Chapter

Sustainable Design in Urban Green Space

Ning Li and Yang Liu

Abstract

As a fundamental part of the urban function, urban green space faced a long-term maintenance requirement. The maintenance of urban green space (i.e., trimming, irrigation, fertilization, pesticide, and plant waste removal) can have environmental impacts, such as energy consumption and greenhouse gas (GHG) emission. This chapter focuses on the adjustment of the plant communities' combinations in urban green space to reduce the environmental impacts in long-term maintenance. The plant communities in urban green spaces are a combination of four plant layers: woodland, shrubs, herbicides, and grassland. In this chapter, we will start to investigate the environmental impacts in the maintenance of urban green space. Then we introduced the quantitative method life cycle assessment (LCA), to quantify the environmental impacts of the maintenance tasks. We analyzed the maintenance environmental impact (MEI) index of 95 plant community samples (20 m × 20 m) in Zhengzhou (China) through LCA and sorted out the changing curves of the MEI index during the change of the combined amount in each plant layers. Finally, we sorted out the MEI strength of the plant layers and summarized the low MEI plant community model. The low MEI model can save energy consumption and GHG emissions of the maintenance tasks, to contribute to the sustainable development of the urban green space.

Keywords: urban green space, plant community maintenance, environmental impact, energy consumption, GHG emissions

1. The environmental impact in urban green space maintenance

1.1 The fast expansion of maintenance workload in urban green space

The increase of the urban green space leads to the expansion of maintenance workload. During the years 2000–2018, due to the 2.6 times growth of the urban built-up area in China (from 2,152,500 ha to 5,622,500 ha), the urban green space increased from 778,200 ha to 2,921,300 ha (**Figure 1**). The dramatical extension of the urban green space increased the maintenance pressure directly. This point can be reflected by the fast increase of the maintenance equipment used in urban green space. **Figure 2** shows that the number of maintenance machine increased 5 times between the year 2000 and 2018, from 44,238 to 228,019 in the Chinese city [1].

The functional expansion of urban green spaces has also increased the workload of maintenance. In the past 40 years, the development goal of urban green space in

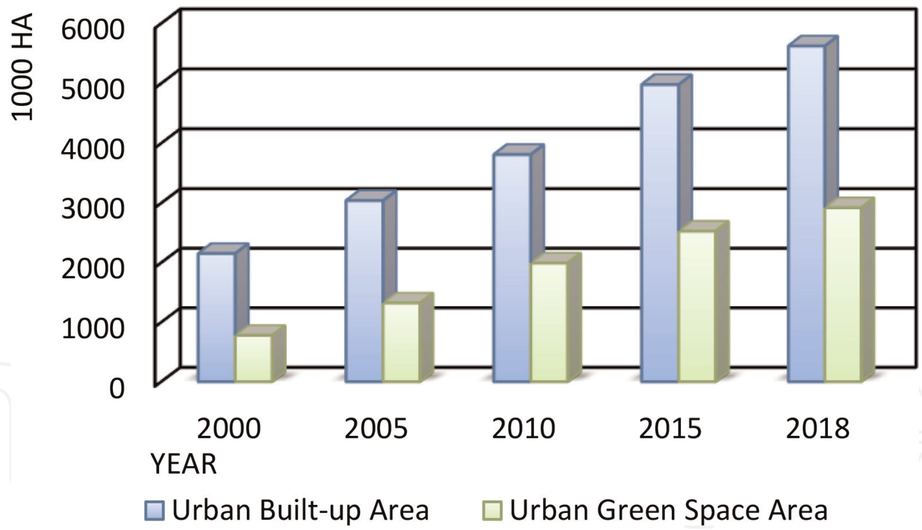

Figure 1.
The increase of urban built-up and green space area in China (2000–2018).

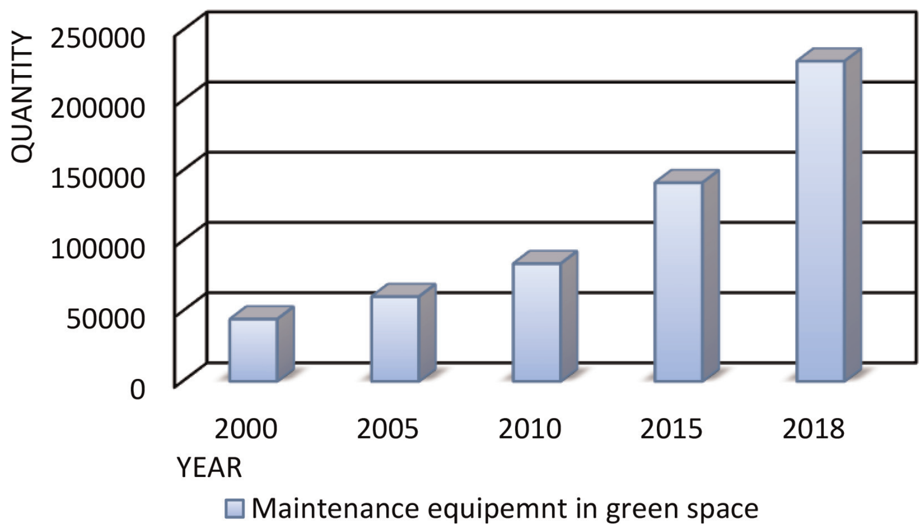

Figure 2.
The increase of maintenance equipment used in Chinese urban green space (2000–2018).

most parts of the world has changed from "quantity" to "quality" [2]. Take China as an example.

The extensive growth period of the urban green space was from 1990 to 2004. With the intention of the "garden city" proposed by the Ministry of Construction, most cities began to expand the green area and pursue high greening rates [3]. During this period, many urban reservations were filled with woodland and lacked maintenance.

From 2005 to 2014, urban green space growth began to focus on the richness of vertical plant layers. This dramatically increases the maintenance workload. With the goals of the "National Forest City" and "Ecological Garden City" proposed by the State Forestry Administration and the Ministry of Construction, the development of urban green space has turned to forest vegetation as the main body, enriching the vertical plant level to improve ecological functions [4]. Multilevel plant communities require more maintenance tasks to maintain the shape or function of each plant layer than traditional woodland green spaces [5]. During this time, the growing maintenance workload has forced city managers to consider increasing productivity and reducing resource consumption to save on maintenance budgets.

In the year 2015, the General Office of the State Council issued the "Guiding Opinions on Promoting the Construction of Sponge City" [6]. This framework aimed to exert the natural ecological functions of the urban green space, to increase the urban eco-securities, such as absorption, infiltration, and sustained release to the rainwater, and decrease the maintenance requirement in simultaneously [7]. That can deliver a clear message that the city managers have to seek a more natural plant combination method to release the maintenance pressure in the future plant community design and management in urban green space.

1.2 The maintenance tasks in urban green space

The maintenance tasks in urban green space include trimming, irrigation, fertilization, and pesticide [8]. During the maintenance record in the urban green space in Zhengdong New District (2018, Zhengzhou, China), the annual trimming frequency in woodland, hedge, and grassland was 1–3 times, 6–10 times, and 13–22 times separately; the average irrigation frequency was 30–50 times/year; the fertilization frequency was 2–4 times/year; the centralized pesticide frequency was 2–5 times/year. In addition, it also includes the removal of plant waste after every time of the trimming work.

The maintenance of green space is related to strong labor work and machine input. According to the official regulation of the number of maintenance team in Zhengdong New District, in a total of more than 460 ha urban green area, they totally configured about 900 site conservation workers responsible for daily maintenance (0.3 ha/per person at 70 ha of CBD area, 0.6 ha/person at other green areas). Besides, the trimming/mowing work is related to the application of power chainsaw, hedge/edge strimmer, and lawn mower. Sprinklers are required for irrigation and pesticide work. Trucks are required for the removal of plant waste and transportation of the maintenance materials.

1.3 The energy consumption and emission discharge in green space maintenance

The maintenance work in urban green space includes the consumption of energy resources and the discharge of waste to the environment, with annual cycles [9]. In daily maintenance, most trimming work and plant waste transportation depend on machine use. This machine work mainly consumes fossil energy and emits harmful gases (including CO_2, NO_x, CH_4, etc.) into the atmosphere. Irrigation mainly consumes urban tap water. The fertilizer and pesticide consumed in fertilization and pest control work can produce soil carbon residues. Besides, the trucks responsible for fertilizer transportation and drug spraying also need to consume fossil energy and generate exhaust gas [10, 11].

The fossil energy (gasoline, diesel, etc.) consumed in green space maintenance is named direct energy (DE) consumption, which can be converted with standard coal that releases the same amount of heat during combustion. The use of water resource, fertilizer, and pesticide is named indirect energy (IDE) consumption. The IDE consumption also has the equivalent conversion coefficient with the calorific value of standard coal, and ultimately all show the consumption of heat energy [12, 13]. Among the harmful gases emitted by green space maintenance, greenhouse gases (GHG) have been recognized as the main source of atmospheric pollution, which account for more than 83% of the total emissions [14]. This energy consumption and exhaust emissions persist with the annual cycle of maintenance tasks.

Although the purpose of maintenance is to provide a safe and healthy development for the green space, which is able to continue the service for the urban public, this long-term human intervention in the green space itself also violates the basic requirements for the sustainable development: maximization of self-renewal and minimization of the artificial disturbance [15]. Therefore, reducing the environmental impact caused by maintenance tasks will contribute to the sustainable development of urban green space.

1.4 The literature review of environmental impact in urban green space maintenance

Few urban environment assessment systems are mentioned about the environmental impacts of green space maintenance. The University of Florida, in the "Florida-Friendly Landscaping Guidelines," proposed that the maintenance team should sign a contract with the green space owners and enact a detailed working plan before maintenance operations. The working plan should estimate the types of maintenance tasks and detail workload. This is important to improve working efficiency, save maintenance materials, and reduce environmental impacts [16]. The "Sustainable Sites Initiative" (proposed by the US Lady Bird Johnson Wildflower Center and US Botanic Garden) point out that during the complete life cycle of the urban landscape (design, construction, operation, maintenance, and disposal), the maintenance procedure occupied around 10–20% of the total environmental impact [17].

Some research point out reducing the maintenance workload can decrease the environmental impact and improve the ecological benefits of the green space. Zhao and Liu pointed out that the city managers should reduce the area of grassland and plant more native woodland to improve the adaptability and tolerance of urban green space. Extensive use of wildflowers and meadows can also benefit to the urban wildlife and reduce the maintenance requirement [18]. Guo in the renewable and recyclable landscape research indicated that the self-maintenance green space is able to maximize the utilization of energy and materials and reduce environmental pollution in the use process [19]. Min put forward that the conservation green space is to improve the utilization rate of maintenance resources and energy use and obtain the maximum ecological, environmental, and social benefits [20]. Shu-Hua pointed out that symbiotic cyclic urban landscape architecture should adopt the design of low environmental impact, including the selection of recyclable, low-consumption, and high-durable building materials, and pay attention to reduce the maintenance material input in the later period [21].

The quantitative study on the environmental impact of urban green space maintenance is limited. After finishing 3 years of urban green space maintenance carbon emission data collection for the three major cities, Seoul, Chuncheon, and Gangneung, Hyun found that the annual increase of urban green space carbon emissions is between 10 and 20%. The average carbon (CO_2-eq) emissions are 264.9, 37.0, and 67.9 $t/ha/y^{-1}$ in Seoul, Chuncheon, and Gangneung, respectively. The annual carbon storage in the three urban green spaces (the amount of CO_2-eq) is about 50% of the respective carbon emissions [22]. Lynch et al. believe that pruning, fertilization, pest control, and other works in green space maintenance can cause heavy carbon discharge. The design phase can directly influence the maintenance workload, such as the time investment, energy, and water consumption in urban green space [23].

2. Life cycle assessment of the environmental impact

2.1 Introducing of LCA

Life cycle assessment (LCA) is a comprehensive tool for evaluating the environmental impact of products or behaviors. This method can comprehensively analyze the potential environmental impact of human behavior from the beginning to the end by collecting the life cycle inventory (LCI) [24]. The LCA method includes four steps (**Figure 3**): goal and scope definition; analysis of life cycle inventory; environmental impact assessment; and interpretation of results [25]. It is mainly used to quantitatively study the negative environmental impacts (i.e., resource energy consumption and waste discharge) on the LCI list and seek ways to decrease the environmental stress of production or behavior system [26].

2.2 The development of LCA

LCA was initially applied primarily to research on resource consumption and environmental impacts of product packaging. In the early 1980s, due to the global energy crisis, environmental problems mainly focused on fossil energy consumption and combustion pollutant emissions, and the life cycle assessment method also entered the stage of academic discussion. At the same time, with the global solid waste problem that emerged from the late 1970s to the mid-1980s, the life cycle method has gradually become a resource analysis tool and has entered the field of scholars. Research at that stage mainly focuses on the assessment method construction, with limited case studies. The earlier LCA research was concentrated in the United States and encouraged by the government [27].

After entering the 1990s, LCA entered a stage of rapid development. In 1990, for the first time, the International Society of Environmental Toxicology and Chemistry (SETAC) hosted an international seminar on LCA. The concept of "life cycle assessment" was first presented at the conference. In the following years, the SETAC hosted and held several academic seminars and conducted extensive research on the theory and methods of life cycle evaluation [28]. Although the current life cycle assessment methodology still has many issues worth studying, the SETAC and the International Standards Organization (ISO) have been actively promoting the international standardization of LCA. The ISO 14040 standard (Environmental Management—Principles and Framework for Life Cycle Assessment) was promulgated on 1997, and the corresponding series of standards ISO 14041 (list analysis), ISO 14042 (impact evaluation), and ISO 14043 (interpretation of impact statements) are also in the following [24]. The standard system has a great improvement to the standardization steps of the LCA concept and the technical framework.

Construction of the LCI database is a vital factor in the development of LCA. LCI database includes the total environmental impact data on every life cycle stage of the upstream product. The LCI database construction starts from the early 1990s.

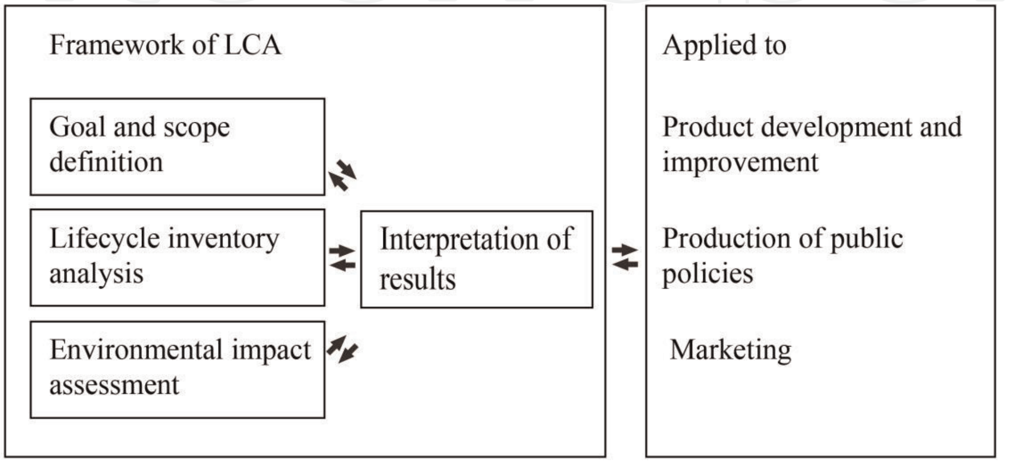

Figure 3.
The framework of LCA [24].

Currently the word mainstream database includes "ecoinvent" in Europe and "Chinese life cycle database" (CLCD) in China [26].

2.3 The quantitative method of LCA

2.3.1 The general characterization model of LCA

Different ecological impact factors have different potential for the same type of environmental impact. Based on a certain ecological impact factor, the relative impact potential could be characterization [29]. Characterization is the main step to quantify the environmental impact intensity, which includes resource and energy consumption and waste discharge:

1. Consumption of resources and energy. Heat consumption is usually taken as a characteristic factor, and the material consumed in the system boundary is converted into a unified heat unit according to their energy consumption coefficients accumulated:

$$EC_s = \sum_{i}^{n} \alpha_i \times RC_i \tag{1}$$

In the formula, *ECs* is the characteristic quantity of resource and energy consumption; take MJ as a characteristic index. RC_i is the consumption of material i in a certain process of the system. α_i is the equivalent coefficient of material i. At present, GB/T 2589-2008 standard offered majority kinds of materials in coal calorific equivalent coefficient.

2. Waste discharge. At present, a unified equivalent model has been established for the environmental impact of the LCA system on climate warming, environmental acidification, eutrophication, and environmental toxicity. The *EIs* of an environmental impact factor in the waste generated within the system boundary can be calculated by the following formula:

$$EI_s = \sum_{i}^{n} \beta_i \times EC_i \tag{2}$$

In the formula, EC_i refers to the emission amount of factor i in waste discharge characteristic factors. β_i is the equivalent coefficient of factor i. The coefficients of factors CO_2, CH_4, and N_2O are 1, 21, and 310, respectively [30].

2.3.2 Standardization and weighted assessment of LCA characteristic result

Standardization refers to the ratio between the LCA characteristic quantity of an environmental impact factor and the regional total or average quantity of the factor, with the aim of eliminating the difference in dimension and series of each environmental impact factor. At present, data of energy and resources and emissions of environmental waste per capita in the world in 2000 are mostly used as standardized reference in the field of environment [31]. The calculation process is as follows:

$$RE_i = E_i / S_{i(2000)}$$

The characterization factors of environmental impact	Unit	The reference value of standardization unit/person [32]	Weight coefficient [33]
Resource and energy consumption	MJ	2.59×10^6	1.1×10^{-1}
Global warming potential (GWP)	kg CO_2-e	6.87×10^3	1.2×10^{-1}

Table 1.
Reference values and weight coefficients of some environmental impact characteristic factors.

In the formula, RE_i refers to the standardized result of environmental impact factor i. E_i is the LCA characteristic quantity of environmental impact factor i, including both EC and EI. $S_{i(2000)}$ refers to the world per capita standardized benchmark of environmental impact factor i in 2000.

The weighted assessment is based on the actual environmental load of each environmental impact factor to determine the weighted coefficient, which is used to revise the standardized results of LCA system:

$$WE_s = \sum_{i}^{n} W_i \times RE_i \tag{3}$$

In the formula, *WEs* is the weighted value of environmental impact within the boundary of the LCA system. W_i is the weighted value of environmental impact factor i.

Standardized reference values and weight coefficients of two environmental impact factors, resource and energy consumption and climate warming potential (GWP), are shown in **Table 1**.

2.4 The application of LCA on ecological research

In the environmental ecology research, LCA has been widely used in plant nursery, forestry management, and agricultural production. *Lazzerini* assessed the carbon emissions of two types of nursery plant cultivation (in-pot and on-field) in Tuscany (Italy). Guided by LCA, this study summarized the carbon emissions of farm structure, aboveground structure, input of cultivation, and packaging in nursery cultivation. He pointed out the GHG emission of in-pot cultivation was 7.4–26.5 kg $CO_2/m^2/y^{-1}$, which was much higher than that of 0.6–1.0 kg $CO_2/m^2/y^{-1}$ of on-field cultivation [34]. *Berg* summarized the energy consumption and carbon emissions in Sweden's forestry management process by LCA. The forestry life cycle includes seedling production, silviculture, logging, and haulage to the wood processing plant. In Sweden forestry, the energy consumption (in m^3 wood unit) is about 150–200 $MJ/m^3/y^{-1}$, and the carbon emissions (CO_2-eq) is about 12.5–17.1 kg/m^3/y^{-1}. The energy consumption and carbon emissions in logging and transportation are the most obvious, accounting for more than 60% of the total amount [35]. *Ingram* used LCA method to study the management carbon footprint of red maple forest during planting. The life cycle of the study included 1-year seedling production and 4-year seedling field management. It was found that the carbon emission (CO_2-eq) footprints were 2.9 kg/plant for tube feeding materials and the consumption of fuel and energy was 10.3 kg/plant during production, at a distance. In 386 km of transportation, 4.0 kg/plant and 3.3 kg/plant in planting and landscape sites, the most carbon emissions were from production to planting, accounting for 17.7 kg/plant and accounting for 86% of the total greenhouse gas emissions [36]. Haas et al. assessed the environmental impacts of intensive, extensive, and organic forage management in 18 grasslands in Allgau, Bavaria, and southwestern Germany by LCA. The energy consumption of tube feeding was 19.1, 8.7, and 5.9 GJ/ha/y^{-1}, respectively, while the greenhouse gas emissions were 9.4, 7.0, and 6.3 t/ha/y^{-1}, respectively. It was concluded that organic animal husbandry was more environmentally friendly and intensive animal husbandry had a stronger environmental impact [37].

At present, there are few studies on the environmental impact of urban green space using LCA. In 2015, Dr. Ji Yuan-yuan summarized the carbon emission inventory of landscape sites in the production, construction, maintenance, and abandonment stage. She believed that the main consumption material in maintenance stage includes fossil energy, irrigation water, fertilizer, and pesticides [38]. Strohbach and Haase believe that the total carbon emissions per hectare of urban green space in Leipzig (Germany) are about 2.6–4.7 t/CO_2 in 50 years after its construction [39].

3. The LCA of urban green space maintenance

3.1 Goal and scope definition

The purpose of urban green space maintenance is to ensure the realization of landscape services. Therefore, the continuous supply of usability of green

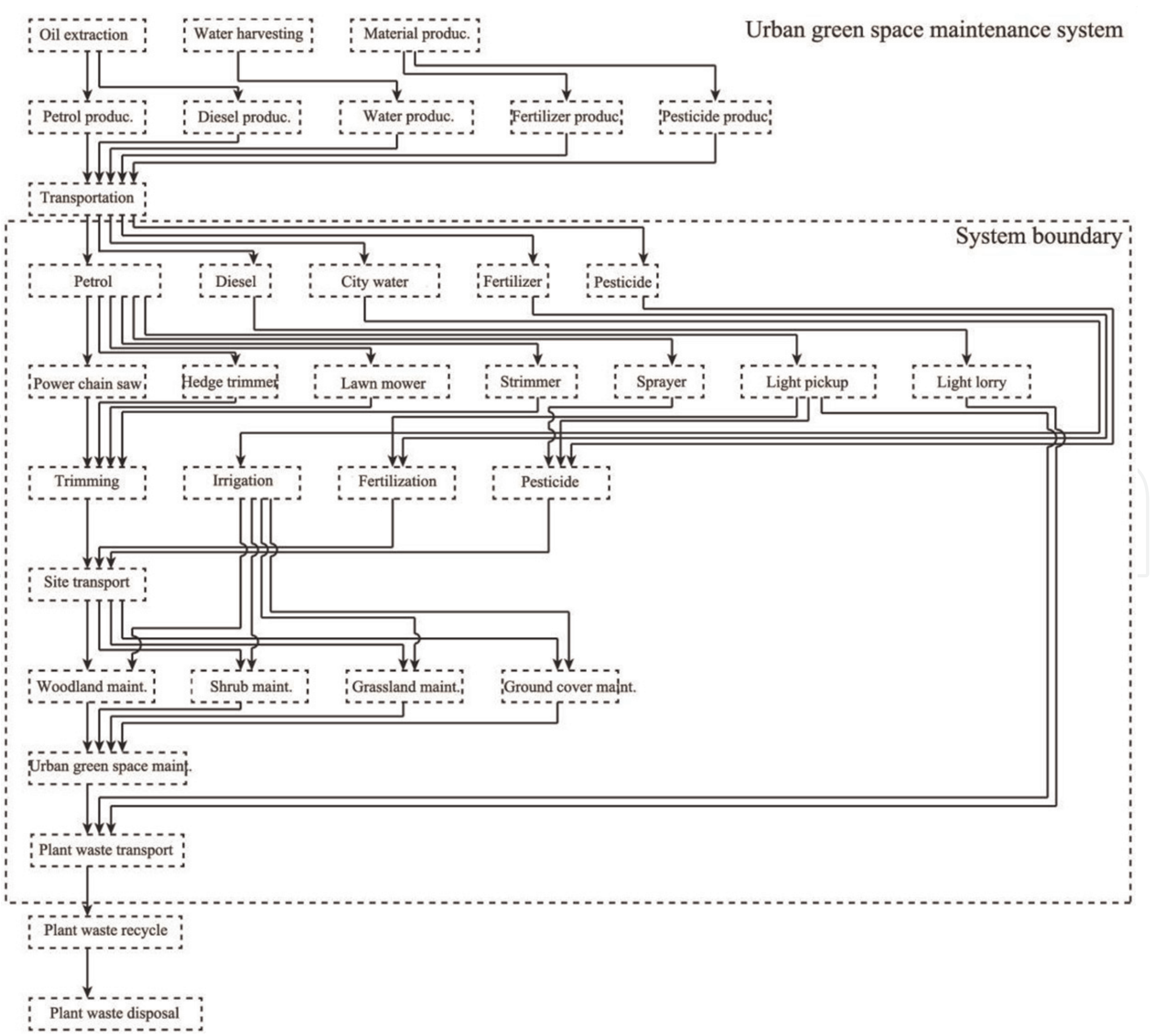

Figure 4.
The LCA system boundary of urban green space maintenance.

landscapes that meet the design requirements can be regarded as the "product" of maintenance work. Therefore, the environmental impact of the maintenance tasks can be defined as the goal of the green space maintenance LCA.

The maintenance of green space has long-term and repetitive characteristics. After the completion of the green space, the management work is continuously carried out. Although the content of the maintenance work will change with the growth of plants, the change is not obvious reflected in the annual period. Jiang Shipping divides the green space into three stages: initial age (≤3 years), middle age (4–10 years), and mature age (>10 years). It is considered that the annual management content of each stage is repeated [40]. Therefore, in the urban green space LCA evaluation, the life cycle of each stage green space can be carried out annually.

3.2 System boundary and LCI data collection

The system boundary is the evaluation scope of the LCA, and the material consumption and waste discharge within the system boundary are the substance list. When conducting LCA evaluation of products or behaviors, the related upstream and downstream processes are very intensive. Some process factors participate in system construction, but the environmental impact on the system is limited, or the environmental impact data is not clear. In order to avoid interference with the accuracy of the evaluation results, these processes are generally excluded from the system boundary. **Figure 4** is a systematic flowchart of urban green space maintenance. The plant combinations of green space are divided into four layer

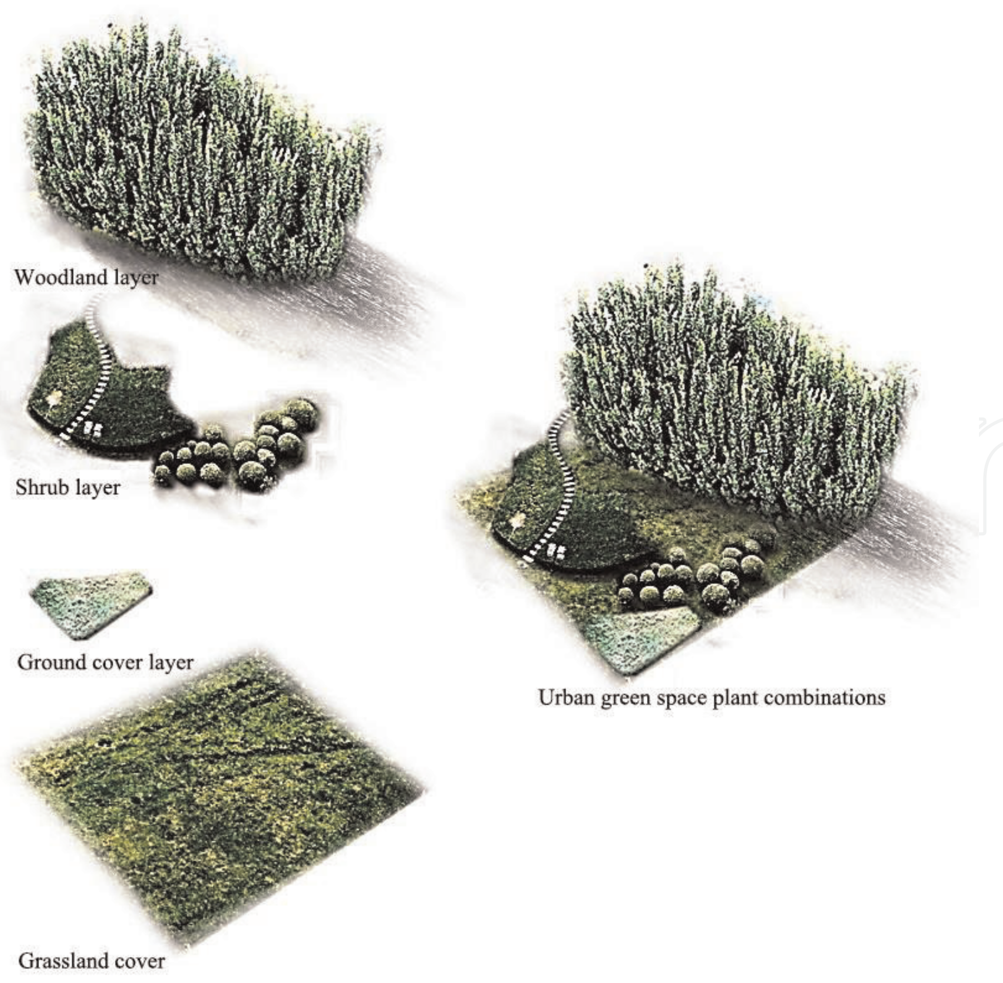

Figure 5.
The plant combinations in urban green space.

subsystems of trees, shrubs, ground cover and turf based on the difference in maintenance work (**Figure 5**).

Figure 4 shows that the upstream of the system mainly contains the production and sales of the maintenance materials. This part of the list can be obtained by referring to the CLCD or by referring to the same LCA evaluation results. However, the upstream data is mostly the market average, and there may be large deviations [41]. In the system downstream, due to the different waste recycle ways taken by the different maintenance teams, the environmental impact list is difficult to obtain. Therefore, The LCA of green space maintenance system mainly includes on-site energy consumption and emissions. The list of this part comes from on-site investigation and has high reliability, which is also a direct reflection of the environmental impact of maintenance.

3.3 Characterization model of environmental impact in urban green space maintenance

Based on the general characterization model of LCA, using the equivalent coefficient of energy consumption and global warming potential (GWP) or climate warming potential, we establish an environmental impact characterization model of the maintenance material input and GHG emission inventory:

$$EC_g = \sum_i^n \alpha_{ei} \times A_{wi} \tag{4}$$

EC_g refers to the characteristic quantity (MJ) of urban green space management resource and energy consumption. α_{ei} represents the resource and energy consumption equivalent coefficient of the species i list in the system. A_{wi} refers to the input amount of the i substance in the system.

The calculation of the A_{wi} value of petrol- and diesel-powered maintenance equipment can be obtained by the following formula:

$$A_{wi} = \sum_a^n \frac{M_{wa}}{E_{ea}} \times \beta_a \tag{5}$$

where a is the maintenance equipment associated with the maintenance substance i in the system. M_{wa} refers to the workload of the maintenance equipment within the system boundary. E_{ea} and β_a represent the working efficiency and fuel consumption per time unit.

The calculation method of the GWP potential (kg/CO_2) EI_g of urban green space management is as follows:

$$EI_g = \sum_i^n \alpha_{ci} \times A_{wi} + EI_{eg} \tag{6}$$

α_{ci} is the GWP equivalent coefficient of the i input in the system. EI_{eg} is the GWP characteristic quantity of the maintenance equipment used in the system boundary, which can be calculated by the following formula:

$$EI_{eg} = \sum_a^n \frac{M_{wa}}{E_{ea}} \times (A\gamma_a \times A\alpha_{ci} + B\gamma_a \times B\alpha_{ci} + C\gamma_a \times C\alpha_{ci}) \tag{7}$$

$A_{\gamma a}$, $B_{\gamma a}$, and $C_{\gamma a}$ are the emission amount of climate warming factors CO_2, CH_4, and N_2O in the system boundary, respectively. $A\alpha_{ci}$, $B\alpha_{ci}$, and $C\alpha_{ci}$ refer to the equivalent coefficient of CO_2, CH_4, and N_2O, respectively.

4. The quantification of environmental impact in urban green space maintenance

4.1 Introducing of research area

The research area of quantification of urban green space maintenance environmental impact was located in Zhengdong New District, Zhengzhou (China). The

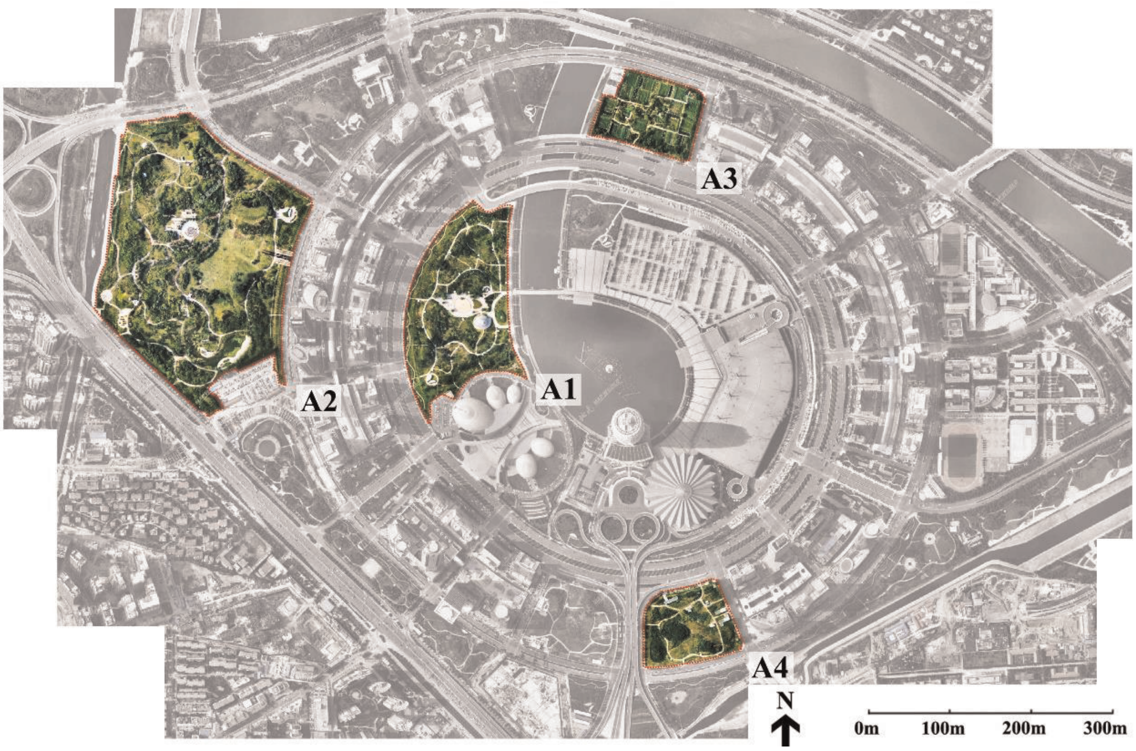

Figure 6.
The research sites in CBD area of city Zhengzhou. Resource: http://map.tianditu.com/

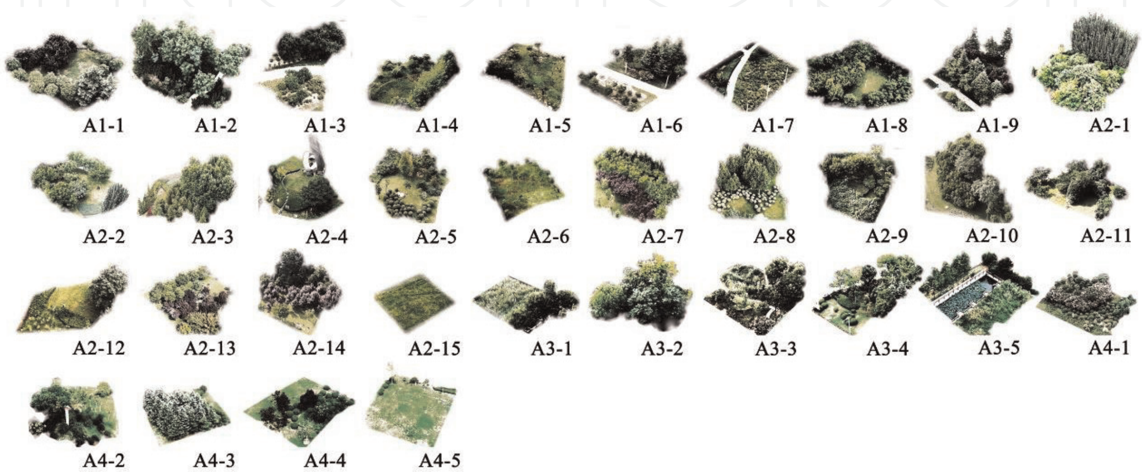

Figure 7.
The sample plots in research sites.

Inventory of maintenance material	Units (U)	Woodland (U/ha/y^{-1})	Shrubs (U/ha/y^{-1})	Ground cover (U/ha/y^{-1})	Grassland (U/ha/y^{-1})
Petrol	kg	0	2×10^1	0	3.6×10^1
Diesel	kg	2.1×10^1	9.8×10^1	3.0×10^1	7.1×10^1
City water	m^3	1.3×10^4	1.5×10^4	1.3×10^4	1.6×10^4
Fertilizer	kg	1.4×10^2	1.6×10^2	1.3×10^2	1.5×10^2
Pesticide	kg	1.0×10^1	2.7×10^1	1.1×10^1	4.5×10^1

Table 2.
Maintenance material input list in urban green space.

Equipment type	Energy type	Unit	Working efficiency/unit	Energy consumption (kg/unit)	GHG emission (kg/unit)		
					CO_2	CH_4	N_2O
Hedge strimmer	Petrol	h	300 m^2	0.60	1.69	8.96×10^{-3}	3.20×10^{-4}
Hand-driven mower	Petrol	h	300 m^2	1.50	1.80	9.10×10^{-2}	9.02×10^{-4}
Riding mower	Petrol	h	2000 m^2	2.30	2.68	3.74×10^{-3}	5.40×10^{-4}
3 m^3 light pickup	Diesel	h	20 km	1.00	3.43	8.11×10^{-3}	5.22×10^{-4}
5 m^3 light lorry	Diesel	h	20 km	2.60	6.20	1.81×10^{-3}	9.39×10^{-4}

Table 3.
Energy consumption and GHG emission inventory of maintenance equipment.

green coverage rate in research area is 49.1%. The construction of green space in the CBD area was completed in 2004, and it is a mature green area. The survey sites are (1) Hongbaihua Park with an area of 106,000 m^2; (2) Zhengzhou Forest with an area of 264,000 m^2; (3) Zhengdong New District Wetland Park with an area of 44,000 m^2; and (4) No. 6 parking lot with an area of 39,000 m^2. The plot area is 453,000 m^2, accounting for about 60% of the total urban green area of the CBD (**Figure 6**). Thirty-four plant community samples of 20 m × 20 m were set in the research sites (**Figure 7**).

4.2 LCI data collection

The LCI data collection consists of two parts (2017.06–2018.07): (1) plant structure: the area (m^2) of each plant layer in the sample survey site and the tree layer are calculated by the projected area of the canopy; (2) material input list: annual workload of each plant layer maintenance (trimming, irrigation, fertilization, pesticide, and plant waste removal). **Table 2** shows the average amount of maintenance material inputs per ha of urban green space calculated according to the data collected in research samples. **Table 3** shows the energy consumption and GHG emission of the maintenance equipment tested in the field.

4.3 The LCA result of environmental impact in urban green space maintenance

See **Tables 4** and 5.

Environmental impact factor	Plant layers	Maintenance task					
		Trimming	Irrigation	Fertilization	Pesticide	Waste transport	Total
Resource and energy consumption (MJ/ha/y^{-1})	Woodland	0	3.14×10^4	1.13×10^4	1.47×10^3	9.00×10^2	4.51×10^4
	Shrubs	8.62×10^2	3.67×10^4	1.25×10^4	3.89×10^3	4.18×10^3	5.81×10^4
	Ground cover	0	3.29×10^4	1.07×10^4	1.60×10^3	1.29×10^3	4.64×10^4
	Grassland	1.56×10^3	4.12×10^4	1.19×10^4	6.41×10^3	3.02×10^3	6.41×10^4
GWP potential (kg CO_2-e/ha/y^{-1})	Woodland	0	0^{*1}	2.12×10^2	3.61	5.29E+01	2.68×10^2
	Shrubs	6.58×10^1	0^{*1}	2.34×10^2	9.52	2.46×10^2	5.56×10^2
	Ground cover	0	0^{*1}	2.00×10^2	3.92	1.13×10^2	3.16×10^2
	Grassland	6.58×10^1	0^{*1}	2.24×10^2	1.57×10^1	2.67×10^2	5.72×10^2

Table 4.
Environmental impact characteristics of each plant layer in mature green space maintenance.

Plant layer	Environmental impact factor	Weighted environmental impact index (ha/y^{-1})					
		Trimming	Irrigation	Fertilization	Pesticide	Waste transport	Total
Woodland	Resource and energy consumption	0	1.33×10^{-3}	4.80×10^{-4}	6.26×10^{-5}	3.82×10^{-5}	1.91×10^{-3}
	GWP potential	0	0	3.70×10^{-3}	6.30×10^{-5}	9.24×10^{-4}	4.68×10^{-3}
	Sum	0	1.33×10^{-3}	4.18×10^{-3}	1.26×10^{-4}	9.62×10^{-4}	6.60×10^{-3}
Shrubs	Resource and energy consumption	3.66×10^{-5}	1.56×10^{-3}	5.31×10^{-4}	1.65×10^{-4}	1.78×10^{-4}	2.47×10^{-3}
	GWP potential	1.15×10^{-3}	0	4.09×10^{-3}	1.66×10^{-4}	4.30×10^{-3}	9.71×10^{-3}
	Sum	1.19×10^{-3}	1.56×10^{-3}	4.62×10^{-3}	3.32×10^{-4}	4.48×10^{-3}	1.22×10^{-2}
Ground cover	Resource and energy consumption	0	1.40×10^{-3}	4.53×10^{-4}	6.81×10^{-5}	5.47×10^{-5}	1.97×10^{-3}
	GWP potential	0	0	3.49×10^{-3}	6.85×10^{-5}	1.97×10^{-3}	5.53×10^{-3}
	Sum	0	1.40×10^{-3}	3.94×10^{-3}	1.37×10^{-4}	2.03×10^{-3}	7.50×10^{-3}
Grassland	Resource and energy consumption	6.61×10^{-5}	1.75×10^{-3}	5.07×10^{-4}	2.72×10^{-4}	1.28×10^{-4}	2.72×10^{-3}
	GWP potential	1.15×10^{-3}	0	3.91×10^{-3}	2.74×10^{-4}	4.67×10^{-3}	1.00×10^{-2}
	Sum	1.22×10^{-3}	1.75×10^{-3}	4.41×10^{-3}	5.46×10^{-4}	4.79×10^{-3}	1.27×10^{-2}

Table 5.
Weighted environmental impact index of each plant layer in mature green space.

Author details

Ning Li[1] and Yang Liu[2]*

1 Henan Agricultural Landscape Planning and Design Institute, Zhengzhou, China

2 College of Forestry, Henan Agricultural University, Zhengzhou, China

*Address all correspondence to: kelivnliu@163.com

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