34.3% of the total greenhouse gas emission in the region. Louisiana contributed 68 Tg C/year (13.5%) and Florida 56 Tg C/year (11.1%). Mississippi has the lowest greenhouse gas emission (25 Tg C/year or 5%).

The energy sector contributed about 85.2% of the total greenhouse gas emission in the region, followed by agriculture (8.0%) and waste disposal (Table 3). The energy sector accounted for 90% of the greenhouse gas emission in Louisiana, Georgia, Florida, and Alabama, while in Mississippi this sector accounted for only 55% of the emission. Utility, transport, and industry subsectors were the three largest contributors (Table 3) among the various subcategories related to the energy sector. The industry subsector contributed 34.1% and 55% of the greenhouse gas emission in Texas and Louisiana, respectively. The contribution of this subsector to greenhouse gas emission was the lowest in Arkansas, South Carolina, and Mississippi. Emission from the transport and utility subsectors (Table 3) was the highest in Florida and Texas (45 and 90 Tg C/year, respectively) and lowest (<10 Tg C/year) in Arkansas and Mississippi. The largest contribution to greenhouse gas emission in Mississippi was agriculture (40.6%). The waste sector contributed 16.6% of the greenhouse gas emission in Virginia.

3.4 Contribution of current annual forest carbon storage to mitigation of total emission

Since crop and grass biomass are harvested and respired in a short time, these two categories of carbon pools are not considered to be efficient terrestrial carbon sequestration for mitigating greenhouse gas. Therefore, only annual forest biomass is considered in estimates of terrestrial carbon sequestration. The total annual forest carbon sink in the region (excluding Arkansas and South Carolina) is 66 Tg C/year, while the total annual greenhouse gas emission was estimated as 505 Tg C/year. Thus, the total annual forest carbon sink in the region could offset 13% of the regional total greenhouse gas emission (Table 4).

3.5 Potentials for terrestrial carbon sequestration

The total land area in the region is 1,583 thousand km^2, including 377,471 and 736 thousand km^2 of cropland, grassland, and forestland, respectively. Texas has the largest cropland (26.7% of total land in Texas) and grassland (65.4%), while other states are

Table 3 Total greenhouse gas emission from the region in 1990

State	Energy							Waste	Agriculture	Industry	Total emission	Percent of the region
	Residential	Commercial	Industrial	Transport	Utility	Other	Total					
			Tg C						Tg C		Tg C	
AL	0.9	0.7	8.2	7.8	13.5	3.1	34.1	1.8	1.0	0.7	37.6	7.5
AR	0.7	0.5	2.5	4.4	5.9		13.9	NA[a]	NA[a]	NA[a]	NA[a]	
FL	0.6	1.5	3.3	22.1	23.3		50.7	2.7	2.5		55.9	11.1
GA	1.6	1.0	6.2	15.1	16.7		40.8	1.7	1.5	0.8	44.8	8.9
LA	0.9	0.4	34.9	16.1	9.0	2.3	63.5	1.1	1.4	2.3	68.3	13.5
MS	0.5	0.4	2.9	6.2	3.0	0.9	13.9	0.9	10.2	0.1	25.1	5.0
NC	1.4	0.9	5.8	10.4	11.4	0.5	30.4	1.5	2.3	0.1	34.3	6.8
SC	0.6	0.4	2.5	6.0	6.0		15.4	NA[a]	NA[a]	NA[a]	NA[a]	
TN	0.9	0.9	4.3	8.4	12.0	0.0	26.8	1.5	1.3	0.7	30.3	6.0
TX	3.5	3.3	52.3	42.1	48.3	3.9	153.5	5.3	9.4	5.0	173.2	34.3
VA	2.0	1.1	6.4	11.2	5.7		28.1	5.8	0.8	0.3	35.0	6.9
Sum	13.5	11	129.3	149.8	154.8	10.7	471.1	22.3	30.4	10	504.5	100

[a] NA: not-available

Table 4 Percentages of current annual forest carbon storage over the total greenhouse gas emission in the region (%)

State	Total carbon emission	Annual sink in forest biomass C	
	Tg C/year	Tg C/year	Percent of the total emission
AL	37.6	8.7	23.1
AR	NA	6.5	
FL	55.9	5.4	9.7
GA	44.8	11.0	24.6
LA	68.3	5.9	8.7
MS	25.1	7.8	31.2
NC	34.3	8.5	24.8
SC	NA	3.7	
TN	30.3	4.3	14.3
TX	173.2	7.8	4.5
VA	35	6.3	18.0
Sum	504.5	76.0	13.0

dominated by forest cover (60–70%) (recalculated from USDA National Agricultural Statistics Service 2003).

Through reforestation, improved agricultural and silvicultural management practices, terrestrial carbon storage in these lands could increase. The total potential for terrestrial carbon sequestration on these lands was estimated to be 53.9 Tg C/year with forestland, cropland and grassland contributing 55, 28 and 17% of that total (Table 5). Our regional estimate represents 13–52% of the potential carbon sequestration (50–200 Tg C/year) over the next 2–3 decades in agricultural and pasture land of the United States (Bruce et al. 1998; Lal et al. 1998). Lal et al. (1999) noted that the total carbon sequestration potential in US cropland could offset 8.5–9.8% of total US greenhouse gas emissions. The potential soil carbon sequestration in the Southeast and South-Central States accounts for 9.3% of the current annual greenhouse gas emission in the region (Table 5). Combining current annual

Table 5 The potentials for terrestrial carbon sequestration in the region

State	Total carbon emission Tg C/year	Potential terrestrial C sequestration				Percent of the total greenhouse gas emission
		Cropland (Tg C/year)	Grassland	Forestland	Sum	
AL	37.6	0.72	0.15	3.55	4.42	11.8
AR	NA	1.63	0.16	2.98	4.78	
FL	55.9	0.59	0.44	2.37	3.40	6.1
GA	44.8	0.43	0.11	3.73	4.26	9.5
LA	68.3	0.89	0.13	2.22	3.23	4.7
MS	25.1	1.05	0.16	3.01	4.22	16.8
NC	34.3	0.95	0.07	3.02	4.04	11.8
SC	NA	0.41	0.04	2.01	2.46	
TN	30.3	1.21	0.09	2.15	3.45	11.4
TX	173	6.49	7.94	1.91	16.3	9.4
VA	35.0	0.70	0.12	2.49	3.31	9.5
Sum	505	15.1	9.4	29.4	53.9	
Average						9.3

rates of forest biomass (76 Tg C/year) and the potentials for soil carbon sequestration (53.9 Tg C/year), the overall annual terrestrial carbon sequestration potential in the region could amount to 130 Tg C/year, offsetting 22.3% of the total greenhouse gas emission in the region. This is in agreement with earlier estimates of the US terrestrial carbon sequestration potential. Houghton et al. (1999) and Holland et al. (1999) reported that terrestrial carbon sequestration in the US due to land management could offset 10–30% of US fossil fuel emission.

Among the 11 states included in this assessment, Texas has the highest potential for terrestrial carbon sequestration (16 Tg C/year) due to large contributions from both croplands (6.5 Tg C/year) and grasslands (7.9 Tg C/year) (Table 5). Forestland contributes most of the sequestration potential (4–5 Tg C/year) computed for Alabama, Arkansas, Georgia, Mississippi, and North Carolina (Table 5). The huge area of histosol in Florida is currently an important C sink, but may become a significant carbon source if cultivated. Further study is required to assess the effects of cultivation on the carbon source/sink dynamics in histosol.

Various management practices can be employed for achieving and increasing the potential for terrestrial carbon sequestration (Bruce et al. 1999; Cole 1996). Reduced tillage and no-tillage, use of winter cover crops, improved crop nutrition and yield enhancement, reduction of summer fallow, proper crop rotation, improved varieties, irrigation, application of animal waste and organic manure, and amendments are the most effective practices for cultivated cropland (Lal et al. 1998, 1999). For grassland, improved grazing regimes, fertilizer application, and irrigation are among the efficient management practices. Various conservation reserve programs could greatly increase the potential for carbon storage. Reforestation, reestablishment of perennial grasses, and erosion-prevention practices (including grassed waterways, shelterbelts and riparian belts) could be applied in revegetated or set-aside land (Bruce et al. 1999). Amendment and reclamation of mined land and degraded land through revegetation with fast-growing crops and grasses, reforestation, application of fertilizer and organic amendments, and drainage could considerably increase the potential for carbon storage. Therefore, the potential carbon gains from adoption of each of these practices and technologies at the state levels of the region require further careful study.

4 Conclusions

Total greenhouse gas emission in the South-Central region of the US is estimated to be 504 Tg C/year with Texas (149 Tg C/year), Louisiana (59 Tg C/ year) and Florida (47 Tg C/year) being the largest contributors. Forest growth represents a sink of 76 Tg C/year and thus could offset 13% of the regional total annual greenhouse gas emission. Through proper policies and best land management practices, an additional 9.3% could be offset by terrestrial sequestration (54 C/year). Combining current annual forest growth and the soil C sequestration potential, the overall annual terrestrial carbon sequestration potential of the region could amount to 130 Tg C/year, offsetting 22.3% of the region's total greenhouse gas emission. Mississippi could have 48% of its annual greenhouse gas emission potentially offset by its annual terrestrial carbon sequestration. In Florida, Louisiana and Texas, the offset capacity is only 15% of the annual emission. Compared to other sinks (such as geological sequestration and ocean sequestration), terrestrial carbon sequestration is a temporary sink. Nevertheless with proper management, healthy terrestrial ecosystems could serve as large carbon sinks and a cost-effective CO_2 mitigation alternative for the region. Terrestrial carbon sequestration plays an important role in mitigating greenhouse gas emission from the region and in reducing the rate of CO_2 accumulation in the atmosphere.

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