Using assessment of net ecosystem services to promote sustainability of golf course in China

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ABSTRACT

Golf courses have been shown to have a positive impact on local biodiversity, quality of life and the economy. However, the impacts of golf courses on local environment, including ecosystem services and dis-services are not clearly understood. To explore this relationship, we took two golf courses in Beijing (a links course and a parkland course) to develop an assessment framework and present estimates of economic values of net ecosystem services, in aspects of ecosystem goods, carbon fixation, soil retention, flood storage, recreation, water consumption and nonpoint-source pollution. The results showed that the two golf courses have provided remarkable net ecosystem services values (links 51.58×10^4 yuan/ha/yr, parkland 42.60×10^4 yuan/ha/yr, 6.19 yuan = 1 US\$ in 2013). Over 95% of this value is generated by three services: recreation, ecosystem goods and flood storage. Our results indicate that the parkland course has better performance in sustainable supply of ecosystem services than the links course. In addition, this study provides useful improvements for golf course design and management concerning positive environmental externalities optimizing, including the scaling of non-playing areas to maximize golf course ecosystem services supply capacity, appropriate grass species selecting and irrigation with recycled water. Moreover, a policy analysis suggests that the development of public golf course in China is a necessary complement to resolve the mismatch between private and public benefits and let more people enjoy the ecosystem services.

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1. Introduction

Golf is a popular sport for hundreds of years. Now there are over 32,000 golf courses around the world (NGF, 2005). The number of golf courses in Europe is more than 5800, and 2600 of them are in British, accounting for 7% of the total land area (Tanner and Gange, 2005). Until 2012, more than 600 golf courses have been opened in China (Shen and Kou, 2012). Compared to other independent and natural green space such as forest, the complexity of these man-made ones can not be ignored (Miroslav et al., 2006). Golf courses are usually located in or nearby urban areas, and contribute to public health and increase the quality-of-life of citizens (Maas et al., 2009). Studies showed that golf has a great socio-economic contribution, and still has great potential for development (KPMG, 2008).

Golf courses provided ecosystem services as defined by Millennium Ecosystem Assessment (2005). Large area turfgrass of golf course with effective management practices is able to absorb

and fixed carbon (Bartlett and James, 2011a). In addition, these vegetation provides the capacity to retain more soil than bare land (Rice and Horgan, 2011). The capacity of flood storage in man-made lakes of golf course is of great significance for surrounding urban areas (Bolund and Hunhammar, 1999). Colding et al. (2009) found that man-made lakes in golf course have a more homogeneous species composition than ponds in nature-protected areas and ponds in residential parkland. This study also suggested that golf courses may significantly contribute to wetland fauna support, particularly in urban settings. The housing estates around golf course have become a choice of accommodation to improve human habitation conditions (Nicholls and Crompton, 2005). Golf course benefits people by providing sports facility or tourism destination to improve health while generating employment opportunities and high incomes (Peter, 2007).

Golf players usually prefers to a monoculture of grass species for consistency in playing characteristics and esthetic quality of the surface, which are generated by intensive managements. Obviously, increasing the intensity of management is a strategy for golf course to attract more visitors under this condition. The intensively managed turfgrass areas are subjected to routine applications of fertilizer and agrochemicals to support plant growth and

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maintain esthetic quality, including tees and greens, and fairways (Soldat and Petrovic, 2008). Meanwhile, the negative environmental effects caused by intensive managements will increase, such as nonpoint-source pollution (Haith, 2010), large consumption of water (Diaz et al., 2007) and greenhouse gas emissions (Li et al., 2013). Though the environmental risks of golf courses have become a public focus from 1980s (Cohen et al., 1999), a significant effect to human health has not been found (Michael and James, 2002).

Golf course was introduced to Beijing, China in 1987 and has since expanded dramatically. The number of golf course in Beijing exceeded more than 70 by 2012 and is in continuous rapid expansion (Shen and Kou, 2012). Continued rapid expansion of golf course in Beijing would amplify the magnitude of both ecosystem services (ES) (e.g., ecosystem goods, carbon fixation, soil retention, flood storage and recreation) and ecosystem dis-services (EDS) (e.g., nonpoint-source pollution, large consumption of water). Although there has been much individual research conducted in China to separately investigate carbon fixation, pesticide residues, nutrients application and dynamics, soil erosion and conservation, soil salinization and water consumption (e.g., Lu and Su, 2010; Zhang et al., 2012; Liu et al., 2009; Yuan and Han, 2006; Jiang et al., 2002; Shen and Kou, 2013), studies to date have not comprehensively quantified the ES and EDS from golf course. Because the rapidly expanding golf courses in China may bring environmental benefits as well as risks, an assessment of the economic benefits and all round environmental roles are urgently needed to better understand this anthropogenic system.

At present, for the purpose of protecting the arable land, the central government of China forbids constructing more golf courses, and shut down a lot of golf courses. Many industry insiders have argued that economic loss is not in the national interest, and developing of golf course industry in China directly related to globalization and acceptance of market economy. In order to elucidate the trade-offs at the center of this debate, we carried out this assessment of the ecosystem services of two case golf courses, including ecosystem goods, carbon fixation, soil retention, flood storage, nonpoint-source pollution, and water consumption. The aims of this study were: (1) to estimate the biophysical and economic value of ES and EDS provided by golf course, (2) to provide useful suggestions for golf course managers in order to optimize ES generated from golf course, and (3) to elucidate the mismatch between private and public beneficiaries of ES under land use pattern of golf course.

2. Materials and methods

2.1. Study site

We examined two different types of golf courses in this study, whose architecture and management are typical of most golf courses in Northern China (temperate zone). One was located in Fangshan District, South West Beijing, and opened in 2007, set among deserted Yongding river course, with deep, well drained sandy soils, which readily supports various indigenous small shrubs and tall fescue in the non-playing areas of the golf course (referred to as 'Links'). Another was a 26 year old 'Parkland' course in Shunyi District, North East Beijing, constructed in a forest park with deep well irrigation and drainage system installed under the surface, with interconnected man-made lakes. The types of greens in both courses are fit to United States Golf Association specification (USGA, 2004). In addition, these two golf course are all private, pure membership clubs, which are the main typical operation mode in China.

Management practices are broadly similar on both golf courses. Mowing is carried out almost around a full year from March to November. At both courses, greens and tees are mown using

Table 1

Value system of ES and EDS for golf course in this study.

Type	Services	Indicator
Ecosystem services	Ecosystem goods	Carp fish
	Carbon fixation	Net carbon storage
	Soil retention	Soil protection by erosion
	Flood storage	Water retained by man-made lakes
	Recreation	Visitors to play golf
Ecosystem dis-services	Water consumption	Net consumed water
	Nonpoint-source pollution	Pollutant load

pedestrian mowers with small petrol engines, compared the self-propelled machinery with larger engines using on fairways and roughs. Nutrients are applied mainly in two periods of a year, one during the spring and another during autumn before closure. Organic fertilizers (e.g., seaweed) and synthetic fertilizers (e.g., slow-release manure) were used for turf fertilization. Both golf courses were spray irrigation using pipes networks controlled by computers. Therefore, the ESs of the two types of golf courses were comparable.

2.2. Indicator system

The value system of ES and EDS for golf course is shown in Table 1. We quantified five ES (ecosystem goods, carbon fixation, soil retention, flood storage and recreation) and two EDS (nonpoint-source pollution, water consumption). Because of lack of data or effective evaluation method, some other EDS (e.g., pesticide pollution) were analyzed qualitatively in this study.

The value assessment process of ES and EDS for golf course is divided into two steps: biophysical values calculation and economic values evaluation. The first step is based on up-scaling with the help of statistical data. Golf courses are human-dominated systems, and therefore the ES and EDS provided by these systems are influenced by a series of external inputs, such as agrochemicals and water. In this study, sufficient and systematic data about these inputs are available due to detailed records. Therefore, the second step transforming biophysical values to economic values is the key point for evaluation. This step usually requires to use some special economic techniques, which will be revealed in following calculations. At last, total net economic benefits were calculated as the algebraic summing of all ES (the values are positive) and EDS (the values are negative) and were used to represent the economic value of ES provided by golf course.

We paid specific attention to the calculation of carbon fixation for golf course systems, because the range of operations or processes in the management of golf course that result in CO₂ emissions is wide. Therefore, to address the research questions, we also calculated CO₂ emissions from golf course boundaries following the methods of Bartlett and James (2011a,b). There were additional carbon discharge from mowing, agrochemical application, fertilizer application and irrigation. Emissions from the production of fertilizer and agrochemicals were also taken into consideration.

2.3. Data collection

For this study, the area of various components of each golf course was obtained from the original data of design and construction through the owners of corresponding golf course. Information about management practices of golf course were gathered from interviews with superintendents. The superintendent at each course supplied detailed records of mowing and aeration frequency and machinery use, agrochemical and fertilizer applications and irrigation scheduling for their facilities over the 2013 annual

cycle. Data and coefficients associated with some ES and EDS were obtained from current literatures with field measurement. Prices and exchange rate data are based on Chinese currency (RMB) in 2013. Price values were discounted to the study period using the general index of retail prices of China when prices for the year were unavailable.

2.4. Valuation approach

2.4.1. Ecosystem goods

A large amount of grass clippings are generated after mowing in golf course. Because grass clippings can be used as a high quality food source for some fish, the both two golf courses in this study stock grass carp (*Ctenopharyngodon idellus* [Cuvier et Valen.]), together with a small quantity of bighead carp (*Hypophthalmichthys nobilis* [Richard.]) and common carp (*Cyprinus carpio* L.) in the man-made lakes to clear up the clippings and keep the pond clear of weeds as well. These fish should be taken to represent as ecosystem goods of golf course. The workers usually net these fish every late autumn and the average output (t/yr) was calculated based on the records of fish yield for each golf course. Ecosystem goods value is estimated by the market price method as:

$$V_f = M_f * P_f \quad (1)$$

where V_f is the ecosystem goods value (yuan/yr), M_f is the average yield of fish of the man-made lakes (t/yr), P_f is the average price of fish (yuan/t). Assuming all carp species fetched the same price, the average market price of grass carp was 1.2×10^4 yuan/t in 2013 (MAC, 2013).

2.4.2. Carbon fixation

For the golf course, the amount of carbon fixed by vegetables and sequestered by soil was calculated based upon a modified life cycle analysis (LCA) by Dalgaard et al. (2001) and Ammann et al. (2009). Based on a simple mass balance equation, the dynamics of the carbon fixation was estimated by emissions from maintenance and the turfgrass sequestration capacity for the whole golf course system (Eq. (2)).

$$T = R - S \quad (2)$$

where T is the carbon fixation of a particular golf course, R is the carbon emissions from maintenance, included emissions of C from mowing, agrochemical application, fertilizer application and irrigation, and S is the total C sequestered by the plant-soil system. All the above parameters are component in t/yr CO₂ (details of methods, see Bartlett and James, 2011a,b).

The value of carbon fixation by golf course is based on the carbon price method (Fankhauser, 1995). The carbon price has been frequently used in evaluating the economic loss caused by carbon emissions for research and international negotiation (Tol, 2010). The equation was used as follows:

$$V_C = 3.67 \times T \times P_C \quad (3)$$

where V_C is the value of carbon fixation (yuan/yr), 3.67 is a standard conversion factor transforming mass of elemental carbon to CO₂ (44/12), T is the same as in Eq. (2), P_C is the carbon price rate per unit weight (yuan/t CO₂). According to the widely accepted carbon price of 22.78 US\$/t CO₂ set in 2011 by US government to reduce emissions of greenhouse gasses (Bell and Callan, 2011) and based on the currency exchange rate of 6.46:1 between RMB and US\$ in 2011, the carbon price in 2011 was estimated at 147.16 yuan/t CO₂. Therefore, the carbon price can be converted into 154.91 yuan/t CO₂ in 2013 at comparable price to China's consumer price indices.

2.4.3. Soil retention

The amount of soil retention was estimated by the difference between potential soil erosion and real soil erosion (Guo et al., 2001; Bini et al., 2006). Thus, the soil retention service provided by golf course emerge as a decrease in soil erosion for covered land respect to non-covered lands, using the following equation:

$$Ac = \sum_i S_i * (Ap_i - Ar_i) \quad (4)$$

where Ac is the amount of soil erosion reduced by a particular golf course (t/yr), S_i is the area of the i th patch (ha); Ap_i and Ar_i are the potential soil erosion and real soil erosion of the i th patch, respectively (t/ha/yr). In this study, unlike the links course is mainly covered by grass, there are density trees in the non-playing area of the parkland course. The real soil erosion expressed from grass and forest areas with identical slopes approximated the contribution to erosion reduction was defined by Yang et al. (2004) with the potential soil erosion simultaneously.

The economic value of soil retention was estimated as the avoided cost of restoring soil where erosion might occur (Morri et al., 2014). Such a contribution was multiplied by the average cost for transporting and restoring a unit volume of soil and divided by the average soil density, as expressed in Eq. (5):

$$V_s = C_s \times \frac{Ac}{D_s} \quad (5)$$

where V_s is the value of soil retention (yuan/yr), C_s is the cost for transporting and locating a unit volume of soil, Ac is the same as in Eq. (3), D_s is the soil density (1.4 t/m³) of the study area. It cost 12.6 yuan/m³ for transporting and locating soil in 2002 (Wang et al., 2008), which can be converted into 17.3 yuan/m³ in 2013 at comparable price to China's consumer price indices.

2.4.4. Flood storage

The flood storage service provides flood control ability and water recover from drought period (Posthumus et al., 2010). Man-made lakes are the main flood storage facilities in the golf course. We assumed that the water storage capacity of the man-made lakes represented the maximum potential regulation, and such amount of water fluctuation was estimated as:

$$W_s = \sum_i S_i \times h \quad (6)$$

where W_s is the flood storage capacity of the golf course (m³), S_i is the area of the man-made lake (m²). h is the maximum change in water level of the man-made lake, and it is set at 0.8 m.

Economic evaluation of the flood storage service was calculated similarly to Guo et al. (2008), using the shadow engineering method. It is based on the cost of constructing a reservoir which would fulfill the same water control function, which can be expressed as follows:

$$V_s = C_w \times W_s \quad (7)$$

where V_s is the value of flood storage (yuan/yr), W_s is the same as in Eq. (6), C_w is the average cost of reservoir constructing per unit storage volume (yuan/m³). C_w is adopted from Wang et al. (2008) as 6.11 yuan/m³ in 2005, which was estimated at 7.83 yuan/m³ in 2013.

2.4.5. Recreation

The recreation resources of golf course are mainly the esthetically pleasing landscape suitable for playing golf. The current private economic benefits of golf course is mostly from exploitation of these resources. In this study, we adopted the travel cost method to estimate the recreation value of golf course derived from

playing golf based on the number of visits per year. This method distinguishes two main, non-overlapping components of value: direct expenditure by visitors and consumer surplus (Wells, 1997). Compared to the consumer surplus, direct expenditure by visitors reflect the monetary value of benefits to stakeholders more obviously and is more practical for assessment (Farber et al., 2002). Therefore, the value of recreation of golf course can be calculated as follows:

$$V_r = (V_1 + V_2 + V_3) \times N \quad (8)$$

where V_r is the value of recreation of golf course (yuan/yr), V_1 is the travel cost, including transportation, food, green fee and service charges. According to personal communication with the customer service manager of each golf course, golf players of both golf courses are mainly from Beijing. Assuming travel time is one day, each player pays 100 yuan for travel, 100 yuan for food and other services, 550 yuan (the links course) and 500 yuan (the parkland course) for green fee. V_2 is the travel time expenditure – assuming each player has a daily pay of 500 yuan. V_3 is caddie tips expenditures – 100 yuan for each player. N is the total annual amount of players.

2.4.6. Water consumption

Maintaining a golf course requires large amounts of water (Salgot et al., 2012). This is sufficient rainfall in wet areas, which can satisfy the turfgrass's demand (Diaz et al., 2007). But in Beijing as drought area, additional water is compensated for the lack of natural rainfall. Water consumed by golf course can reduce water available to agricultural production. We estimated the economic losses of water consumption by golf course based on the amount of irrigation water as:

$$V_w = I_w \times p \quad (9)$$

where V_w is the economic losses of water consumption by golf course (yuan/yr), I_w is the amount of irrigation water (not including the water pumping from man-made lakes, m^3/yr), p is the water price (yuan/ m^3), defined by the Beijing local government as 2.30 yuan/ m^3 in 2013 (BMCDR, 2013).

2.4.7. Nonpoint-source pollution

Fertilizer and agrochemicals applied on golf course can become nonpoint-source pollutants if the turfgrass land is not managed well (Haith, 2010). The nutrient balance method can be used to estimate the nonpoint-sources pollutant load of chemical fertilizer (Borin et al., 2005). Due to limited data, the present study only considers nitrogen fertilizer and its pollutant load. Using this method, we calculated the nitrogen load as:

$$F_r = \sum_i F_i \times C_i \times I_r \quad (10)$$

where F_r is the total amount of nitrogen load (t/yr), F_i is the annual amount of the i kind of nitrogen fertilizer applied (t/yr), C_i is the average percentage of nitrogen of the i kind applied fertilizer, I_r is the ratio of the applied fertilizer losses due to runoff (30% N, Zhang et al., 2010).

Logically, the non-point source pollution may lead to economic losses in many ways, including fishery, travel, water use for daily life, water use for industry and human health. The external cost of nitrogen fertilizer was 3.81 yuan/kg estimated by Lv and Cheng (2000). Therefore, economic losses of nonpoint-source pollution was calculated as follow equation:

$$V_r = F_r \times C_N \quad (11)$$

where V_r is the economic losses of nonpoint-source pollution (yuan/yr), F_r is the same as in Eq. (10), C_N is the external cost of nitrogen fertilizer, which was estimated at 5.27 yuan/kg in 2013.

Table 2

Annualized inputs parameters and the C emissions from each golf course.

	Links		Parkland	
	Inputs	C emissions ^a (kg)	Inputs	C emissions (kg)
Insecticide (kg)	54	266.2	66	325.4
Fungicide (kg)	832	4309.8	934	4838.1
Nitrogen fertilizer (kg)	1285	938.1	2069	1510.4
Phosphorous fertilizer (kg)	142	8.5	193	11.6
Potassium fertilizer (kg)	951	38.0	1257	50.3
Diesel (t)	2.5	1725	3.1	2139
Petrol (t)	1.2	756	1.4	882
Electricity (kWh)	770	115.5	820	123
Total		8157.1		9879.7

^a Constants used to estimate the C emissions from each input on the golf course are based on those recommended by Bartlett and James (2011a,b).

3. Results

3.1. The value of ecosystem goods

According to the field surveys, the average yield of fish in the man-made lakes of each golf course in 2013 was 50.5 t and 84.0 t, respectively. According to the average market price of grass carp was 1.2×10^4 yuan/t in 2013, the direct value of ecosystem goods of each golf course produced in 2013 was estimated at 60.6×10^4 yuan and 100.8×10^4 yuan, respectively.

3.2. The value of carbon fixation

The total annual C emissions from each golf course in 2013 were estimated at 8157.1 and 9879.7 kg/yr C, respectively (Table 2). The C emissions from the parkland course were larger than those from the links course. On these surfaces emissions from fungicide application were the largest (due to high application amounts and the large greenhouse gas effect). The second majority emissions were from the use of diesel with the smallest emissions deriving from phosphorous fertilizer. The C sequestrations were assumed to be constant among surfaces and therefore the C sequestrations were estimated depending on the surface area (Table 3). The C sequestrations were greater from trees area on both courses, compared to the turfgrass area, which results in sequestrations from the parkland course (101,912.0 kg/yr C) were approximately seven times greater than the links course (15,349.7 kg/yr C). According to assessment the C emissions and sequestrations in the golf course, the total carbon fixation was 7192.6 kg/yr C and 92,032.3 kg/yr C by the links and parkland, respectively.

Using the US government carbon price of 22.78 US\$/t CO_2 , the total value of carbon fixation for the golf course was approximately 4089.13 yuan/yr for the links course compared with 52,322.18 yuan/yr for the parkland course.

Table 3

Area of each golf course component and C sequestration by them.

	Links		Parkland	
	Area (ha)	C sequestration ^a (kg)	Area (ha)	C sequestration (kg)
Tees	0.8	255.9	1.0	319.9
Fairways	10.8	3455.0	13.6	4350.8
Greens	1.1	351.9	1.4	447.9
Rough	18.7	5982.3	28.3	9053.4
Trees	0.5	1381.2	31.4	86,741.1
Other	21.6	3923.3	5.5	999.0
Total		15,349.7		101,912.0

^a Constants used to estimate the C sequestrations from each area of the golf course are based on those recommended by Bartlett and James (2011a,b).

Table 4

Soil retention values in the land cover types for the golf courses.

Type	Real soil erosion*(t/ha/yr)	Potential soil erosion (t/ha/yr)	Course A (t/yr)	Course B (t/yr)
Grass	2.1	5.0	91.1	128.5
Trees	1.3	5.0	1.9	116.2
Others	1.5	5.0	75.6	19.3
Total			168.5	263.9

Constants used to estimate the soil retention by each area of the golf course are based on those recommended by Yang and others (2004).

3.3. The value of soil retention

The amount of soil retention of each golf course was calculated to be 168.5 t/yr and 263.9 t/yr, respectively (Table 4). The data showed that the better performance in soil retention occurred in the parkland course due to larger area of trees. Based on the local soil density and the cost for transporting and locating a unit volume of soil, the total value for soil retention services was approximately 2082.18 yuan/yr for the links and approximately 3261.05 yuan/yr for the parkland.

3.4. The value of flood storage

In each golf course, the total man-made lakes area is 5.2 ha and 7.8 ha, respectively. Thus, the flood storage capacity of each golf course was approximately $4.16 \times 10^4 \text{ m}^3$ and $6.24 \times 10^4 \text{ m}^3$, respectively. Using the shadow engineering method, the value of the flood storage from Eq. (7) was 32.57×10^4 yuan/yr in the links, while the parkland was 48.86×10^4 yuan/yr in 2013

3.5. The value of recreation

In 2013, the links course received 25,000 players and the recreation value was 33.75×10^6 yuan. Simultaneously, there were 30,000 annual players visiting the parkland course. Using the same approach, the value derived from recreation was estimated to be 39.00×10^6 yuan in this course.

3.6. The value of water consumption

Golf course requires plenty of water because of intensive management. The total amount of water consumed by the links course was less than that of the parkland in 2013 ($23.5 \times 10^4 \text{ m}^3$ vs. $31.3 \times 10^4 \text{ m}^3$). Then the economic loss of water consumption in golf course was 54.05×10^4 yuan and 71.99×10^4 yuan, respectively.

3.7. The value of nonpoint-source pollution

Given that nitrogen fertilizer applications in each golf course were 1285 kg and 2069 kg in 2013, respectively. Meanwhile, it caused 385.5 kg and 620.7 kg of N flow into surface water, respectively. Based on the external cost of nitrogen fertilizer, total external environmental cost of agricultural non-point source pollution was 2031.59 yuan and 3271.09 yuan, respectively.

3.8. The economic value of ecosystem services and dis-services

Added together, our estimates showed that the overall net value of ecosystem services resulting from golf course was 34.15×10^6 yuan and 39.83×10^6 yuan, respectively. We distinguished ES and EDS values per unit area presented in Table 5. Among all the calculated categories of ES, the recreation services provided the highest economic value for both golf courses with values exceeding 40.00×10^4 yuan/ha/yr. The economic value of regulating ES were estimated at 5013.2 yuan/ha/yr and

Table 5

Economic value of ES and EDS for golf course.

Item	Economic value (yuan/ha/yr)	
	Links	Parkland
Ecosystem services	523,986.0	433,713.2
Ecosystem goods	9154.1	10,780.8
Regulating services	5013.2	5820.1
Carbon fixation	61.8	559.6
Soil retention	31.5	34.9
Flood storage	4919.9	5225.7
Recreation	509,818.7	417,112.3
Ecosystem dis-services	8195.3	7734.5
Water consumption	8164.7	7699.5
Nonpoint-source pollution	30.7	35.0
Total net economic value of ES	515,790.6	425,978.7

5820.1 yuan/ha/yr, respectively. The economic values of water consumption and nonpoint-source pollution caused by the links course were 8164.7 yuan/ha/yr and 30.7 yuan/ha/yr higher than those of the parkland course, respectively. The total net economic values of ecosystem services generated from golf course were 515,790.6 yuan/ha/yr and 425,978.7 yuan/ha/yr, respectively.

4. Discussion

Our study shows that the two golf courses have provided remarkable values generated from the net ecosystem services. Compared to the results 9548.77 yuan/ha/yr of an average value for a mix of ecosystem services provided by forests in Beijing (Xie et al., 2010), the outcomes of this study were much greater. For the five ecosystem services we assessed, recreation service was the most important ecosystem service of golf course, accounting for 97.3% and 96.2% of the total values of ecosystem services, respectively. Recreation service is closely interrelated with the private economic benefits of land owners. Driven by the relatively high economic return compared to traditional cropland type, golf courses have expanded nearly 50 times increase from 1990 to 2012 in China (FMG, 2013). Among the other ecosystem services, ecosystem goods and flood storage were the two main ecological function of both golf courses. The scale and type of man-made lakes are critical in determining the ecosystem goods and flood storage capacity of whole-course. With more man-made lakes, values generated from these two services for the parkland course were higher than those for links course (Table 5). Because the net carbon fixation amounts of turf on a per hectare basis are far less than those of trees, the value of carbon fixation calculated in the links course was obviously smaller than those in the parkland course. In most papers, the value of carbon fixation is usually the main value of green space ecosystem services (Jim and Chen, 2009; Xie et al., 2010; Lovell and Taylor, 2013), but not in golf course due to vegetation type and intensive management.

The two evaluated EDS (i.e., water consumption and nonpoint-source pollution) are both environmental drawbacks of golf course, which are directly caused by the intensive management of turfgrass (Diaz et al., 2007; Haith, 2010). The amount of water consumed in the parkland course was higher than that in the links course as a result of larger area of greens and fairways. At the whole-course

scale, the much larger non-playing area without irrigation means that despite having a relatively small water consumption on a per hectare basis, the value of this EDS in the parkland course was less than that in the links courses contrarily (Table 5). Of course, relatively larger area of man-made lakes in the parkland course captured more rain water and reduced the water consumption. The average of nitrogen applied for the turfgrass area (including greens, tees and fairways) in the parkland course was 129.3 kg/ha/yr N, higher than that N application in the links (101.2 kg/ha/yr N), and much higher than the fertilizer N recommendations for golf course in similar condition (73 kg/ha/yr N, Mankin, 2000). This suggests that there is an urgent need to improve the efficiency of fertilizers application, especially in the parkland course.

The parkland course, which has higher productivity and carbon fixation efficiency, has a promising future for its good performance on flood storage and retaining soil. Moreover, larger non-playing area in the parkland course can offer more significant cushioning effect to the EDS than the links course. Based on the above results and analyses, it can be established that compared to the links course, the parkland course is more environmental friendly.

Unlike natural ecosystems, golf courses are distinctive ecosystems relying on intensive management and resource inputs by human, which reflect the ecosystem services from golf course are relative and adjustable. This also means human can control and adjust the ecosystem services of a golf course through means such as land use planning and management practices. For a golf course, non-playing area accounts 40 to 70% of its total area (Minelli et al., 2008). But trees in this area can fix more carbon and protect the soil better per unit area, comparing with turf area (Nowak and Crane, 2002; Qian and Follett, 2002; Yang et al., 2004). To make the carbon fixation and soil retention services provision more valid, recommendations to increase non-playing area are directly applicable. Besides, there is potential to increase fish production and flood storage capacity of golf course if more man-made lakes are built as water barrier and isolation strip between fairways.

The choice of species and cultivar of turfgrass in playing area is another important consideration to regulate the ecosystem services. Compared to zoysiagrass (*Zoysia japonica* Steud.), using Kentucky bluegrass (*Poa pratensis* L.) in fairway can achieve better playing surface. This situation is based on frequent close mowing, continuous irrigation and high nitrogen application rates (Bartlett et al., 2008). These management practices will increase the risk of environmental pollution: Lawnmower is a main carbon emission source in golf course; high nitrogen application rates cause high pollutant load; large water consumption makes the golf course become the focus of public attentions. In order to attract more members to play golf, both of the golf courses in this study choose bluegrass as fairway grass. This phenomenon is very common in pure membership clubs of China. From the perspective of keeping the ecosystem services of golf course sustainable, course design should reduce the size of the maintained area of a golf course, especially in non-playing areas. Moreover, to save water and reduce the application of fertilizers, recycled water can be used instead of piped water in golf course (Candela et al., 2007).

This study shows how many ecosystem services can be supplied by golf course, and then the question arises as to how the public enjoy these economic values. The differences between forest and golf course consist in not only the type and value of ecosystem services generated but also the distribution of benefits. Under land use of forest, there is greater societal benefit to a much broader range of stakeholders, including many local citizens with some long-distance visitors. Yet not too much direct economic value was produced by forest, and a sizeable direct subsidy from the taxpayer was used to forest protection. Under land use of golf course, just people living around the course and workers in course gain the majority of the ecosystem service benefits provided by the site.

Besides, a lot of tax accrue to the local government. Golf players are also beneficiaries, but the number of this group is much smaller due to costing more money compared with visitors to forest. This mismatch between private and public benefits can be reflected in policy making about golf course. In China, golf course construction was encouraged before 2004 under the policy of attracting investments, but imposed half restrictions after 2004 due to the policy for arable land and environment protection, and then got permission in the name of tourism development in 2009, before totally forbidden in 2011. At present, up to 23% of the tax rate is imposed on the golf courses of China, which make the finance of these golf courses face large pressure.

Golf courses provide valuable green space in urban, it will be proposed in this study to promote the construction and management of golf courses. In addition, with the rapid development of China, more and more people are interested in playing golf and getting close to the nature in the course. Golf club membership is at 10% annual consumer population ratio growth in the past 5 years (FMG, 2013). However, the existing tax policy has resulted in high green fee and consumer demand limit. In this case, public golf course may be a solution. In developed countries, such as the US, the government provides cheap or free land to build public golf course, where the local citizens can play at a very low price (Richard and Faircloth, 1995). Unlike private golf course, the public golf course relies mainly on government support. Therefore, more civilians will enjoy the pleasure of playing golf, as well as ecosystem services of golf course are better off contributing to public constantly and closely. In any case, valuation assignment is not the ultimate goal of the study. We hope that in the decision-making process of government, enough attention should be given to these services produced by golf courses. In this sense, the economic valuation of ecosystem services for golf course is just a useful starting point.

5. Conclusions

The study identified and quantified ecosystem services (ecosystem goods, carbon fixation, soil retention, flood storage and recreation) and ecosystem dis-services (water consumption and nonpoint-source pollution) generated by two typical golf courses (links and parkland) in Beijing. A conservative estimate of the economic benefits generated by the links golf course was 51.58×10^4 yuan/ha/year, while the same value for the parkland was 42.60×10^4 yuan/ha/year. The most important three ecosystem services of the golf course were recreation, ecosystem goods, and flood storage. Recreation value accounted for more than 95% of the total value of ecosystem services of both golf courses. The management measures for golf course also generated ecosystem dis-services. However compared to the positive values of ecosystem services, these negative values were much smaller. As a unique type of urban green space, golf course provides people with ecosystem services that have brought huge ecological benefits. Further more, the parkland course has shown to be a more environmental friendly land use pattern than the links course.

From the perspective of keeping the ecosystem services of golf course sustainable, recommendations for golf course design and management include the scaling of non-playing areas to maximize golf course ecosystem services supply capacity, appropriate grass species selecting and irrigation with recycled water. Besides, improving the management efficiency and operation quality are also important. Most golf courses in China are in the face of finances pressure due to policy to suppress and high rate tax. To get substantial ecosystem services from golf course and let more people to participate in playing golf, the development of public golf course is an effective solution.

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