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Can a Golf Course be Carbon Neutral? A Preliminary Assessment

Green house gases (GHG) are in the news and pressure is mounting in Congress to pass legislation to regulate GHG emissions. The Washington Post reported on March 10th that the Senate would vote on legislation in June that will set restrictions and ultimately cap US emissions of GHG. The legislation is expected to impose a cap-and-trade system similar to systems in other world markets where carbon offsets or emissions certificates must be purchased for any carbon emissions over an established cap. Many banks and other investors are scrambling to invest in carbon offsets as legislation is expected to boost the price of U.S. credits from \$2 to \$5 per ton of carbon to \$30 to \$50 a ton.

Clearly, major utility and industrial firms will fall within the scope of any regulations. How far will the mandates reach? What are the consequences if golf courses, sports fields, and public parks would be required to assess and control GHG emissions? Turf management has increasingly improved environmental stewardship through improvements in water quality protection, reduction in water use, and increased efficiencies in fertilizer and pesticide use. How does a golf course figure into the GHG discussion?

A project was undertaken by students enrolled in the Advanced Turfgrass Science Class at Cornell University to establish the carbon budget for the operation of a golf course in a northeast climate. The course was considered to be an average course from the GCSAA Environmental Profile Research with total golf course property of 150 acres with 100 acres or managed turf to calculate the energy or Carbon Equivalents (CE) for management factors including mowing, fertilization, pest control, and irrigation. (Table 1.)

Several months were spent to review available literature to establish the relative contribution of a golf course to carbon sequestration. Would a golf course be a better sink for atmospheric CO2 than a parcel under agricultural management, a typical urban lot, or a forest system? In particular, is a woodlot a better carbon sink than turf? If so, can a golf course offset its carbon use by increasing the density of trees and total wooded area or simply pass along the cost of carbon offsets to the golfer through green or membership fees?

In the final summation, can a golf course be carbon neutral? How does the operation of the course affect the carbon balance? In our example we are using data generated from the Bethpage State Park Green Course that has been managed experimentally for eight years. This study has compared traditional management relying primarily on synthetic fertilizer and pesticides

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This Times

New York State Turfgrass Association

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Feature Story

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applied without restriction to a bio-based IPM management system choosing reduced risk pesticides and overall reduced fertilizer use.

Table 1. Average 18-hole golf course profile based on 2007 GCSAA data.	
GCSAA Survey Typical Course	**150**
Greens	3
Tees	3
Fairways & Turf Nurseries	31
Rough	51
Driving Ranges & Practice Area	7
Clubhouse Grounds	3
Acres Managed Turf	98
Forest/Woodland (38.2% of 24)	9.0

Calculating Carbon Budgets

The energy consumed for agricultural production was summarized extensively in the 1970's and 80's with an emphasis on fuel consumption. The first USDA benchmark study was immediately after the oil-price shock of 1973-74 and the oil embargo of 1973. (Dovring, 1985). The figures presented in a number of journals and reports were criticized as representing only the direct energy of operating equipment or as direct (factory) energy inputs into the production of materials. Dovring (1985) contends that many reports neglected to account for the indirect or "embodied" energy implicit in the material components particularly with regard to the manufacture of fertilizers and pesticides. While the emphasis may still be on the accounting of limited oil resourses, the focus now is also on the carbon (C) consumed and/or emitted as a greenhouse gas.

To assess the carbon inputs in golf, consideration was given to the direct energy that was expended such as the gas to operate the mowers and the electricity to power the irrigation system. The direct energy could also be obtained by totaling the fuel consumed over the year and power metered for battery charging, irrigation and shop operation.

It is not clear how legislation will assess carbon use and emissions. Therefore, all energy embodied in the fertilizers and pesticides are counted including the manufacturing inputs, direct energy, formulation, packaging and transport. There is considerable data for the embodied energy in agricultural inputs reported in the Energy in Agriculture report. (Fluck, 1992). This report is a synthesis of the available information on energy use in farm operations, and its conversion into CE units; that a principal advantage of expressing energy use in terms of carbon emission as kg CE lies in its direct relation to the rate of enrichment of atmospheric concentration of CO2. (Lal 2004). (Table 2.)

Equipment Energy

The direct energy inputs on the golf course were based on course management over an eight-month season. Greens and tees were hand-mowed; fairways were cut with lightweight five-plex mowers and the rough was cut with a 20-foot wide area mower. Calculations were made for weed trimming and rotary mowing edges around the rough once each week. A boom sprayer was used for fertilizer and pesticide applications except for a small amount of manual spreader applications. The energy input calculated from available fuel consumption statistics is shown in Table 3.

Table 2. Carbon emission coefficients, different fuel sources and the energy conversion units (Fluck, 1992) (Lal,20)	
Equivalent carbon emission (kg CE)	
Diesel	0.94
Gasoline	0.85
Oil	1.01
LPG	0.63
Natural Gas	0.85
Energy Units	
Million Calories (Mcal)	93.5 x 10
Gigajoule (GJ)	20.15
BTU	23.6 x 10
Kilowatt hour (kW h)	7.25 x 10
Horsepower	5.41 x 10

Irrigation Energy

The energy for irrigation depends on the pumps used, the distribution system, the pressure and the lift required. The 100 acres of maintained turf averaged 0.5" of water per week over the entire season (32 weeks) or a total of 47,357,012 gallons. Assuming ideal distribution and 70% pump efficiency, 1.46kWh are needed to lift 325,851 gallons of water one vertical foot. (Peacock, 1998) With 200 feet of lift from a deep well or pond, 42,437 kWh or 3.1 metric tons

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How to be smart about carbon: #1

Use the most efficient equipment to minimize hours of operation and fuel efficient engines. Most engines are rated on gas consumption per hour on the basis of the horsepower of the engine. Check your suppliers. Wider cutting widths will have a significant impact. (Suppliers need to get on board with published data)

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How to be smart about carbon: #2

Nitrogen has the highest embodied energy of all the fertilizers and that energy varies by the form of nitrogen fertilizer. Choose carefully. All fertilizer elements, N, P and K, each have significant energy formulations as do micronutrient packages. Design a suitable fertilizer program based on your turf requirements. Anything more is costly.

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of CE per year is required to pump the needed water for the entire season.

Farm irrigation was reported as 125-285 kg ha-1yr-1. (Lal, 2004) This equates to a range of 5.5 - 12.6 t of CE for the 109-acre course. Metering the pump house will provide a more accurate number for the irrigation system.

Fertilizer and Pesticide Energy

Most fertilizers are reported as the production energy equivalent per pound or kilogram of N, P2O5, K20 and active ingredient (AI) for the pesticides. Dovring (1985) reported that many of these reports do not report all of the direct and indirect energy associated with the product manufacturing. (Dovring, 1985) The values reported vary considerably (Lal 2004).

In the absence of a standard convention, the selection of data appropriate for a turf application is difficult at best. The assessment for this study is based on weighted averages for agricultural applications. (West and Marland 2002). This data included energy of formulation into emulsifiable oils, wettable powders or granules for the pesticides. However they did not include them in the fertilizers. An additional 0.4 kg CE/kg is required for formulation. (Green, 1987). A summary of fertilizer and pesticide applications relative to carbon emission and cost comparing two management systems is shown in Table 5.

Carbon Sequestration from Turfgrass

In general, any activity that increases plant growth will increase carbon sequestration. Carbon will be stored in the biomass of the plant or within the soil matrix. Photosynthesis will convert CO2 and transfer carbohydrates to stems, branches and roots. Carbon will also be deposited on and in the soil in the form of litter; detritus and soil carbon will increase notably as soil organic material (SOM). There is a soil respiration affecting Soil Organic Carbon (SOC), which is really the respiration of microorganisms and the decomposition of biomass. Respiration is a function of temperature, water and nitrogen. (Kimble et al. 2003)

SOM and SOC will have an initial loss after tillage or disturbance. After conversion to urban use, the SOM and SOC will increase over time. The greatest increases have been observed in the most highly managed soils. For example, SOM in a golf course fairway was 1.76% one year after turfgrass planting, 3.8% after 20 years, and 4.2% after 31 years (Qian & Follet, 2002). Work by Monsieur et al (2005) and Robertson et al (2000) concluded that highly managed urban soils such as irrigated turfgrass are better than urban soils at net removal of greenhouse gases. Their calculations included net CO2, N2O and CH4 emissions associated.

Qian and Follet (2002) report that turfgrass carbon sequestration is 1 ton C ha-1yr-1. The measurements were taken in the west, an arid

Table 4. Production energy equivalent per pound or kilogram of N, P_2O_5, K_2O and active ingredient (AI) for the pesticides

N	0.86	+0.4	=1.26	Kg CE/Kg N
P_2O_5	0.17	+0.4	=1.57	Kg CE/Kg P_2O_5
K_2O	0.12	+0.4	=0.52	Kg CE/Kg K_2O
Herbicide	4.7			Kg CE Active Ingredient
Insecticide	4.9			Kg CE/Kg AI
Fungicide	5.2			Kg CE/Kg AI

Table 3. Energy input calculated from available fuel consumption statistics

Operational Carbon Input	Total Hrs/Yr Machine Opera-tion	Gals/hr	Fuel Con-sumed (Gal)	Fuel Con-sumed (kg)	kg CE per kg fuel	Carbon Equiva-lent (kg CE)	Carbon Equiva-lent (t ce yr1)
Mowing							
Mowing Rough-Batwing	611	4.5	2748.8	9367	0.94	8805.3	8.8
Mowing Rough - Rotary	121	1.5	182.2	517	0.85	439.8	0.4
Line Trimming Rough	146	0.5	72.9	207	0.85	175.9	0.2
Mowing Fairways	903	3.8	3385.1	9613	0.85	8171.0	8.2
Mowing Greens	1032	1.5	1547.3	4394	0.85	3735.0	3.7
Mowing Tees	754	1.5	1130.3	3210	0.85	2728.3	2.7
Fertilizer & Pesticide Application							
Greens	99.0	3.8	371.3	1265	0.94	1189.2	1.2
Fairways & Tees	140.3	3.8	525.9	1792	0.94	1684.7	1.7
Total Fuel			**9963.8**			**26929.1**	**26.9**

climate that would show lower SOC and SOM. They noted that turfgrass was on par with land placed in the Conservation Reserve Program (CRP). This program was set up in the 1985 and 1990 Farm Bills to convert highly erodible land (HEL) to permanent vegetative cover. Additional information on CRP is available (Lal, et al., 1999).

Additionally, Qian (2003) further specifies contributions from various golf turf features for 12 golf courses in the Denver area and one in Wyoming. Greens were reported to sequester an average of 0.4 t C ha-1yr-1(0.99 t C ha-1yr-1) and fairways at 0.44 t C a-1yr-1 (1.09 t C ha-1yr-1). Furthermore, Qian indicates fairways constructed from previous agricultural land had 24 percent less SOM than fairways converted from grasslands.

Pouyat et al (2006), in a study of urban soils of several cities across the United States, confirmed that SOC in residential lawns are relatively high and of low variability compared to other non-wetland soil types in urban areas. The SOC of Northeastern cities is higher than other cities due to the cooler and wetter climate

Table 5. Summary of fertilizer and pesticide applications relative to carbon emission and cost comparing two management systems.

Traditional Mgmt.		**kg ce**	**t ce yr-1**	**cost**
Fertilizer	Greens	459	0.5	3,863
	Tees	494	0.5	3,958
	Fairways	2,520	2.5	13,609
	Rough	4,716	4.7	12,810
	Total	8,189	8.2	$34,240
Pesticides	Greens	482	0.5	10,407
	Tees	532	0.5	8,789
	Fairways	1,288	1.3	33,403
	Rough	211	0.2	610
	Total	2,513	2.5	$53,209
Grand total		**10,702**	**10.7**	**$87,449**
Bio-Based IPM Mgmt.		**kg ce**	**t ce yr-1**	**cost**
Fertilizer	Greens	583	0.6	7,527
	Tees	272	0.3	3,579
	Fairways	2,703	2.7	8,029
	Rough	1,415	1.4	3,843
	Total	4,973	5.0	$22,978
Pesticides	Greens	507	0.5	13,488
	Tees	318	0.3	8,340
	Fairways	1,798	1.8	39,418
	Rough	0	0.0	0
	Total	2,623	2.6	$61,246
Grand Total		**7,596**	**7.6**	**$84,224**

and the inherent SOC from pre-urban soils that were heavily forested lands.

The relevance to golf courses is that managed turf is better at carbon sequestration than other urban (suburban) developed areas. Therefore, using 0.4 t C a-1yr-1, the 109 acres of managed turf in the example for this paper will sequester 44 t C yr-1.

Carbon Sequestration from Trees

There is some controversy on the measured net contribution of agroforestry to carbon sequestration. For example, younger, faster growing trees sequester more carbon than older mature trees. The differences are partly in the measurement methods. Studies show that factors such as stand density, water availability and fertilization are significant factors. Sequestration is also a function of species and mixed stands may be better than monostands. (Kimble et al 2003)

Most studies are done on tropical forests. Watson et al, (2000) report carbon sequestration at rates of 0.2 to 3.1 t C ha-1yr-1. In a review by Pataki, annual sequestration rates identified by Nowak and Crane (2002) ranged from 0.26 x 10-9 MtCm-2 (2.6 t C ha-1yr-1) for average forest cover in Atlanta to 0.12 x 10-9 MtCm-2 (1.2 t C ha-1yr-1) cover in New York, with a median value of 0.2 x 10-9 MtCm-2 (2.0 t C ha-1yr-1) cover. (Pataki, D., et al, 2006).

At the median level 2.0 t C ha-1yr-1, trees are much better at carbon sequestration than turfgrass. Any course with a significant portion of the property as woodland, will have an advantage in their carbon balance.

Calculation Results

For the purpose of this class exercise we totaled the direct and indirect carbon energy for machine operations, irrigation, fertilizer and pesticides. For the course evaluated, a total of 40.7 t of carbon was used in a year. Fuel accounts for between 66 percent and 72 percent of the total carbon emission.

The golf course used in this exercise offset the carbon emitted between 115 and 125%. Surprisingly there is little difference between the two management systems with both systems by our calculations and our assumptions indicating the course used in our example is in fact carbon neutral and likely to a provide significant sequestration.

Discussion

The carbon assessment provides an interesting perspective for shaping the activities

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How to be smart about carbon: #3

Based on calculation methodology, pesticides are based on the percentage of active ingredient. Use chemicals with the lowest % AI per acre for recommended effectiveness.

How to be smart about carbon: #4

Managed turf is a carbon sink. Trees are an even greater carbon sink. Native vegetation and grassland is neutral.

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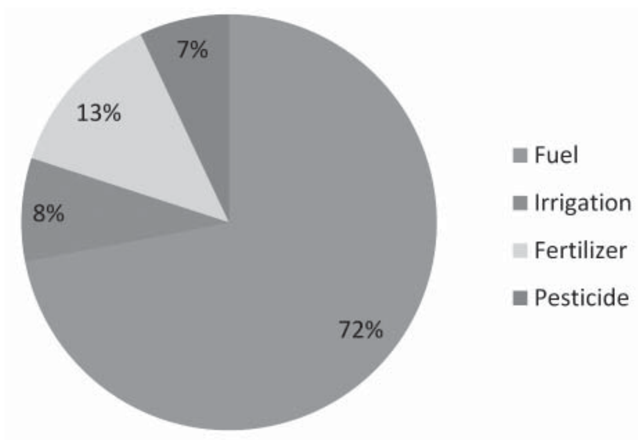
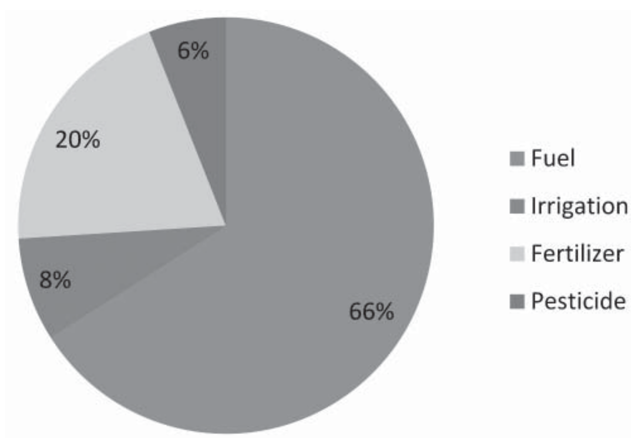
Carbon Input

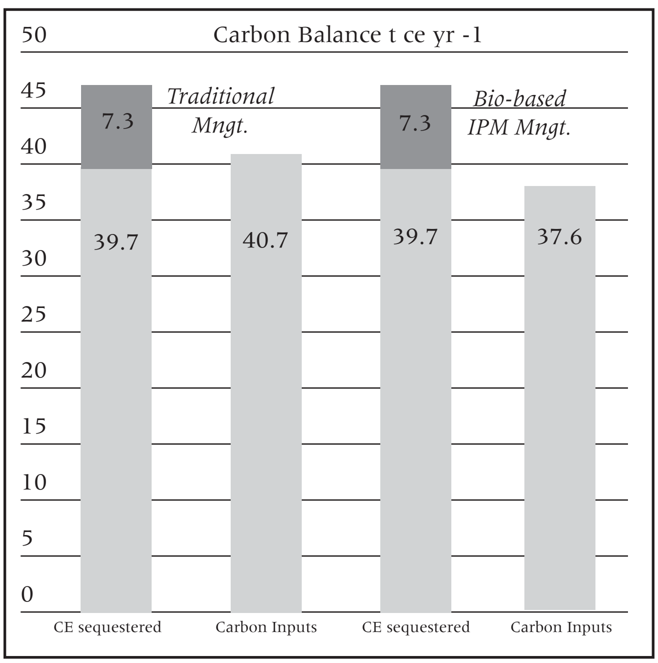
Bio-based IPM Mgmt. T ce yr-1



Carbon Input

Traditional Mgmt. t ce yr-1





and the choices made in managing a golf course in a climate sensitive world. For example, when selecting a mower, fuel-efficient equipment may be measured in hrs per gal or in terms of the gals per acre managed for that particular piece of equipment. Wide area mowers are larger pieces of equipment but can get they get the job done faster and with less overall fuel. What is the carbon efficiency?

From our calculations it appears that fuel use is the most important aspect of management. From a product perspective the bio-based IPM programs can help reduce the dosage as well as the number of applications. Alternative products can be selected to be equally effective while reducing the overall carbon input. As the industry is already selecting chemicals with lower environmental risk, selection of pesticides might also be made on a "Carbon Index". Perhaps, legislation will lead to developing such carbon indexes as part of the EPA labels so that we can make informed decisions on the proper selection of chemical inputs.

Truly there is one aspect of this work to consider: the "Carbon Footprint" that is made in operating a golf course. The greater question is on managing a golf course to minimize its Greenhouse Gas Emission.

It is imperative that we identify this issue in our work and discussions. Golf operations are significant emitters of greenhouse gases. Carbon dioxide may be the least of the GHG's. Emissions standards at SETAC included all environmental outputs to the air, the soil and the water. The largest of these is nitrous oxide. Other NOx, POx and SOx oxides are also important factors. Given the degree of fertilization and volatility of some nitrogen fertilizers, nitrous oxide may be a greater contributor to GHG.

The studies referenced in our readings have a range of values for embodied energy. All that data is outdated. There is a lack of information for modern day pesticides and there is question to the methodology that researchers used to determine their values. The chemical manufacturers have to step up and provide the information.

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