Saito, Dr., Osamu
Assistant Professor
Waseda Institute for Advanced Study, Waseda University
3-4-1 Okubo, Shinjuku, Tokyo 169-8555, JAPAN

Measuring the Lifecycle Carbon Footprint of a Golf Course and Greening the Golf Industry in Japan

Intended category: Beyond today's infrastructure

Abstract: Currently, approximately 35,000 golf courses exist globally. In Japan, there are over 2,400 golf courses that are developed mostly in rural areas. This study focuses on measuring the lifecycle greenhouse gas carbon footprint (CF), which would help in developing effective environmental management strategies. The lifecycle inventory assesses land preparation, course development and maintenance, equipment for turfgrass maintenance, clubhouse construction and operation and transportation used by golfers including golf carts. We found that in Japan the lifecycle emissions of a typical golf course with 18 holes are 39,188 t-CO_2 for 30 years, and carbon sequestration by the forest and planted trees in the course accounts for 16,944 t-CO_2 during the same period. Depending on the quantity and frequency of fertilizer use, fertiliser-derived N_2O emissions may overcompensate for the CO_2 uptake. In addition, management of the existing forest within a course can positively or negatively impact the CO_2 sink. The paper proposed measures to minimize CF: improving the energy efficiency of the equipment, the clubhouse facilities and the vehicles; maximizing CO_2 uptake by reducing forest loss; promoting reforestation and practicing sound forest management.

1. Introduction

Land-use change is influenced not only by local needs, but also by local urban demands and remote economic forces. Urban expansion occurred at the expense of farmlands and forests, and is currently highest in developing countries (UNEP, 2007). Recreation in the countryside has also been a cause of land-use changes and a source of controversy over balancing between rural economic development and environmental conservation (Bell, 2000). In Japan, large-scale resorts were developed on rural hills and mountains, often replacing local farmers who managed an essential part of the traditional agricultural system called *satoyama* (Takeuchi et al., 2002). From the late 1980s to 1990s, there were protests in Japan regarding the destruction of the local landscape for the development of resorts, especially golf course development (Yamada, 1990; Matsui, 2003). Similar problems caused by golf course development have occurred not only in developed countries (Balogh and Walker, 1992), but also in newly industrialized countries including China (Richards, 2010). However, reliable data pertaining to golf course development are scarce at the global level.

On the other hand, as in other industries, greening, i.e. embedding environmental considerations into industrial processes, products and services is considered as an effective management strategy essential for the survival of the tourism industry (Bramwell and Lane, 1993; Harris et al., 2002). It was acknowledged that tourism growth could no longer continue without addressing its major impacts (Berry and Ladkin, 1997). Hammond and Hudson (2007) discovered that there was a considerable interest in environmental concerns amongst golf course managers in the UK. In Japan, in a similar context, Greenery by Golfer Group (GGG), whose members are golf club managers, golfers, government agencies and scientists, has been promoting environmental conservation and nature restoration including reforestation. However, studies on lifecycle greenhouse gas (GHG) emissions, which would serve as a base for planning effective mitigation measures, have not yet been conducted for a golf course.

Therefore, the aim of this paper is to (i) summarize the recent increase in the number of golf courses at the global scale, (ii) assess the lifecycle GHG emissions of a golf course as its carbon footprint (CF) and (iii) identify key factors and measures for more effective environmental management of golf courses.

2. Golf Course Growth

How many golf courses have been built in the world? There is no official statistics to answer this question. Gange et al. (2003) described that globally there are over 25,000 golf courses, and Golf Research Group (2000) reported a total of 30,730 courses in 119 countries and 57 million golfers. In 2008, Ikki-Shuppan, which publishes a monthly journal of golf management in Japan, found that there are 32,300 courses in 198 countries and regions, based on a survey conducted in cooperation with golf associations in each country and region (Ikki-Shuppan, 2008). In addition, the WorldGolf website (http://www.worldgolf.com/) provides extensive course guide information for courses in over 100 countries.

The author integrated available lists provided by WorldGolf.com and the world list made by Ikki-Shuppan (2008). The result indicates that in 2008 there were over 35,100 golf courses globally (Fig. 1). The USA accounts for 50% of the global total, and the top five countries (USA, UK, Japan, Canada and Australia) account for 76%.

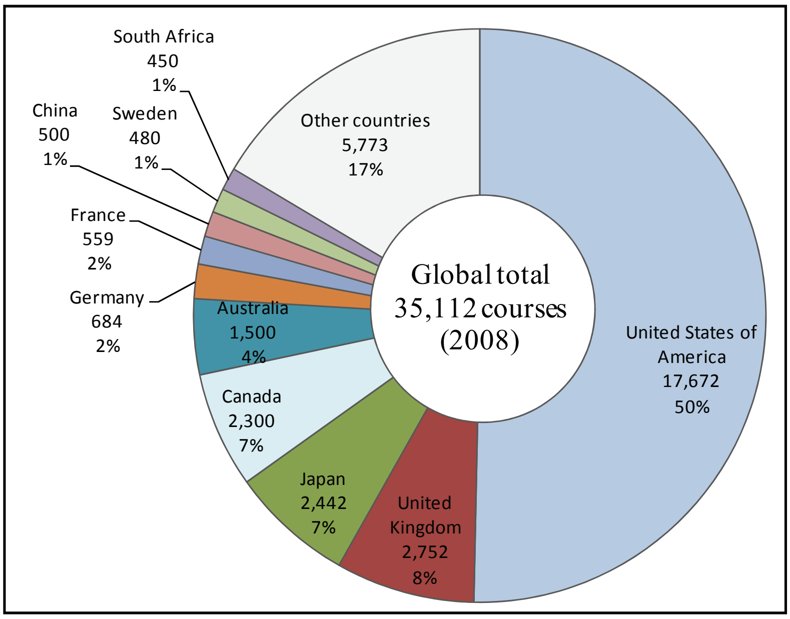

Figure 1. Number of golf courses in the world

It is estimated that an 18-hole golf course requires approximately 50–60 hectares (ha) of land (Gössling, 2002). Assuming an average size of 50 ha per 18-hole golf course worldwide, and taking into account the global composition of 6-hole, 9-hole, 18-hole, 27-hole, 36-hole, 45-hole and 54-hole courses (Ikki-Shuppan, 2008), the golf courses worldwide may cover at least an area of 17,238 km^2, an area equivalent to the size of Kuwait. Golf courses cover a mere 0.14% of the global arable land and permanent cropland (The World Bank, 2010), and 0.06% of the global forest area (The World Bank, 2010). However, if golf course development in developing countries continues hand-in-hand with their economic development, golf courses would cover a few percent of the forest and agricultural land, and increasingly compete with those land use types.

In Japan, there are over 2,400 golf courses, most of which have been developed in rural areas. The golf courses in Japan occupy 0.6% of the total land area (Saito, 2009). Following the burst of Japan's economic bubble in the late 1980s to early 1990s, many existing golf courses had to make tough management decisions, and some were forced to close (Saito, 2008).

3. Assessment of the Lifecycle Carbon Footprint (CF)

3.1. Methodology

In this study, the lifecycle CF was measured by analyzing documentation collected on golf course development specifications and by interviewing managers and greenkeepers. The lifecycle inventory considered land preparation, course development and maintenance, equipment for turf maintenance, clubhouse construction and operation and transportation used by golfers including golf carts (Fig. 2, Table 1). In general, golf course vegetation is treated as a carbon sink, while other inventory items are a source of GHG emissions. Due to the lack of reliable data and examples, the CF of closing phase is not assessed in this study (Fig.2).

Although there are many golf courses that operate for more than 30 years, this study considers 30 years as the course lifecycle. This duration was chosen because managers who were interviewed indicated that a golf course and clubhouse are often renovated more or less 30 years after they were built. The study assumes that all assumptions and emission factors used for the assessment in Table 1 would not change for the 30-year life of the course.

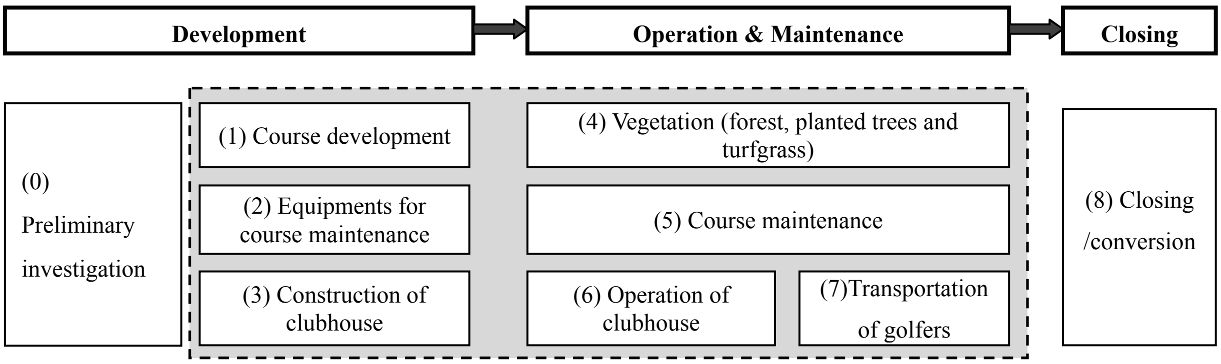

Figure 2. Lifecycle inventory of a golf course

: Inventory items in the grey area with dashed line are measured in this study

Table 1. Lifecycle inventory structure of a golf course and the assumptions for CF assessment

Lifecycle Inventory	Inventory items	Assumptions for CF assessment (18-hole course)	Source	Eq.
1. Course development	1-1. Land preparation	Survey, logging work, treatment of logged trees (chipping)	a	(1)
	1-2. Stormwater management work	Grid chamber, drainage, regulating ponds	a	(1)
	1-3. Ground work	Removal of soil surface on the course, cutting earth and embankment, rough formation of course, land leveling	a	(1)
	1-4. Course construction	Green construction, nursery construction, tee construction, banker construction, fairway construction, rough construction	a	(1)
	1-5. Placing turf grass	Green turf, tee turf, fairway turf, rough turf, turf sand	a	(1)
	1-6. Drainage work	Drainage (drainpipe, drainage work of the surrounding area)	a	(1)
	1-7. Effluent processing facilities	Effluent pumping and treatment facility, and piping work	a	(1)
	1-8. Maintenance road construction	Construction of maintenance road, bridge, drainage ditch, etc.	a	(1)
	1-9. Access road and parking construction	Permeable pavement work, U-shaped gutter, buried drain piping	a	(1)
	1-10. Water supply facilities	Watering and supplying drinking water facilities	a	(1)
	1-11. Electric facilities	Substation facilities, outdoor lights	a	(1)
	1-12. Planting trees	2,120 tall trees (H = 3-4m), 3,820 semi-tall trees (H = 2-3m), 7,720 shrubs (H = 1m)	a	(1)
	1-13. Ancillary facilities	Fences around the course, road relocation, management of remained forest, fire prevention water tank, etc.	a	(1)
	1-14. Turf grass management	Turf grass management of green, tee, fairway and rough	a	(1)
	1-15. Temporal works	Temporary road, temporary water supply facilities and so on.	a	(1)
	1-16. Forest loss due to course construction	Change in forest area before and after the course construction	Table 2	(1)
	1-17. Carbon stock of planted trees	2,120 tall trees (H = 3-4m), 3,820 semi-tall trees (H = 2-3m), 7,720 shrubs (H = 1m)	a	(1)
2. Equipments for course maintenance	2-1. Equipments for course maintenance	3 green mowers, 1 fairway mower, 2 rough mowers, 1 sweeper, 1 spray vehicle for herbicide and fertilizer and 3 pickup trucks	b,c	(1)
	2-2. Golf carts	65 golf carts per 18-hole course	b,c	(1)
3. Clubhouse construction	3-1. Clubhouse construction	Steel-reinforced concrete (SRC) construction with gross floor area of 2,500 m^2	b,c	(1)
4. Vegetation (forest and planted trees)	4-1. Carbon sequestration by forest	40.9 ha forest	Table 2	(3)
	4-2. Carbon sequestration by planted trees	13,660 planted trees	a	(3)
5. Course maintenance	5-1. Mowing (green, tee, fairway and rough)	5,000 liter gasoline/yr and 5,000 liter diesel/yr	c	(2)
	5-2. Spaying herbicide and fertilizer	Fuel consumption by spaying equipments is included in 5-1. Carbon emissions from herbicide and fertilizer production are taken into account	c	(1)
	5-3. Supplemental planting	30 trees/yr	b	(1)
	5-4. Course renewal	Every 30 years	c	(1)
6. Clubhouse operation	6-1. Gas	27,514 m^3/yr	b	(2)
	6-2. Electricity	360,000 kWh/yr	b	(2)
	6-3. Water	18,000 m^3/yr	c	(1)
	6-4. Sewage treatment	18,000 m^3/yr	c	(1)
	6-5. Waste (food waste, etc)	18t/yr	b	(1)
7. Transportation of golfers	7-1. Passenger vehicle use of golfers to access golf course	35,000 golfers/yr, 1.5 golfers/passenger vehicle, 80 km (driving distance)/passenger vehicle, 10km/liter(gasoline mileage)	b, c	(2)
	7-2. Use of golf cart	35,000 golfers/yr, 10,000 rounds/yr (3.5 golfers/round), 1 liter gasoline/round(18 holes)	b, c	(2)

(Source) a. From the planning documents of a new golf course development in Chiba prefecture, Japan (S. Kurihara, personal communication, January 7, 2010). The course was planned in 2009 and is under construction in 2010.
b. From the interview with golf course manager and greenkeeper in Tochigi prefecture, Japan (January 14, 2010).
c. From the interview with golf course manager and greenkeeper in Chiba prefecture, Japan (January 18, 2010).
(Equation) Eq. (1)–(3) are explained in the text.

Table 2 indicates the land use composition of the golf course for this assessment. The land use prior to development is based on the planning documents of a new golf course development in Chiba Prefecture, Japan (S. Kurihara, personal communication, January 7, 2010). Changes from the forest area to the golf course are considered as forest loss in the assessment. The value used for the total land area and most of the components associated with a golf course are the result of averaging these parameters for the courses found throughout Japan (Ikki-Shuppan, 2010).

Table 2. Land use composition of the golf course for CF assessment

Phase		Land use types	Area (ha)	Percentage	Note and source
Golf course site		Total land area	86.40	100.0%	Average in Japan (n = 898) Ikki-Shuppan (2010) *The Greenkeeper 2010*.
	Prior to the development	Arable land	8.64	10.0%	The planning documents of a new golf course development in Chiba prefecture, Japan
		Forest	77.76	90.0%	
	After the development	Tee	1.18	1.4%	Ikki-Shuppan (2010) *The Greenkeeper 2010*.
		Fairway	12.89	14.9%	
		Rough	27.13	31.4%	
		Green	1.53	1.8%	
		Banker	0.60	0.7%	From the interviews with golf course managers and greenkeepers in Tochigi and Chiba prefectures, Japan
		Pond	0.20	0.2%	
		Parking	0.70	0.8%	
		Clubhouse and other buildings	1.30	1.5%	
		Forest	40.87	47.3%	The difference between the total area and the summation of other land use types except forest
	Forest loss		36.89	42.7%	77.76(ha) - 40.87(ha)

The following three equations are used to calculate the lifecycle CF. The relationship between inventory item and equation is identified in Table 1.

$$CF_p = \Sigma_i (C * EF_p), \qquad (1)$$

where CF_p is price-based carbon footprint (t-CO_2), C is cost (JPY) of the inventory item, EF_p is price-based CO_2 emissions factor (t-CO_2/million JPY) and i is inventory item. EF_p is available for about 400 commodity sectors from the Embodied Energy and Emission Intensity Data (3EID) for Japan using Input-Output Tables developed by NIES (http://www-cger.nies.go.jp/publication/D031/eng/index_e.htm). The average price of equipment for golf course maintenance, such as green mowers, is taken from the yearbook of golf course materials and equipment (Ikki-Shuppan, 2009).

$$CF_e = \Sigma_i (E * GCV * EF_e), \qquad (2)$$

where CF_e is energy-based carbon footprint (t-CO_2), E is energy consumption (kg, l, m^3), GCV is higher calorific value (MJ/kg, MJ/l, MJ/m^3) and EF_e is energy-based CO_2 emission factor (t-CO_2/MJ). E is collected by interviewing managers and greenkeepers in Japan, and GCV and EF_e are obtained from the *National Greenhouse Gas Inventory Report of Japan 2010* (GHG Inventory Office, 2010).

While the equations above are for calculating carbon emissions, equation (3) addresses carbon sequestration by forests.

$$CF_{sq} = - \Sigma_j (A * SQ)*44/12 \qquad (3)$$

where CF_{sq} is carbon footprint by carbon sequestration (t-CO_2), A is area of forest (ha), SQ is annual carbon sequestration (t-C/yr) and j is forest type. A is obtained from the interviews with greenkeepers and from Table 2, and SQ is obtained from the research conducted by the Forestry and Forest Products Research Institute, Japan (FFPRI, 2010).

3.2. Results

We found that in Japan the lifecycle (30 years) emissions of a typical golf course with 18 holes are 39,188 t-CO_2, and carbon sequestration by the forest and planted trees in the course accounts for 16,944 t-CO_2 (Table 3). This means 43.2% of the emissions are offset by carbon sequestration owing to vegetation (Fig. 3), and the net CF is 22,224 t-CO_2. If we divide this net CF by 30 years, annual CF would be 741 t-CO_2/yr, which is equivalent to an annual GHG emission from 147 households in Japan (GHG Inventory Office, 2010).

Of the total emissions, course development, clubhouse operation and transportation by golfers are the three largest contributors, accounting for 33.4%, 16.5% and 34.9%, respectively (Table 3, Fig. 3). The breakdown of the CF during the course development phase indicates that CO_2 emissions from forest loss are the largest of the development phase activities (Fig. 4). Course maintenance and clubhouse operation together share 26.7% of the total CF. Although the estimated CF for the transportation of golfers (433 t-CO_2/yr for passenger vehicles and 23 t-CO_2/yr for golf carts) depends on certain assumptions (Table 1), the result suggests that golfer transportation accounts for a significant portion of the total emissions (34.9%).

Table 3. Estimated lifecycle CF of the golf course

Inventory			Cost (million JYP)			CF (t-$CO_{2\text{-eq}}$)		
			Annual	30 years	(%)	Annual	30 years	(%)
	Develop-ment	1. Course development	–	1,931	(30.6%)	–	13,089	(33.4%)
		2. Equipments for course maintenance	–	443	(7.0%)	–	740	(1.9%)
		3. Clubhouse construction	–	363	(5.8%)	–	1,211	(3.1%)
	Operation and maintenance	5. Course maintenance	80	2,400	(38.1%)	133	3,999	(10.2%)
		6. Clubhouse operation	14	428	(6.8%)	215	6,461	(16.5%)
		7. Transportation of golfers	25	738	(11.7%)	456	13,688	(34.9%)
Emission sub-total				6,302	(100.0%)		39.188	(100.0%)
Sequestration		4. Vegetation (forest and planted trees)				−565	−16,944	(−43.2%)
Total cost/ Net emission				**6,302**			**22,224**	

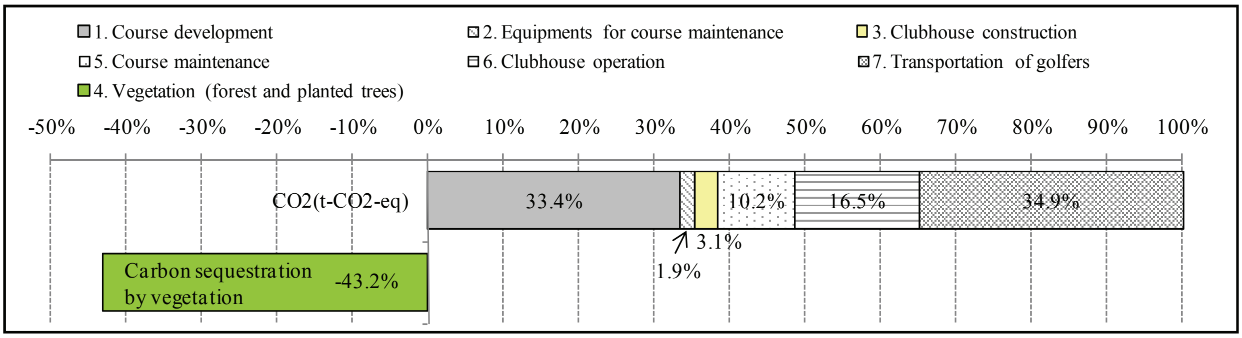

Figure 3. Estimated lifecycle CF of the golf course by inventory proportion

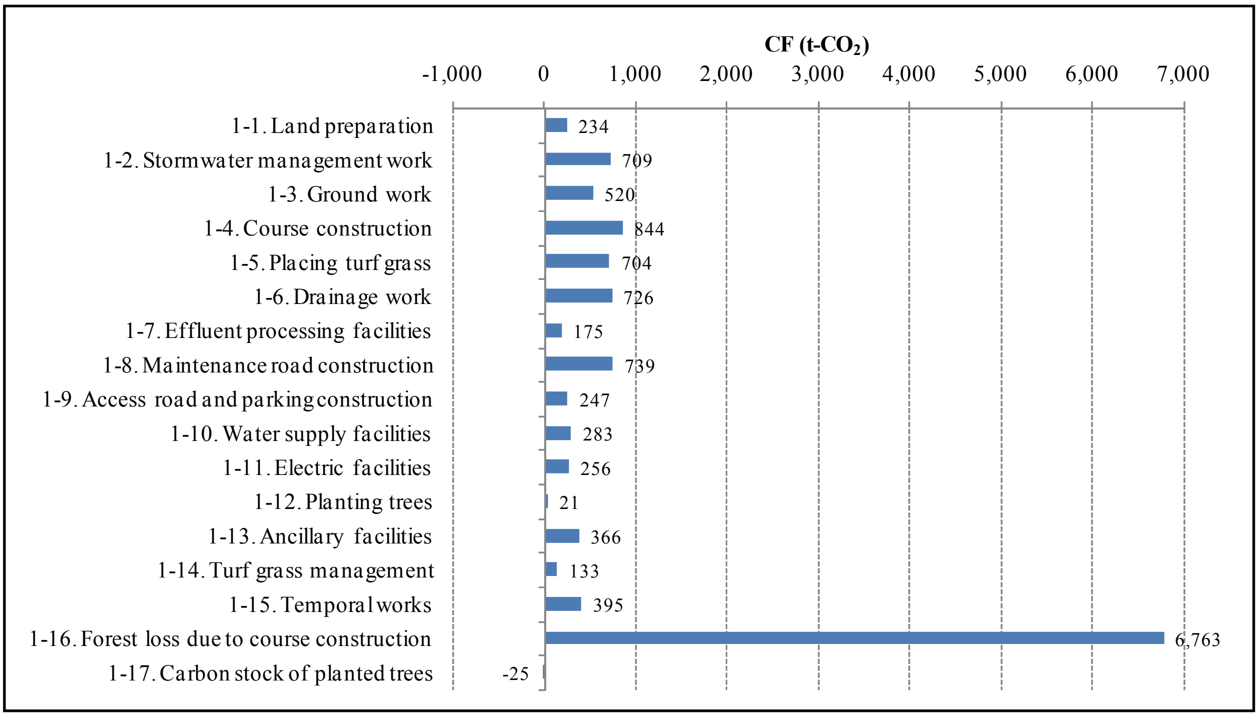

Figure 4. Breakdown of lifecycle CF during course development phase

4. Discussion and Conclusion

Analyses throughout the Global Environmental Outlook 4 (UNEP, 2007) highlight the rapidly disappearing forests, deteriorating landscapes, polluted waters and urban sprawl. Golf course development is seen as one of the symbolic and sensitive issues pitting urban versus rural, nature versus society and environment versus economy. This study estimated that globally around 35,000 golf courses exist currently, of which the top five countries (USA, UK, Japan, Canada and Australia) account for 76% (Fig. 1). The study found that these golf courses cover an area of approximately 17,238 km^2, an area equivalent to the size of Kuwait. Several developed countries have applied stricter regulations including environmental impact assessments (EIAs) for golf course construction and management. However, in developing countries, where course development is being done under the name of economic development, regulations have been relatively loose, such as in China (Richards, 2010). With this trend, the number of golf courses in developing countries will increase over the next decade. Those countries need to introduce not only EIAs and other regulations to protect the local environment, but also assess and manage the CF and carbon offset scheme to reduce the impact on global climate change. In addition, for the existing golf courses in both developed and developing countries, assessing their own CF and reducing it would improve management efficiency and increase the success of differentiated marketing.

This study developed the inventory and methodology for the lifecycle CF assessment (Fig. 2 and Table 1) by using sample golf courses in Japan. The results showed not only the total GHG emissions from a golf course but also the carbon sequestration by forests and planted trees within the course. The net CF for a 30-year lifecycle was estimated to be 22,244 t-CO_2. The breakdown of the inventory contributing to the lifecycle CF was also provided (Figs. 3 and 4, Table 3). The study showed that 43.2% of the emissions may be offset by carbon sequestration by vegetation on the course. However, N_2O emissions associated with frequent use of fertilizers may overcompensate for this CO_2 uptake, depending on the quantity and frequency of fertilization (Townsend-Small and Czimczik, 2010).

Agata (2008) estimated carbon uptake and storage by all vegetation types on a golf course, and showed that in Japan an 18-hole course would absorb 1,684 t-CO_2/yr. This figure is approximately three times larger than that estimated by this study (565 t-CO_2/yr). This discrepancy is because Agata (2008) used net primary productivity (NPP) for his assessment instead of using net ecosystem productivity (NEP), which is significantly smaller than NPP. In addition, Agata (2008) counts carbon uptake and storage by turfgrass; however, this study did not include these aspects because carbon uptake by turfgrass is regularly removed as grass residues (clippings) during the course maintenance and are usually collected for waste disposal or simply left on the turf to decompose naturally.

The English Golf Union provides a tool called the ‘carbon calculator’ on its website (http://www.englishgolfunion.org/) that enables club managers to estimate a club’s CF on the basis of energy and water bills. This tool focuses only on the CF of course maintenance (5) and clubhouse operation (6) in Fig. 2, while this study expands the boundary of the CF assessment to cover the lifecycle of a golf course, and provides a more comprehensive outlook of a golf course’s CF.

Based on the lifecycle CF assessment, following measures should be considered to minimize CO_2 emissions and maximize CO_2 uptake and storage:

(1) The CF resulting from course development can be reduced by minimizing forest loss.

(2) Forest management and tree planting in golf courses can offset carbon loss.

(3) Improving the energy efficiency of equipment used for course maintenance and of the clubhouse facilities can contribute to the reduction in the CF of the operation and the maintenance phase.

(4) Improving gasoline mileage of passenger vehicles and golf carts and promoting ride sharing would contribute to the reduction in golfer’s travelling CF.

This study presented a baseline lifecycle CF of a golf course in Japan. Since a CF labelling scheme has been applied to more and more products and services in Japan (Ministry of Economy, Trade and Industry, 2009), sooner or later the scheme may be applied to the golf industry. At that time, the golf industry should develop a standardized method for the lifecycle CF assessment. In addition, each golf course will need to assess their lifecycle CF by a standardized method to establish a baseline, and subsequently establish various operating scenarios. Future work includes assessing the golf course CF of other countries, improving the assessment methodology and developing a more tailored approach for managers to propose effective measures of CF reduction.

ACKNOWLEDGEMENTS

This study was supported by the program, 'Promotion of Environmental Improvement for Independence of Young Researchers', under the Special Coordination Funds for Promoting Science and Technology provided by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan. I would like to express my gratitude to H. Tezuka, H. Naito, T. Nishimoto, H. Kita, T. Mizuno, S. Kurihara, H. Tanikawa and K. Tani for their valuable discussions and information during the development of this study. I would like to thank the golf course managers and greenkeepers who provided me with valuable data and information for this study.

REFERENCES

Agata, W. (2008) Contribution of Golf Courses to Purification and Warming Prevention of Atmosphere, *Journal of Japanese Society of Turfgrass Science*, *37*(1), 18-26.

Balogh, J.C. and Walker, W.J. (Eds.) (1992) Golf Management and Construction: Environmental Issues, CRC Press LLC.

Bell, J.P. (2000) Contesting rural recreation: the battle over access to Windermere, *Land Use Policy*, *17*, 295-303.

Berry, S. and Ladkin, A. (1997) Sustainable tourism: a regional perspective, *Tourism Management*, *18*(7), 433-440.

Bramwell, B. and Lane, B. (1993) Sustainable tourism: an evolving global approach, *Journal of Sustainable Tourism*, *1*(1), 6-16.

Forestry and Forest Products Research Institute, Japan (FFPRI) (2010) How to measure carbon sink by forest? (in Japanese). Retrieved June 27, 2010, from http://www.ffpri.affrc.go.jp/research/ryoiki/new/22climate/new22-2.html

Gange, C.A, Lindsay, D.E. and Schofield, J.M. (2003) The Ecology of Golf Courses, *Biologist*, *50*, 63-68.

GHG Inventory Office (Eds.) (2010) *National Green house Gas Inventory Report of Japan 2010*. Center for Global Environmental Research, National Institute for Environmental Studies, Japan.

Golf Research Group (2000) The Global Golf Report. Retrieved June 1, 2010, from http://www.golf-research-group.com/reports/index.html

Gössling, S. (2002) Global environmental consequences of tourism, *Global Environmental Change*, *12*, 283-302.

Hammond, R.A. and Hudson, M. D. (2007) Environmental management of UK golf courses for biodiversity — attitudes and actions, *Landscape and Urban Planning*, *83*, 127-136.

Harris, R., Griffin, T. and Williams, P. (Eds.) (2002) *Sustainable Tourism* (Second Edition): *A Global Perspective*, Butterworth-Heinemann.

Ikki-Shuppan (2008) The Number of Golf Courses in the World, *Monthly Journal of Golf Management*, No.300, Ikki-Shuppan, Tokyo, Japan. Retrieved June 1, 2010, from http://www.mmjp.or.jp/tubaki-golf/newsfail/2008/0725-sekaigolf.html

Ikki-Shuppan (2009) *Yearbook of Golf Course Materials and Equipment 2009* (Extra Number of *Monthly Journal of Golf Management*), No.310, Ikki-Shuppan, Tokyo, Japan.

Ikki-Shuppan (2010) *The Greenkeeper 2010* (Extra Number of *Monthly Journal of Golf Management*), No.317, Ikki-Shuppan, Tokyo, Japan.

Matsui, K. (2003) *Golfjo haizanki* (in Japanese), Fujiwara-Shoten, Tokyo, Japan.

Richards, G. (2010) Inclusion in the 2014 Olympics feeds a boom time for golf in China, *Guardian*, March 6, 2010.

Saito, O. (2008) Restructuring existing rural resorts as a sustainable infrastructure for basin socio-ecological systems in Japan: A case of redundant golf courses in the Tokyo Metropolitan Area, *Proc. 3rd Int. Conf. on Sustainability Engineering and Science*, Auckland, December 8-12, 2008.

Saito, O. (2009) Environmental and Economic Scenario Analysis of the Redundant Golf Courses in Japan, *World Academy of Science, Engineering and Technology*, *58*, 593-599.

Takeuchi, K., Brown, R. D., Washitani, I. and Yokohari, M. (Eds.). (2002) *SATOYAMA - Traditional rural landscape of Japan*. Springer.

The World Bank (2010) *2010 World Development Indicators*, Washington, D.C., USA.

Townsend-Small, A. and Czimczik, C.I. (2010) Carbon sequestration and greenhouse gas emissions in urban turf, *Geophysical Research Letters*, *37*, L02707.

UNEP (2007) *Global Environmental Outlook 4: environment for development*.

Yamada, K. (Eds.). (1990) *Golf jo boukoku ron* (in Japanese), Fujiwara-Shoten, Tokyo, Japan.