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Ecosystem Services at Permata Sentul Golf Club in Bogor Regency

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Abstract

Golf courses are green open spaces created for golfing recreation with dominant vegetation in the form of grass. In Indonesia, as one form of green open space landscape, golf courses are widely criticized for their development, resulting in fragmentation and loss of wildlife habitat, two significant causes of biodiversity loss. To address the problem, the golf industry is moving towards more sustainable golf course management to support Sustainable Development Goal 13 on climate change. Through this study, Permata Sentul Golf Club (PSGC) in Bogor Regency, Indonesia was selected to be studied and analyzed to determine its ability to maintain and utilize ecosystem services. PSGC was a natural forest ecosystem in a hilly area that has now been converted into golf course because of a land conversion process without much change to the original condition. This golf course consists of 25% tree-covered rough areas and 54% open areas for gameplay. Located in Tangkil Village, a rural area with extensive rice fields, the course occupies 8% of the village's area. The average air humidity at PSGC is 70.3%, with an air temperature of 27.7°C. Trees at PSGC can store 19.83 tons/ha of carbon, which is included in the low category with carbon absorption of 1.33 tons/year/ha. The dominant tree vegetation types on the PSGC golf course are *Mimusops elengi, Acacia mangium,* and *Schefflera actinophylla*. Through the presence of the PSGC golf course, its contributions include providing a microclimate and diverse vegetation, which help create a cooler urban environment and serve as a habitat for various wildlife. However, its carbon storage capacity is still relatively low compared to other green open spaces, especially primary forests. Based on the research findings, strategies can be implemented to optimize the ecosystem services provided by the PSGC golf course. These strategies include enhancing collaboration with various stakeholders from governmental and non-governmental organizations and educating both internal and external parties about the importance of working together to support environmentally friendly programs on the golf course.

Keywords: biodiversity, carbon cycle, ecosystem services, golf course, microclimate

1. Introduction

Urban areas often need more green space. The urbanization process causes the loss of natural vegetation, posing a threat to specialist species and resulting in the decline and extinction of several wildlife species [1]. Specialist species refers to species that have special adaptations to live in a particular ecosystem and are usually not found elsewhere. These species often have habitat needs and are vulnerable to environmental changes. In addition, changes in land cover due to urbanization also threaten the welfare of urban residents [2][2]. Urbanization worldwide has caused as much as 57% of the population to live in urban areas in 2020 and is expected to continue [3]. In the same year, Indonesia had 56.7% of the population living in urban areas. This trend will increase and is expected to reach 66.6% in 2035 [4]. Therefore, prioritizing the preservation of limited green spaces in urban areas has become an important focus in urban planning [5].

Urban planning that prioritizes ecological sustainability often conflicts with social and commercial needs. As a result, efforts to preserve the natural environment to maintain specialist habitats are challenging. Actions to overcome this include integrated urban landscape maintenance and restoration using a combination of public and private green spaces [6-9]. The larger the area preserved, the greater the landscape services produced. A large, semi-private green space in urban areas with communities providing restoration efforts to maintain the local environment is the golf course [5].

As one form of green open space landscape, golf courses have been criticized for their ecological impacts. For example, some golf industries have destroyed large areas of nature by constructing courses. These development activities contribute to fragmentation and loss of wildlife habitat, two significant drivers of biodiversity loss [10-11]. In addition, golf course maintenance requires regular mowing and considerable use of agricultural chemicals. These products, especially fertilizers and pesticides, will likely contaminate air, soil, surface water, and groundwater. Ultimately, this pollution will create areas detrimental to biodiversity [12-13].

To help achieve Sustainable Development Goal 13 on Climate Change, the golf industry has initiated a dynamic towards more sustainable golf course management [14], such as reducing the use of chemical products and the frequency of mowing [15]. In addition, establishing golf courses in urban and suburban areas contributes to limiting urban expansion and intensive agriculture [16], two significant factors in the decline of biodiversity [11]. Golf courses also provide ecosystem services such as a cooling effect in urban environments through the presence of trees and other green spaces [5].

A golf course is one of the green open spaces created for recreational golf sports facilities, with the dominant vegetation being grass. Half of the golf course area consists of intensively managed playing surface areas (tees, greens, fairways, and roughs); the other half generally consists of semi-natural areas. Because of these semi-natural areas, golf courses can provide a variety of habitats (e.g., grasslands, forests, water features, sandy and rocky areas). Maintaining these functional ecological areas can benefit various flora and fauna species [17,18], including rare and endangered species [19].

Bogor City and Regency have more than ten golf courses that continue growing. The existence of these golf courses needs to be studied and analyzed to determine their ability to maintain and utilize ecosystem services. Through this study, the Permata Sentul Golf Club (PSGC) golf course was chosen, which is in Tangkil Village and has 18 holes with a single-track design with nine turns.

PSGC covers a total area of 75 hectares, with 1% consisting of buildings, 1% water bodies, 54% open area for gameplay, 25% rough with tree vegetation, and 20% other areas covered with non-tree vegetation and not part of the main playing area. The research focuses on the 25% area that consists of trees. Located in Tangkil Village, a rural area with many rice fields, PSGC occupies 8% of the area. Its location in a hilly region makes this golf course a place for playing golf and a high-quality recreational space for residents and the surrounding community. Previously, this site was a forest and underwent land-use changes, with part of it converted into a golf course. As a result, the lush forest-like atmosphere can still be felt while playing on this course, as the surrounding environment retains many natural vegetation stands left undisturbed.

Therefore, this study aims to study and analyze the ecosystem services of regulating and supporting functions. The study includes an assessment of flora biodiversity, microclimate regulation, and carbon storage and sequestration capacity (carbon cycle). Furthermore, recommendations for PSGC golf course management based on the utilization of ecosystem services are formulated, which are expected to help maximize the potential for utilizing ecosystem services on the related golf course.

2. Materials and Methods

2.1. Study Location

The research has been done at the Permata Sentul Golf Club (PSGC) golf course on Jl. Permata Sentul Raya, Tangkil, Citeureup District, Bogor Regency, West Java, with an area of 75 ha (Figure 1). The research area focuses on the rough part of the golf course, which has a lot of tree vegetation. The rough area covers 25% of the total, equivalent to 18.75 ha. The PSGC golf course is in a hilly region at an elevation of 200–300 meters above sea level, surrounded by trees, rice fields, and settlements set a bit farther away. The research was conducted from

December 2023 to July 2024 including administrative licensing activities, field data collection, data processing, and preparation of recommendations. Specifically, the field data collection stage was carried out from February to March 2024 during the rainy season and the weather tends to be cloudy.

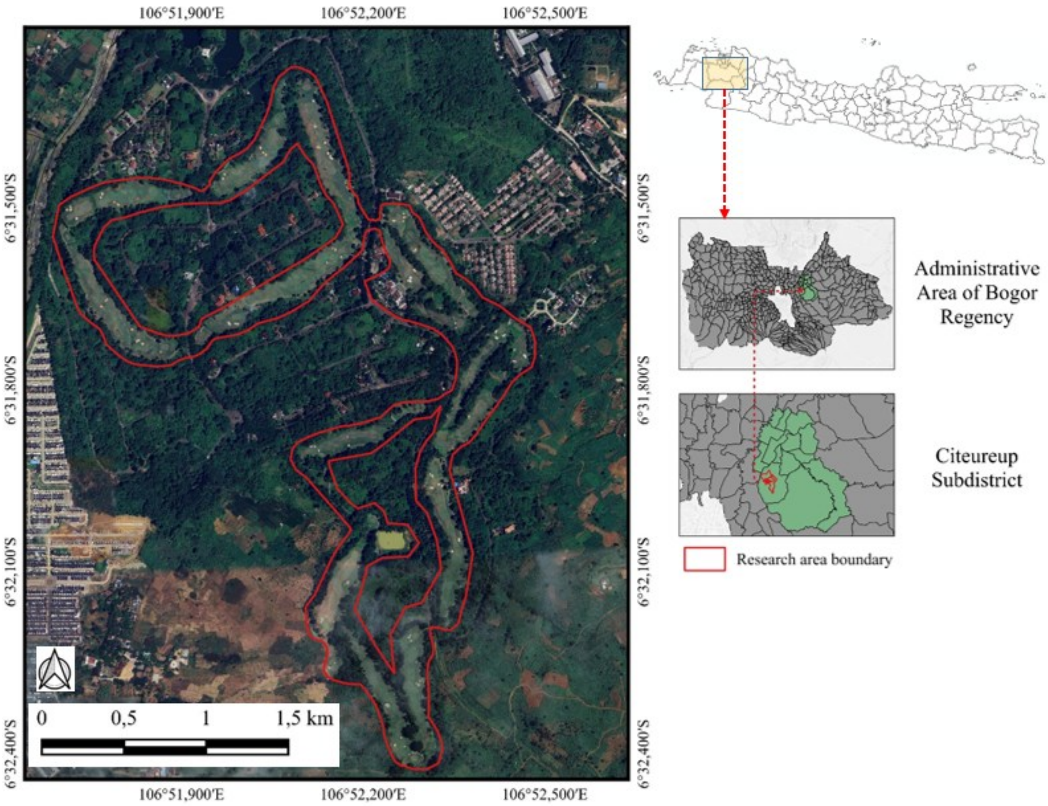

Figure 1. Study area map of Permata Sentul Golf Club.

2.2. Materials

This study utilized various hardware and software to support the data collection process. Data collected directly through field observation is referred to as primary data, while data obtained from other sources is referred to as secondary data. The details of the tools and materials used are listed in Table 1.

Table 1. Tools and materials used for research.

No.	Category	Function
	Tools (Hardware)	
1	Smartphone	Communication tool, collect photos in the field
2	GPS Garmin Etrex 10	Collect coordinates
3	Measuring tape	Measure tree diameter and plot area
4	Stationery	Write research result
5	Laptop	Process and analyze data
6	Range finder	Measuring tree height
7	Tally sheet	Form for recording research result
8	Thermohygrometer	Measuring air temperature and relative humidity
	Tools (Software)	
1	Microsoft Office 365	Write reports, process and analyze data
2	i-Tree Eco v6	Process field measurement data
3	ArcMap 10.8 & QGIS	Determine area boundary

No.	Category	Function
	Tools (Hardware)	
4	Digital compass	Discover wind direction
	Material	
1	Map from Google Earth	
2	Temperature and humidity in the field	
3	Vegetation diversity data in the field	
4	Vegetation character data in the field	

2.3. Data Collection and Analysis

2.3.1. Microclimate

Microclimate assessment data was collected directly by measuring the temperature and humidity in the field. The data was measured using a thermohygrometer placed at a height of 150 cm above the ground. The time used for sampling is morning (07:00 – 09:00), midday (11:00 -13:00), and afternoon (15:00 – 17:00) on the same day. The sampling technique uses a grid system created with AutoCAD software [20]. The size of each grid is 200m x 200m, with a total of 39 grids, the middle of which is the measurement point. The grid was determined by purposive sampling because it is expected to represent all forms of land cover on the golf course. In addition, several points were also taken around the golf course as a comparison of conditions inside and outside the golf course.

After obtaining the temperature and humidity in the field, the data was processed in tabular form at each measurement time and averaged from the measurement results for morning, afternoon, and evening. Next, a spatial map of the average temperature and humidity measurements is created using the Inverse Distance Weighted (IDW) method. This method assumes that the interpolation value is more like the nearby sample data than the farther ones. According to [21], the weight will change linearly according to distance from the sample data.

2.3.2. Carbon Storage and Carbon Sequestration

Inventory for carbon storage and carbon sequestration assessment using i-Tree Eco with plots placed randomly in the rough area of the golf course. I-Tree Eco is a software suite developed by the USDA Forest Service. It was used to input all the data and information from the field survey, as it included accessible data templates for calculating carbon storage and sequestration. Based on calculations, the number of plots on the PSGC golf course was 50, representing 10% of the total rough area with an additional 5-10% to avoid data loss [22]. Each plot is circular with an area of 0.4 ha or 400m2 with a diameter of 22.6 m or a radius of 11.3 m. The use of the i-Tree Eco application to assist in calculating carbon cycles in trees is carried out by entering tree data in the form of species name, DBH (Diameter at Breast High), tree canopy health, total tree height (m), height to base of crown (m), crown width (N/S, E/W), percent of crown loss, crown health, and percent of crown exposed to light. Each aspect has specific criteria, which are detailed in the i-Tree user guide [22]. This study only measured trees with DBH of more than 10 cm because they have been formed in the ecosystem and will continue to grow until adulthood [23]. In addition, the stabilized vegetation structure can be managed in the future.

There is a classification [24] related to wood total carbon (Wtc), which is carbon stored in the woody part of the tree (trunk, branches, twigs). The criteria for this classification are as follows:

$Wtc < 42.172$ (tons per ha) = Low carbon storage

$42.172 \leq Wtc \leq 64.150$ (tons per ha) = Medium carbon storage

$Wtc > 64.150$ (tons per ha) = High carbon storage

2.3.3. Flora Biodiversity

Primary data collection for flora biodiversity in the field used the single plot method in the rough area. Samples were taken from a large single plot with small plots scattered to be analyzed. There were ten plots with plot sizes: 2 m x 2 m for seedling observations, 5 m x 5 m for sapling observations, 10 m x 10 m for pole observations, and 20 m x 20 m for tree observations. Ten plots are chosen because PSGC has homogeneous plant communities (where plant species and their distribution are relatively uniform), so the diversity within the plot is likely to reflect the diversity across the larger area. The four types of vegetation were then calculated for the Important Value Index (IVI), Species Diversity Index (H'), Species Dominance Index (C), Species Evenness Index (E), and Margalef Species Richness Index (R).

2.3.4. Permata Sentul Golf Course Management Strategies

Green management for golf courses that support the utilization of ecosystem services is formulated using the SWOT analysis method. This method is carried out by identifying internal and external factors through information from managers, expert sources, field observations, and qualitative literature studies. Internal factors will be on the horizontal axis, while external factors will be on the vertical axis. These determining factors are then connected to see the relationship between factors expected to be a synthesis. The ecosystem services that are the focus are microclimate and carbon management processes regulation and biodiversity.

3. Results and Discussion

3.1. Result

3.1.1. General Information

Permata Sentul Golf Club (PSGC) is a golf course located in the Sentul hilly area with an altitude of about 200-300 m above sea level. This course is defined by the bounding box at the geographical coordinates of 6° 31.338' - 6° 32.404' latitude south and 106° 51.773' - 106° 52.498' longitude east. PSGC is surrounded by dense trees which act as natural buffer against the surrounding urban environment. The PSGC golf course was established in 1997 and is currently under the auspices of PT. Putra Sentra Prasarana. Thompson Wolveridge & Perret, a company from Australia designed this golf course. According to the manager, this course is the result of clearing forest land by cutting down part of the natural forest area. This process resulted in the golf course area still having a forest ecosystem in the form of trees and several wild animals, such as wild boars, monkeys, and other bird species. The condition of the PSGC golf course, which has a view of Mount Pangrango, can be seen in Figure 2.

Figure 2. This borrowing landscape view of Mount Pangrango can be seen in hole 14.

This golf course has various facilities, including a sauna, guest house, clubhouse, practice putting green, restaurant, pro shop, meeting room, etc. The PSGC golf course consists of 18 holes and 71 pars that stretch 5,843 meters from the championship tee. The first nine holes are built in a lower area, while the next nine holes are in a higher area. The design of the game hole arrangement on this golf course is a single-track golf course type with nine turns. The administrative boundaries of the site are PMPP TNI Sentul Dormitory in the east, Citra Sentul Raya Housing in the west, Jalan Permata Sentul Raya in the north, and vegetable garden in the south.

3.1.2. Ecosystem Services Identification

a) Microclimate

The results of daily data collection at the PSGC golf course show that the lowest daily relative humidity is 64.3% at point 36, and the highest is 75.3% at point 24, with an average of 70.3%. Meanwhile, the lowest daily air temperature is 26.8°C at point 24, and the highest is 28.4°C at points 13 and 35, with an average of 27.7°C. The average changes in humidity and air temperature at the PSGC golf course can be seen in Figure 3. The graph shows that relative humidity is inversely proportional to air temperature. It means that the air can hold more water vapor when the air temperature rises, so the relative humidity decreases. Conversely, when the temperature drops, the air cannot hold much water vapor, so that the relative humidity increases.

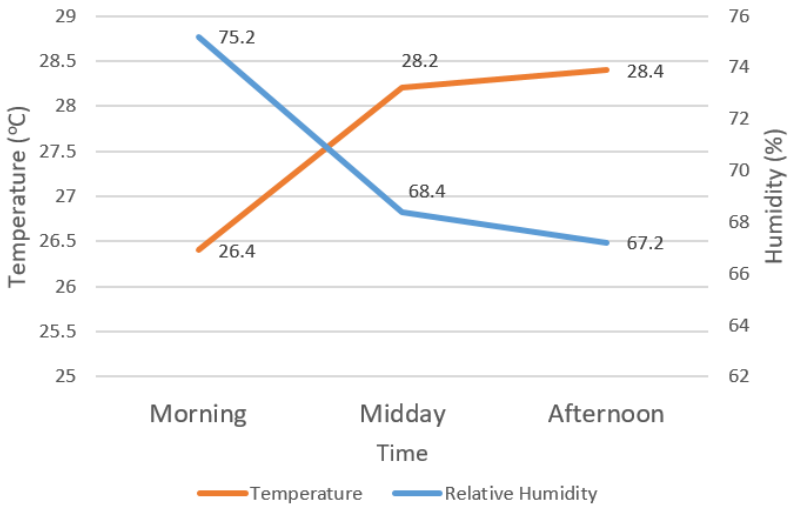

Figure 3. The graph shows the average temperature and air humidity changes at all observation points on the PSGC golf course, both in open areas and under tree canopies. The temperature at midday is lower than in the afternoon due to data collection being conducted during overcast weather.

The map generated from the IDW analysis shows that the closer a location is to a known data point, the greater the influence of that data point on the estimated value. This means that color changes or gradients may appear sharper near data points and smoother in areas farther away. Figure 4 shows the Inverse Distance Weighted (IDW) analysis results for the relative humidity category and Figure 5 for the air temperature category. Figure 4 shows that the PSGC golf course has a relative humidity that is not much different from its surroundings. Points 13 and 20, located outside the golf course and are residential areas, have lower relative humidity. Points 35, 36, and 38 are points inside the golf course and have lower relative humidity because they are around the vegetable garden location.

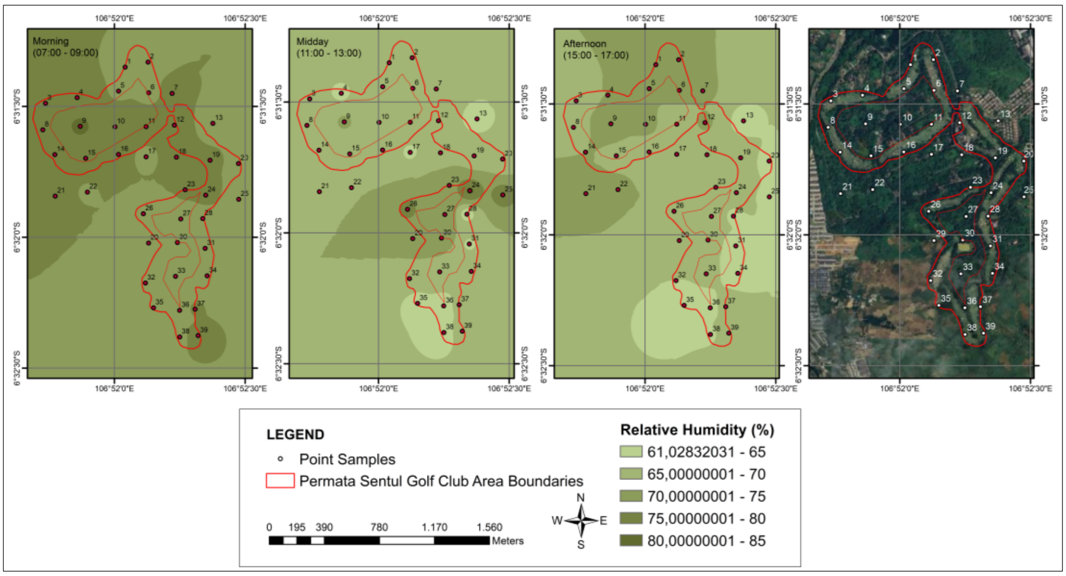

Figure 4. IDW map of relative humidity at PSGC. The image shows that the average relative humidity in the morning is higher and decreases during the afternoon and evening as shown in Figure 3.

Similar to relative humidity, the air temperature (Figure 5) at the PGSC course is not much different from the surrounding environment. Point 13, a residential area, and point 38, around the vegetable garden location, have higher air temperatures than other golf course areas. However, the temperature range at the PSGC golf course is slightly lower than the KGBR golf course. The PSGC golf course is located in an area surrounded by forests with large trees, so the microclimate inside the course is not significantly different from the surrounding environment.

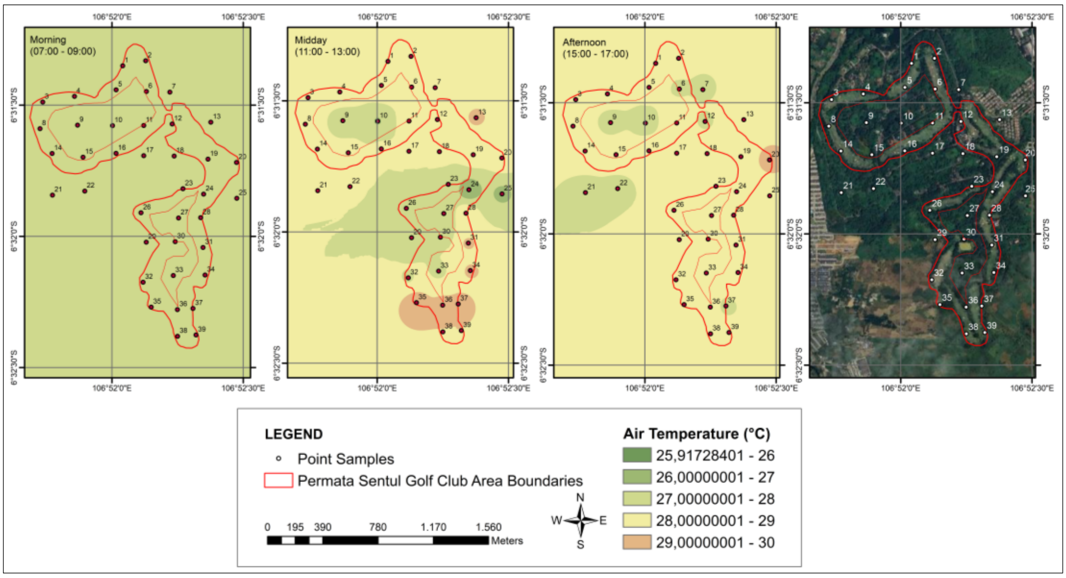

Figure 5. IDW map of air temperature at PSGC. The image shows that the average air temperature in the morning is lower and increases during the afternoon and evening as shown in Figure 3.

At the fairway points of the PSGC golf course that are exposed to sunlight from morning to evening (points 3, 4, 6, 11, 14, 15, 19, 31, 34, 35), air temperatures range between 25°C – 20°C with humidity levels reaching 65% - 80%. The PSGC golf course is located at an elevation of 200 meters above sea level in a hilly area, allowing it to experience wind circulation. In hilly areas, wind movement is more dynamic compared to urban areas, and at some locations without vegetation cover obstructing wind flow (points 35, 36, 38), the air temperature tends to be cooler in the morning, reducing relative humidity. Data collection at the PSGC golf course was conducted under overcast skies. Therefore, secondary data from the Badan Pusat Statistik (BPS), a government agency in Indonesia responsible for conducting statistical surveys regarding relative humidity, air temperature, and wind speed in Bogor Regency, is needed, as shown in Table 2. With wind speeds of 2-5 m/s, humidity is dispersed, and evapotranspiration occurs, increasing evaporation from leaf and soil surfaces, which helps lower the local air temperature.

Table 2. Average of Relative humidity, air temperature, and wind speed in Bogor Regency.

Month	Relative Humidity (%)			Air Temperature (ºC)			Wind Speed (m/s)		
	2021	2022	2023	2021	2022	2023	2021	2022	2023
January	90	87	85	25.2	21.3	25.6	0.9	1.0	3.3
February	82	87	86	24.6	21	25.4	1.2	1.0	3.6
March	86	85	86	25.9	21.8	25.8	0.9	0.9	3.3
April	86	88	83	26.7	21.8	26.8	1.0	0.7	3.2
May	85	87	83	26.8	22.1	27.0	1.0	0.9	3.3
June	88	88	84	25.8	21.3	26.4	0.8	0.8	3.1
July	81	86	80	26.0	21.6	26.3	1.0	0.8	3.5
August	84	86	76	25.9	21.6	26.4	1.0	1.0	4.0
September	85	87	84	26.3	21.5	26.0	1.1	0.9	3.4
October	87	89	74	26.4	21.3	27.7	0.9	0.8	4.0
November	88	87	85	26.4	21.3	26.9	0.9	1.0	3.5
December	89	90	81	26.1	20.8	27.2	0.8	1.0	3.2

b) Carbon Cycle

Carbon reserves in a landscape vary according to the structure of the stands that make up the landscape. In addition, human activities are one of the causes of increasing carbon concentrations in the form of CO2 in the air. It can have adverse effects, namely the greenhouse effect, due to the increase in the average temperature of the earth's surface. One way to overcome this is to maintain green open spaces, including golf courses. Carbon has a cycle divided into three stages: absorption, storage, and release. Carbon absorption is the process of trees absorbing CO2 in the atmosphere, which is used for plant growth and development to form leaves, stems, and roots through photosynthesis. The absorbed carbon will be stored as biomass in various forms, ranging from wood, roots, leaves, and organic matter in the soil. This storage occurs through biological processes such as photosynthesis and recycling of organic matter. Plants store the most carbon in their stems. After that, a release process is usually caused by tree felling, forest burning, or land clearing. This activity can change the form of stored carbon (C) into carbon dioxide (CO2) because it is bound to O2 in the atmosphere, which is the basis for calculating emissions [25].

Calculation of carbon storage estimates and carbon sequestration in trees was obtained using the i-Tree Eco v6 software. The higher a tree's health level and size, the greater the amount that can be stored. It is because the volume of biomass it has is more significant, namely all parts of the plant that are still alive. The conversion of carbon (C) to carbon dioxide (CO2) is carried out to show how much greenhouse gas is stored by trees, which is directly related to climate change mitigation. The area that focuses on calculating carbon reserves is the rough area filled with trees. The area of the PSGC rough area is 18.75 ha which covers 25% of the total golf course area.

In the rough of the PSGC golf course, the total carbon storage results were 1,488 tons or equivalent to 79.3 tons/ha. This number equals 5,455 tons of CO2 or 290.9 tons/ha. The overall valuation value for carbon stored on the PSGC golf course is equivalent to 4.58 billion rupiah. Meanwhile, carbon storage for the entire field, including grass, was calculated, yielding an estimated value of 19.83 tons/ha. This calculation is an approximation, as measurements were taken only in the tree areas. Ten species with the highest carbon storage capacity can be seen in Table 2.

Table 3. Ten species with the highest carbon storage capacity.

No.	Tree species	Common Name	Carbon Storage (ton)	Carbon Storage (%)	CO2 Equivalent (ton)
1	*Acacia mangium* Willd.	Akasia	512.5	34.5	1879.2
2	*Albizia chinensis* (Osbeck) Merr.	Sengon	236.6	15.9	867.5
3	*Mimusops elengi* L.	Tanjung	164.3	11.0	602.4
4	*Filicium decipiens* (Wight & Arn.) Thwaites	Kirai payung	132.3	8.9	485.1
5	*Artocarpus heterophyllus* Lam	Nangka	56.4	3.8	206.8
6	*Polyalthia longifolia* Sonn. B.Xue & R.M.K.Saunders	Glodokan tiang	44.8	3.0	164.3
7	*Pterocarpus indicus* Willd.	Angsana	35.7	2.4	130.9
8	*Cananga odorata* (Lamk.) Hook.	Kenanga	32.0	2.2	117.3
9	*Hymenaea courbaril* L.	Courbaril	20.5	1.4	75.2
10	*Alstonia scholaris* R. Br.	Pulai	17.5	1.2	64.2

Carbon absorption on the same course is 100.1 tons/year, equivalent to 5.34 tons/year/ha. It is equivalent to carbon dioxide (CO2) of 367 tons/year or 19.57 tons/year/ha. The overall valuation value for carbon sequestered on the PSGC golf course is equivalent to 308 million rupiah. Meanwhile, the calculation of carbon sequestration for the entire field, including grass yields an estimated value of 1.33 tons/year/ha. Ten species with the highest carbon sequestration ability can be seen in Table 3.

Table 4. Ten species with the highest carbon sequestration ability.

No.	Tree species	Common Name	Gross Carbon Seq. (ton/yr)	CO2 Equivalent (ton/yr)
1	*Acacia mangium* Willd.	Akasia	22.95	84.15
2	*Albizia chinensis* (Osbeck) Merr.	Sengon	11.5	42.17
3	*Mimusops elengi* L.	Tanjung	16.37	60.02
4	*Filicium decipiens* (Wight & Arn.) Thwaites	Kirai payung	10.83	39.71
5	*Artocarpus heterophyllus* Lam	Nangka	2.88	10.56
6	*Polyalthia longifolia* Sonn. B.Xue & R.M.K.Saunders	Glodokan tiang	3.91	14.34
7	*Pterocarpus indicus* Willd.	Angsana	3.00	11.00
8	*Cananga odorata* (Lamk.) Hook.	Kenanga	3.08	11.29
9	*Hymenaea courbaril* L.	Courbaril	0.58	2.13
10	*Alstonia scholaris* R. Br.	Pulai	1.24	4.55

Based on these criteria [24], the carbon storage on the PSGC is classified as low. However, most of the plant species that contribute to storing large amounts of carbon on the PSGC golf course are exotic plants. Exotic plants are introduced intentionally or unintentionally from their native habitat to a new habitat. It happens for various reasons, including aesthetics, maintenance, course function, availability, or commercial appeal. Endemic plants with high carbon sinks can be an alternative to maintaining the sustainability of the golf course environment.

c) Vegetation Analysis

Table 4 summarizes IVI at the PSGC golf course from 10 observation plot points for tree, pole, and sapling vegetation types. The seedling type could not be identified because it is classified as undergrowth. The Importance Value Index (IVI) shows the proportion of a plant species to its community. Vegetation analysis by looking at IVI values in various vegetation types produces different IVI values. The density, frequency, and dominance values of each type in various vegetation types influence the difference in IVI values. A high IVI value does not indicate that these species should be encouraged to be planted in the future. Those high values indicate that these species currently dominate the rough structure of the golf course.

Table 5. Summary of IVI value in PSGC.

No.	Tree species	Common Name	IVI (%)	Species Amount	Avg. Diameter (m)	Status
	Tree					
1	*Acacia mangium* Willd.	Akasia	25.7	6	0.6	Exotic
2	*Albizia chinensis* (Osbeck) Merr.	Sengon	23.6	5	0.7	Native
3	*Annona squamosa* L.	Srikaya	3.8	1	0.4	Exotic
4	*Artocarpus heterophyllus* Lam	Nangka	15.5	6	0.4	Exotic
5	*Averrhoa carambola* L.	Belimbing	4.0	1	0.4	Native
6	*Bauhinia purpurea* L.	Kupu-kupu	4.7	2	0.3	Exotic
7	*Cananga odorata* (Lamk.) Hook.	Kenanga	18	8	0.3	Native
8	*Citrus maxima* (Burm. F.) Merr.	Jeruk bali	3.7	1	0.4	Native
9	*Delonix regia* (Bojor ex Hook.) Raf.	Flamboyan	10.7	3	0.5	Exotic
10	*Ficus lyrate* Warb.	Biola cantik	3.5	1	0.3	Exotic
11	*Filicium decipiens* (Wight & Arn.) Thwaites	Kirai payung	17.3	5	0.5	Exotic
12	*Garcinia mangostana* L.	Manggis	7.2	5	0.2	Native
13	*Leucaena leucocephala* (Lam.) de Wit	Lamtoro	3.6	1	0.4	Exotic
14	*Magnolia virginiana* L.	Sweetbay	3.6	1	0.3	Exotic
15	*Malphigia emarginata* Seese & Moc. Ex DC.	Sianci	3.6	1	0.3	Exotic
16	*Mangifera indica* L.	Mannga	16.7	7	0.4	Exotic
17	*Manilkara zapota* (L.) P. Royen	Sawo	13.5	7	0.4	Exotic
18	*Melia azedarach* L.	Mindi kecil	11.5	6	0.3	Exotic
19	*Mimusops elengi* L.	Tanjung	40.8	16	0.3	Exotic
20	*Nephelium lappaceum* L.	Rambutan	3.6	1	0.3	Native
21	*Plumeria rubra* L.	Kamboja	3.1	1	0.2	Exotic
22	*Polyalthia longifolia* Sonn. B.Xue & RM.K.Saunders	Glodokan tiang	22.5	16	0.3	Exotic
23	*Pongamia pinnata* (L.) Pierre	Ki beusi	7.4	3	0.4	Native
24	*Pterocarpus indicus* Willd.	Angsana	23.3	7	0.6	Native
25	*Syzygium cumini* (L.) Skeels	Jamblang	5.4	2	0.4	Native
26	*Trichilia dregeana* Sond.	-	3.6	1	0.3	Exotic
	Poles					
1	*Acacia mangium* Willd.	Akasia	300	1	0.1	Exotic
	Sapling					
1	*Polyalthia longifolia* Sonn. B.Xue & RM.K.Saunders	Glodokan tiang	94.08	1	0.1	Exotic
2	*Bougainvillea glabr* Choisy	Bugenvil	96.41	1	0.1	Exotic
3	*Schefflera actinophylla* (Endl.) Harms	Umbrella tree	109.50	1	0.1	Exotic

Table 4 shows the IVI values for tree, pole, and sapling vegetation levels at PSGC. Tree-level vegetation contains *Mimusops elengi* with an IVI of 40.8% and pole level contains *Acacia mangium* with an IVI of 300% because it is the only one. Meanwhile, the sapling level contains *Schefflera actinophylla* with an IVI of 109.50%.

The study was conducted in a rough area of a golf course predominantly consisting of rows of trees, resulting in only a single tree stratum. However, the surrounding environment, which is forested, contains many fast-growing trees, forming a multi-strata canopy with thick and tiered canopies. The dense canopy reduces ground temperature by shading and minimizing direct solar radiation. Evapotranspiration from leaves and soil moisture increases atmospheric humidity, creating a cooler and more humid microclimate.

Mimusops elengi is an exotic tree originating from India and spreading to Myanmar and other tropical areas [26]. This tree has evergreen leaves with a dense, round canopy, so it has a role in reducing surface temperatures. This plant also produces small, fragrant white flowers to add a pleasant fragrance to the golf course. This tree is easy to maintain with its drought-tolerant nature making it suitable for golf courses during the dry season [27].

Acacia mangium as the only pole in the sample is a tree originating from humid tropical forests in Australia. This tree can tolerate various soil types and environments, even on acidic and degraded soils. Its ability to regulate air nitrogen and produce much litter can increase soil biological activity and rehabilitate the physical and chemical properties of the soil. This plant is intolerant of shade and can cause it to grow stunted and thin [28]. Acacia flowers, composed of many small flowers, can be an obstacle for golfers allergic to pollen. Therefore, the presence of acacia on golf courses that are widely used for human interaction can be considered by management. Umbrella trees or *Schefflera actinophylla* on golf courses can be maintained because they can survive the dry season and become a habitat for living things. This plant has flowers that can attract pollinators, such as birds and bees, to maintain local biodiversity.

Species diversity can be used to measure community stability, namely the ability of a community to remain stable despite a disturbance to its components [29]. The value of the species diversity index is greatly influenced by the number of species at each level of vegetation and their distribution in an area. **Figure 6** shows tree and sapling vegetation levels have medium values, while poles have low values. It means the diversity or abundance of individuals on the golf low to medium level.

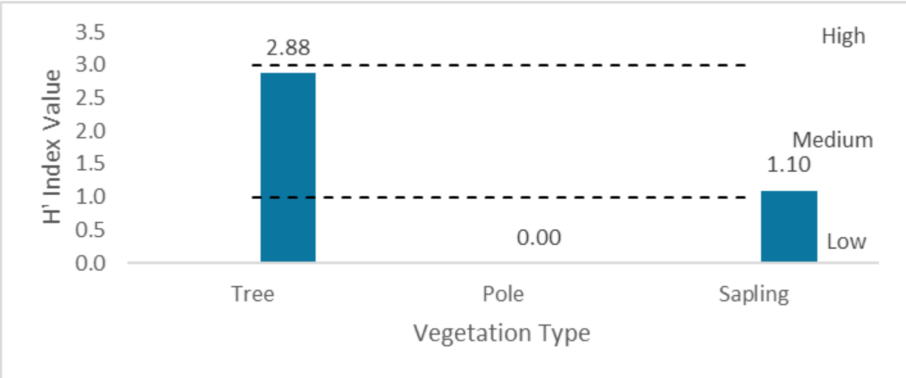

Figure 6. Graph of diversity index at PSGC. Both tree and sapling levels have medium values, meanwhile pole level has low values.

The species evenness index measures the degree of evenness of the abundance of individual species in a community. Evenness means balance between one community and another [30]. According to the graph (Figure 7), the tree and sapling vegetation levels have high evenness index values, and the pole vegetation level has low values. It means each vegetation level has a balanced number of dominant individuals, except for the poles.

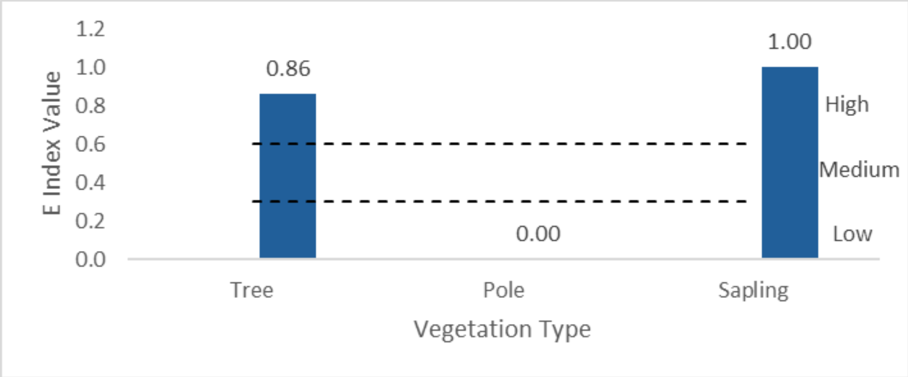

Figure 7. Graph of evenness index at PSGC. Both tree and sapling levels have high values, meanwhile pole level has low values.

The species richness index on the PSGC golf course shows low and high categories. The richness index is influenced by the sample size and the time required to achieve it [31]. In Figure 8, the species richness index of the tree vegetation level has a high value. Meanwhile, the pole and sapling levels have low values. It shows that the number of individual tree species on the golf course is high, while the poles and saplings are low.

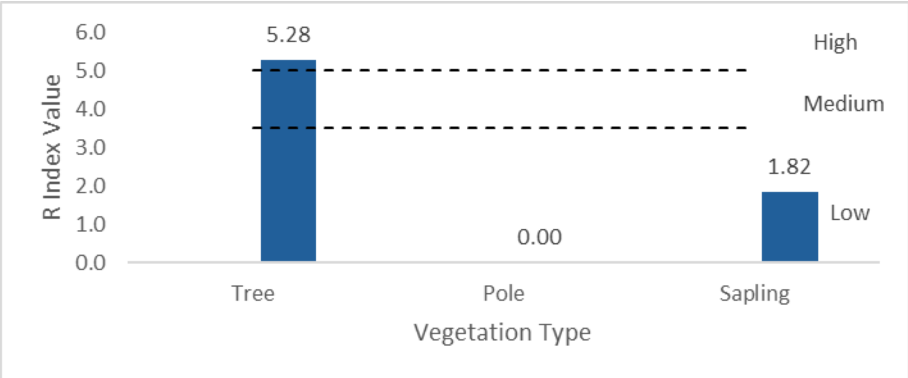

Figure 8. Graph of richness index at PSGC. The tree level has a high value. Meanwhile, both pole and sapling levels have low values.

Dominance indicates a main plant species that influences and can control its community through many species, large size, and dominant growth [32]. In Figure 9, the dominance index of the pole vegetation level has a high value, and the tree and sapling vegetation level has a low value. This means that no species dominates, except for the pole type, which is only concentrated by one species.

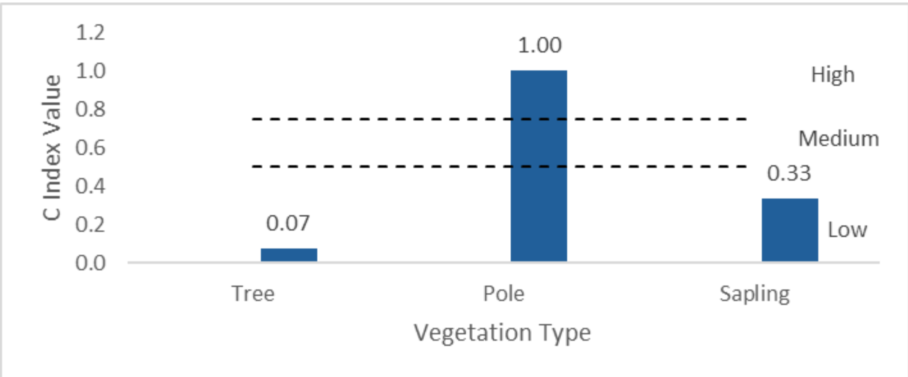

Figure 9. Graph of dominance index at PSGC. Both tree and sapling levels have low values, whereas the pole level has high values.

3.2. Discussion

3.2.1. Ecosystem Services at Permata Sentul Golf Course

The PSGC golf course area is surrounded by rows of trees that act as a natural fence and buffer against the surrounding urban environment (main road). With the distance that must be traveled between the front gate and the clubhouse being 1.8 km, this causes vehicle access to be limited other than those belonging to visitors and managers. In addition, the number of vehicles operating inside the golf course is also limited, namely motorbikes and electric golf carts. It reduces the effects of anthropogenic heat, such as vehicle exhaust.

The cooling effect produced by the PSGC golf course on the surrounding environment can be felt. Areas close to wide-crowned trees or water bodies have high relative humidity values and low temperatures, while areas around grasslands and settlements have low relative humidity values and high temperatures. This is following the research [33] which states that golf courses in urban areas have lower daytime ground surface temperatures compared to other urban land use categories, except for conservation areas. Golf courses, most of whose surface area is covered by a combination of vegetation (shrubs and trees), water bodies, and grass, act as 'cool islands' and 'natural shelters' in cities dominated by building structures and hard surfaces that absorb heat. These terms refer to the unique ability of golf courses to create pockets of cooler air and provide refuge from the urban heat island effect.

Research [34] related to the assessment of cooling effects on different vegetation arrangements at the Hong Kong Golf Club showed that the daily average temperatures of the control plot, rough grass area, and tree line were 31.3°C, 30.4°C, and 30.0°C respectively. Meanwhile, the daily average relative humidity between the control plot, rough grass area, and tree line was 77.2%, 82.5%, and 82.2% respectively. The control plot was a plot located on a barren rooftop of a second story building that reflected the urban conditions of the city. The results of this study are in line with the general knowledge that trees are the most efficient elements for cooling air temperatures on the course than just grasslands [35-36]. Leaves can create shade from solar radiation which can make temperatures cooler through evapotranspiration, a process where plants release water vapor through their leaves. Tree shade can contribute up to 80% to the cooling effect [37]. Tree clusters with a smaller height-to-width ratio have a stronger cooling effect because the amount of air trapped in the cluster that needs to be cooled is less. Another study [38] found that plots of trees can limit the rate of global temperature increase by 1.1 to 1.3 times, while in plots of the same size composed of concrete and open grass, it increases at a rate of 1.6 to 2.1. Thus, the presence of urban greening including the presence of golf courses can provide benefits for the microclimate through several physical processes. For example, plants and shade trees can reduce solar heat gain on buildings and reduce terrestrial radiation because the surface temperature is lower. Also, latent heat for cooling in the atmosphere increases due to the addition of moisture in the air through plant evapotranspiration so that local cooling occurs [39].

Research [40] about the assessment of carbon storage in the rough area at Cibodas Golf Park (9 holes, double track), Bogor Golf Club (9 holes, core course), and the Golf Pantai Indah Kapuk (18 holes, double track) showed different results. Cibodas Golf Park has a carbon storage of 10.33 tons/ha, Bogor Golf Club 35.93 tons/ha, and the Golf Pantai Indah Kapuk 23.49 tons/ha. These three studies are included in the low-carbon storage category. It can occur due to differences in the number of holes and course design. A double-track golf course has a lower value than a core golf course and a single-track. Because rough on a double track act as a separation border of two holes, the tree distribution is less. The core track is also not much different from the double track, while the single track only acts as a separation border between the outside area of the field so that its distribution is more significant. An illustration of the differences between single, double, and core tracks can be seen in Figure 10.

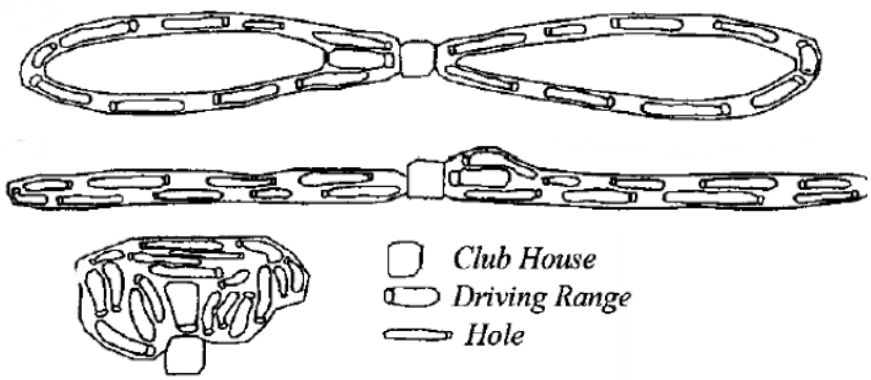

Figure 10. Illustration of single-track, double-track, and core golf courses in order respectively.

A literature review [12] shows that the most frequent interactions on golf courses are by groups of birds (34%), insects and earthworms (19.4%), amphibians (13.6%), mammals (11.7%), reptiles (9.7%), aquatic and terrestrial vegetation (4.9%), fish (2.9%), and benthic macro-invertebrate communities (1.9%). It is also related to a study in Japan that assessed the diversity of biota on golf courses, which stated that areas outside the hole boundaries, namely forests and green strips, provide a wider variety of biota than grasslands [41]Some golf courses in Indonesia do not have areas outside the holes in the form of forests because they are in the city center. Therefore, this can be utilized by maximizing the rough area consisting of rows of trees and grass to maximize the interaction of groups of animals and vegetation, which can increase biodiversity.

3.2.2. Permata Sentul Golf Course Management Strategies

Green management for golf courses that support the existence of ecosystem services is formulated using the SWOT analysis method. This method is carried out by identifying internal and external factors from golf course managers, field observations, and literature studies focusing on ecosystem services: microclimate, carbon management processes regulation, and biodiversity. From this analysis, three main strategies were made for the PSGC golf course manager to enhance the ecosystem services.

The first strategy is developing the golf course's ability to produce ecosystem services in urban areas. Several activities included in this strategy are creating a biodiversity conservation zone that is sensible (visual, audio, aroma) even though visitors are focused on the game; selecting and keeping endemic tree species that can also provide shade, reduce noise, store carbon, and food sources for surrounding animals because the exotic plant is hazardous for the preservation of natural ecosystems because it is very invasive; providing services that can increase visitors' opportunities to explore non-playing areas so they can feel closer to nature. Besides that, the management needs to reduce the use of chemicals for fertilization, even though it takes time.

The second category is increasing collaboration and cooperation with various stakeholders in managing the golf course. Several activities included in this category are making annual routine activities with staff and visitors to maintain biodiversity, such as releasing birds in the field's conservation area and planting trees. Next, it will collaborate with the government, external organizations, and managers in planning green policies specifically for golf courses and prize programs for golf courses that remain committed to maintaining biodiversity. Also, it is necessary to add environmental expert staff to help formulate local course management policies.

The third category is educating internal and external golf courses related to ecosystem services. Several activities included in this category are creating digital media for golf course promotion that also provides information related to the uniqueness and biodiversity of the golf course to attract new customers. In the course, the management also can create information boards in the golf course area related to vegetation habitat and the advantages of each vegetation.

4. Conclusions

Permata Sentul Golf Course is a single-track golf course located in hilly area at Bogor Regency, Indonesia. This study analyzed the ecosystem services provided, focusing on regulating and supporting functions such as flora biodiversity, microclimate regulation, and carbon storage and sequestration capacity. The findings indicate that PSGC contributes to a cooler urban microclimate and serves as a habitat for various wildlife, despite its relatively low carbon storage capacity. Dominant vegetation, including *Acacia mangium*, *Mimusops elengi*, and *Schefflera actinophylla* plays a significant role in these services. Based on the research findings, strategies can be implemented to optimize the ecosystem services provided by the PSGC golf course. These strategies include enhancing collaboration with various stakeholders from governmental and non-governmental organizations and educating both internal and external parties about the importance of working together to support environmentally friendly programs on the golf course.

Author Contributions

FAA: Conceptualization, Formal analysis, Investigation, Project administration, Visualization, Writing – original draft; **BS**: Supervision, Writing - Review & Editing; **RH**: Supervision, Writing - Review & Editing

Conflicts of interest

There are no conflicts to declare.

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