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**Original Research Article**

# Research on parametric landscape design for urban biodiversity conservation

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## ABSTRACT

Biodiversity has brought rich material products and non-material benefits to mankind, and is an important support for the sustainable development of human society. Although people realize the importance of improving biodiversity under the pressure of rapid disappearance of biodiversity, few people have fully explored the parametric design of biodiversity in urban landscapes. Therefore, this article briefly describes the development process of urban landscape biodiversity, taking examples of different types and different scales at home and abroad as examples, comparing its parameterized evaluation and design models, and analyzing the parametric design in the urban landscape and the biodiversity target organic ways and means of combination. On this basis, the approach of urban landscape design for biodiversity is explored, its development trend and main problems are prospected, and the corresponding enlightenment for the future development of urban biodiversity and practical reference are provided.

***Keywords:*** landscape architecture; biodiversity; urban landscape; parametric; landscape approach; design system

Biodiversity is an important support for human survival, which is of great significance to the ecological balance and sustainable development of cities [1–2]. At the same time, biodiversity is also an important evaluation index of ecological health of human settlements [3–4]. However, in urban areas, under the interference of intense and frequent human activities, the ecosystem is rapidly degraded, the natural habitat is decreasing and the degree of fragmentation is increasing, and the urban biodiversity is facing a sharp decline [5]. Under this background, the research on urban biodiversity protection has become a hot spot of social concern. Many studies have found that human-led landscape design can restore and protect biodiversity, and even improve local biodiversity [6–7]. This indicates an effective way of protection, that is, by rationally regulating the existing landscape ecosystem and planning and designing a new landscape pattern, the fragmentation of habitat can be reduced, and it will have a positive impact on biodiversity and urban landscape [8]. Therefore, landscape planning and design has become an effective way to solve the problem of urban biodiversity. However, due to the complexity of the urban environment, the landscape planning and design under the guidance

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of biodiversity conservation is still in the research stage of continuous exploration, and the research ideas and means are in urgent need of new breakthroughs. At present, from the perspective of urban development history and frontier research at home and abroad, parametric design just provides a new way of thinking and technical means.

Parameterization, as a medium, can establish a comprehensive connection between nature, technology and human beings, and control and visualize the process and results [9]. Facing the complexity and variability of urban society, the design based on parametric thinking more scientifically explains the relationship and generation process between the site and the final design form, and makes the design couple with the inherent characteristics, laws and processes of the site [10–11]. Applying parametric thinking method to urban landscape planning and design is also of great significance to the protection and promotion of urban biodiversity. Therefore, this article first summarizes the landscape planning and design based on urban biodiversity conservation research progress, and secondly by comparing the case study of different types, different scale at home and abroad, analyzes its parametric evaluation index system and model of evaluation and design of concrete application method, finally, the future urban landscape biodiversity research trend was discussed, It provides theoretical and practical reference for landscape planning and design of urban biodiversity conservation.

# 1. Development history

## 1.1. Enlightenment Stage

Biologic diversity/biodiversity (Biologic diversity/biodiversity) is the total diversity and variability of living organisms and their constituent systems, including the sum of various ecological processes related thereto [12]. Since the early 1980s, biodiversity protection and related research have attracted widespread attention from the international community, and China's biodiversity research has gradually emerged in terms of the conservation value of biological species, ecological characteristics, threatened status, germplasm resources and so on [13]. Thanks to the rapid development of the modern theory of many subjects, especially in geographical science, landscape ecology and protect the development of ecology, the connotation of biodiversity is no longer limited to traditional biodiversity research ecosystem diversity, species diversity and genetic diversity of three aspects, but extended to the differences of geographical environment, biological habitat and diversity [4]. At the same time, with the rapid development of the theory and practice of landscape architecture towards modern science, its field of concern has gradually shifted from the traditional garden construction and spatial organization to the planning and design of regional and territorial space, thinking about the role of landscape architecture in the construction of human settlement environment from a larger pattern. In particular, under the guidance of the theory of landscape ecology, there have been discussions on landscape diversity, including the diversity of landscape structure, function and time change [14].

In the process of this study, some scholars have proved that biomass diversity is closely related to landscape diversity [15], and traditional biodiversity protection focuses on the protection of individual species while ignoring the construction of species' living environment, which cannot achieve good results. This promotes the transformation of biodiversity conservation approach from species-centered nature conservation approach to landscape ecological planning and design approach [16–17]. At the same time, theories and methods of landscape planning and design based on biodiversity conservation have been gradually developed.

## 1.2. Development Stage

With the development of urbanization process, the developing mode of sprawl and the sustainable use of natural resources, and landscape heterogeneity of habitat fragmentation, the genetic variation within the species and species richness has a negative effect [18], prompting them to biodiversity low conversion system, has a major impact on global biodiversity (19–20). Cities are faced with serious ecological problems such as loss of biodiversity, reduction of natural habitat area, habitat fragmentation, and fragile ecosystem [21]. In order to promote the urban development in the direction of the benign and sustainable evolution, biodiversity protection is no longer simply the natural shelter in a limited number of reserve [22], management of specific green space, or inside some of the preservation and restoration of city habitat [23], but consider the construction of urban ecological network, from a perspective of the overall urban planning of biodiversity protection, Therefore, landscape planning and design based on urban biodiversity conservation has been gradually carried out around the world (**Table 1**).

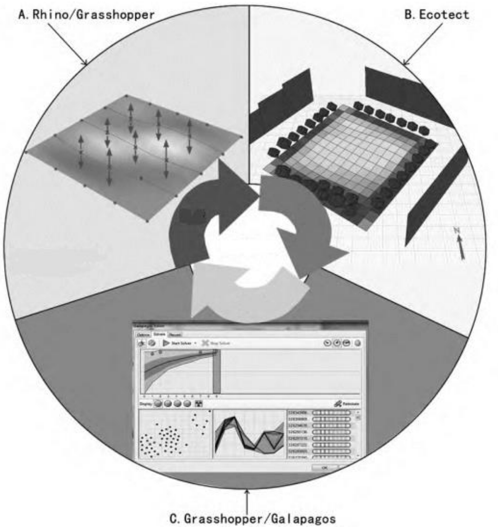

**Figure 1.** Design flow of terrain generation subsystem (modified from reference [37])

At this stage, scholars at home and abroad put forward a series of landscape planning approaches for urban biodiversity protection based on the actual situation, and landscape planning oriented by urban biodiversity protection developed rapidly. However, most of the existing studies focus on large-scale planning and strategy, and the method at the planning level is relatively macro. There is still a lack of more effective design methods to comprehensively implement the multi-scale planning and design objectives of urban macro -, meso - and micro-scale, especially to use parametric methods to deeply explore urban biodiversity at small and medium-sized scales.

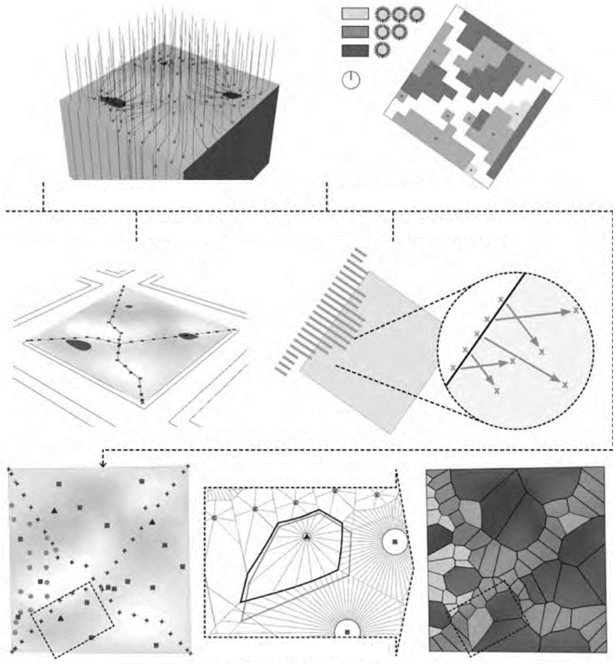
**Figure 2.** Design flow of spatial organization subsystem (modified from reference [37])

## 1.3. In-depth exploration stage

The digital revolution produced by the rapid development of computer technology also brings new opportunities for the development of landscape architecture. As a product of information technology development at a certain stage [29], landscape parametric design occupies a prominent position in the digital planning and design process of landscape architecture and is one of the most important development directions in the future.

At present, the research focus of landscape parameterization includes landscape digitalization and simulation technology, landscape architecture analysis and evaluation, and parametric design [30]. The former led to the development of ecological auxiliary parametric design technology, the corresponding software platform is in constant construction, and form the relatively perfect system, including based on the analysis of meteorological data analysis, thermal environment, wind environment simulation, simulation of water environment, light environment simulation, parametric analysis of ecological environment [31], as the latter in the study of the introduction of digital technology, To solve practical problems in the field of landscape architecture. In recent years, the focus of research on parametric landscape has gradually shifted from landscape digitalization and simulation technology to landscape architecture analysis and evaluation and parametric design, which provides an important basis for in-depth exploration of landscape planning and design methods for urban biodiversity conservation.

Parametric design is different from the previous design which emphasizes sensibility and aesthetics, and pays more attention to scientific and rational analysis. In a word, it is a kind of thinking method that emphasizes logical description relations. It can understand the essence of things by associating mathematics, geometry and algorithmic logic with design problems, instead of parameterization as a technique

Tools to assist the realization of design results [32]. In particular, parametric models based on understanding ecological processes play an important role in assessing biodiversity and guiding landscape planning and design [33]. At this stage, Julius Fabos developed the quantitative landscape analysis model, and William Marsh developed the theories and technical means closely related to biodiversity planning [4]. Rod Barnett used Netlogo software to simulate the movement of complex systems and provided an effective reference for the design of biodiversity restoration after hurricane disturbance [34]. At the same time, some parameterized landscape design methods and cases of urban biodiversity conservation at small and medium-sized scales have emerged in the academic community (Table 2), focusing on how to coordinate the relationship between biodiversity conservation and other macro planning and design objectives in practice. Although these cases need to be improved, they can still provide valuable practical experience and inspiration for future urban biodiversity planning and design.

## 2. Parametric landscape design system case study

### 2.1. Landscape design generation system

The Generative Landscape Design System (GLDS) was proposed by E. Charalampidis of Aristotle University in Thessaloniki, Greece, in their research on urban public Spaces in Thessaloniki. It aims to improve urban green infrastructure development and ecological performance while enhancing biodiversity through natural processes, algorithms and statistical analysis [37]. The GLDS consists of four different subsystems with linear correlations, each governed by a model of several self-organizing strategies (Figure 1–4).

The biodiversity design of the system is mainly manifested in the following aspects: 1) combining biodiversity with human activities, using mathematical models of natural processes, algorithms and statistical analysis, directly linking the form of the design scheme with its environmental and ecological performance, and rationally planning human activities and plant spatial forms; 2) The form generated by mutual correlation and mutual influence between its sub-systems; 3) As an analytical tool, parameterized software such as Rhinoceros, Ecotect and Grasshopper can be used to provide relevant feedback on the effects of sunlight, solar radiation, hydrology and topography on plant species.

This system is an effective way to support the improvement of biodiversity in green space at a small scale in the city. However, the functional characteristics of biodiversity protection in this system are not obvious at present. If the vegetation can be combined with the suitable habitat of other species, the function of this system will be stimulated more greatly. For example, marycarol Hunter took butterfly pollination characteristics, bird habitat and vegetation into comprehensive consideration to design habitats supporting birds and butterflies co-habitat [39]. Chad Hawthorne generates vegetation type structures in butterfly habitats gardens based on butterfly life history, butterfly needs, and butterfly behavior throughout the butterfly life cycle. Therefore, the establishment of a species activity analysis subsystem closely related to other subsystems in the landscape design generation system will further enhance the biodiversity protection function of the system.

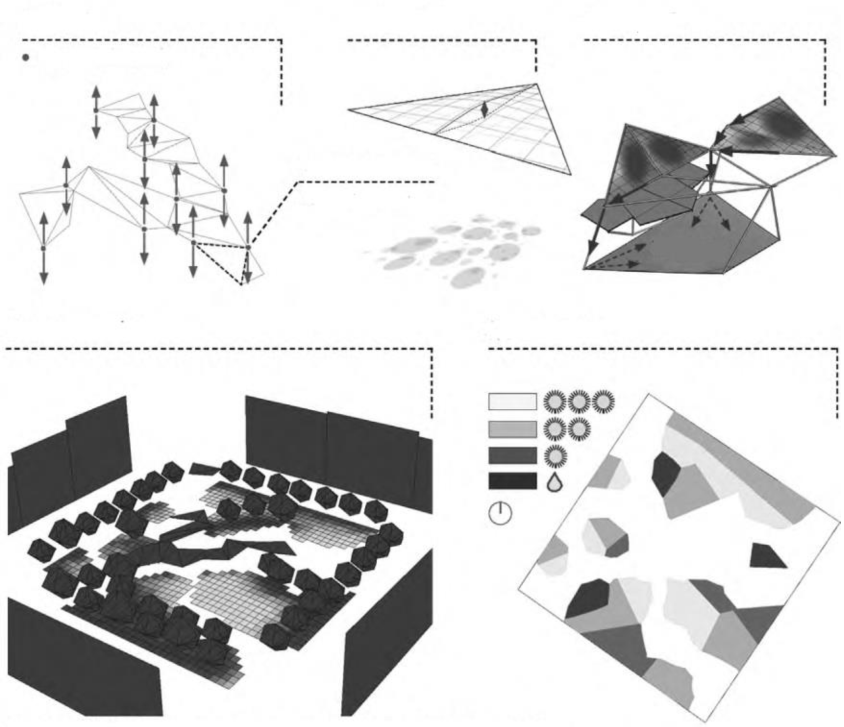

**Figure 3.** Design flow of shading structure generation subsystem (modified from reference [37])

**Table 1.** Studies on landscape planning approaches for urban biodiversity conservation at home and abroad

| To build | Way | Characteristics of the |
|---|---|---|
| Czech Republic and other Eastern European countries | "Landscape stability" approach | Based on the establishment of the spatial structure of the landscape, the harmonious relationship between vegetation and natural state is created by determining and improving the defects in the ecological network [24]. |
| The United States | The "Green Corridor" approach | Planning the maintenance and establishment of corridors from a broader landscape scale, green corridors often have other ways, such as leisure, wood production, environmental protection, etc. [24] |
| Germany | "Community mapping" approach | Using biota mapping as an important tool to protect urban biodiversity, formulate urban scale and design strategies for ecological protection policies [25] |
| In the Netherlands, | The "focal species" pathway | Certain "focal species" will be selected from biological populations, and their requirements for ideal living space and living habits will be used as guidelines for planning ideal landscape [26] |
| Japan, Australia | The "natural introduction" approach | The introduction of natural community structure mechanism or the establishment of artificial communities with similar structure in the city protects and enriches urban biodiversity [16] |
| Belgium | The "multiscale" approach | Planning, design and management are carried out from different levels of spatial scale, from the site environment of a plant to the whole urban ecosystem and even the surrounding area of the city [27] |
| Spain, Finland | "Habitat Islands" approach | A series of conservation strategies proposed based on studies of biological distribution patterns and processes (habitat island size, connectivity, complexity, edge effects, external disturbances, etc.) [27] |
| China | "Landscape ecological security pattern" approach | By identifying the key local and spatial connections of landscape, the species' ability to explore and occupy space is used to protect biodiversity [28]. |

## 2.2. Ecological model design system

Eco-model designsystem (EMDS) was proposed by Shanghai natives and Ignacio Lopez of tongji university in the practice of managing parks in Shanghai. It is a conceptual method of integrated application of landscape design, computing technology and remote sensing technology [38]. EMDS helps designers assess and design the environment by inferring and analyzing the relationship between elements in the site through data superposition. This model adopts the main techniques used in large-scale regional design, and applies similar techniques to the largely unexplored medium and small scale environments. It aims to break through the large-scale planning of contemporary urban diversity conservation, and further explore the biodiversity design of medium and small scale sites.

**Table 2.** Parameterized landscape design for biodiversity conservation from the perspective of urban small-scale

| Study author and time | Design method | Meaning | The application case |
|---|---|---|---|
| Connery, 2009 | Design system integrating regional ecological Network at block and site scale [35] | The concept of Biotope Area Factors (BAF) provides a method to quantify biodiversity at the block scale | Vancouver East Fraser Community planning and design |
| AECOM, 2013 | Landscape biodiversity Planning and Design System based on Landscape Biodiversity Index as an important parametric evaluation method [36] | Landscape Biodiversity Index (LBI) also provides a method to quantify Biodiversity and effectively coordinate the relationship between the planning and design objectives of Biodiversity in multi-dimensional scales | Singapore Jurong Lake District, Porto Paulo Wallada garden landscape planning and design |
| Charalampidis et al., 2015 | A Generative Landscape Design System for Urban Green Infrastructure Development [37] | In the small scale public space of the city, it provides a kind for human activities and ADAPTS to it However, the landscape design is helpful to enhance the biodiversity of the site | Thessaloniki Urban public space |
| Ignaciolopez (ignaciolopez) et al. 2018 | Ecological zone model design system established by inferring and analyzing the relationships among elements in the site through data superposition method [38] | Consider Biodiversity in Urban Small and Medium Scale Design through an Alternative Perspective and Technical Approach | Shanghai Guan Nong Park landscape planning and design |

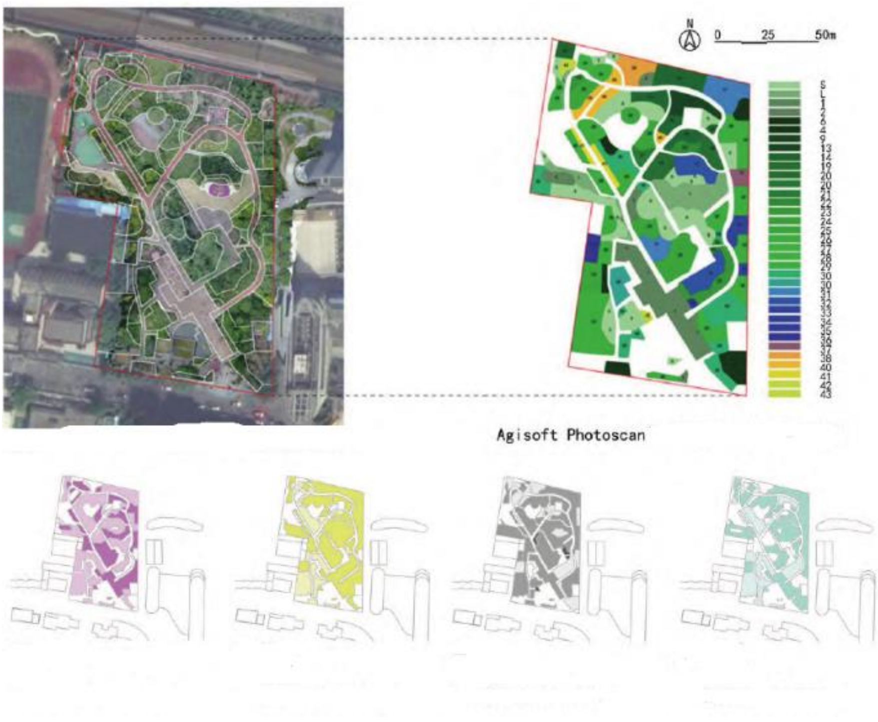


**Figure 4.** Application practice of ecological zone model design system–Shanghai Guan Nong Park (adapted from reference [38])

EMDS applications can be divided into: 1) mapping; 2) Environmental simulation and analysis; 3) Data stacking; 4) Ecological model design consists of four steps (Table 3). Of surveying and mapping of the system in integrated digital model of the field, on the basis of plant species within the area of shade, flood, wind, and high and low temperature tolerance analysis of the classified, and the field of solar radiation, wind and water runoff simulation analysis, and then the analysis data can be divided into high, medium and low three types and render the chart. Finally, the climate suitable zoning of the site was obtained by superposition of the data to guide plant selection and site design (Figure 5).

The key points of biodiversity planning and design in this system are as follows: 1) the combination of biodiversity and climate environment is taken into account, and the tolerance of plants to the environment is taken as the focus of zoning; 2) Emphasizing the functional design of ecological regions and designing landscape patterns dominated by ecological functions; 3) Improving and supplementing the system information through the parametric platform is of great benefit to the continuous research of landscape and urban biodiversity.

Similar to the GLDS system, if the tolerance analysis of plant species to various ecological environments can be combined with other species in the EMDS system, then the ecological zone formed by parametric superposition will provide more biodiversity for the site.

### 2.3. Landscape biodiversity planning and design system

The Landscape Biodiversity Planning & Design System (LBPDS) was proposed by the internationally renowned Design company AECOM in 2013 [36]. It is a design system that enhances regional biodiversity and habitat benefits through the integration of planning and design. It aims to help guide habitat conservation, restoration, urban form and landscape improvement in urban environments, including urban forests, private and public landscapes, and community open Spaces. Different from Singapore's urban Biodiversity Index from the perspective of urban macro, the Landscape Biodiversity Index (LBI) proposed in LBPDS is a more specific Index to guide Landscape practice. It is a means to enhance biodiversity, ecosystem services and achieve protection of specific areas, allowing designers to make a detailed and comprehensive assessment of the urban landscape in a quantitative manner.

The basic principle of LBI application is to compare the planned and designed landscape biodiversity with the reference ecosystem with local biodiversity. The greater the similarity between the intervention area and the ecosystem or habitat in terms of structure and pattern, the higher the LBI will be. The LBI score of each index is divided into 1~5 points [40]. The scoring system covers the performance of multiple indicators of landscape biodiversity. Basic indicators are set based on project history, empirical literature, or expert recommendations, and include landscape structure and pattern features, such as priority species, habitat quality, connectivity, and total habitat area. At the same time, the threshold value suitable for the project site is put forward by calculation analysis and Autocad drawing software. Since LBI is a "calibration" of local ecology and conservation priorities, it can be applied to multi-scale sites to evaluate the effectiveness of local biodiversity and guide the specific application of landscape biodiversity planning and design systems. The application of LBPDS includes analysis and planning steps, which can be divided into 6 parts: 1) field evaluation; 2)LBI model calibration; 3) LBI benchmark measurement of existing conditions; 4) Measure the LBI score of alternatives; 5) Create landscape guidelines (if necessary); 6) Conduct detailed landscape design.

The biodiversity planning and design of the system focuses on: 1) Taking biodiversity conservation as the leading role, using LBI assessment to guide landscape planning and design, and emphasizing native ecology and conservation priorities; 2) Using the vertical structure and horizontal pattern of habitat as the LBI index framework, biodiversity assessment indicators could be added according to site characteristics on this basis. 3) Assessment of biological features in any type of landscape, from nature to city; 4) Plant community design in landscape construction as the key, through different development strategies to protect and enhance biodiversity and habitat connectivity, to achieve the co-prosperity of human and nature.

## 3. Enlightenment and Prospect

### 3.1. Construct landscape design methods to

**enrich urban biodiversity**

The benefits brought by biodiversity to human society and ecosystem have been verified in more and more studies, and habitat planning and design with diversity as the core is gradually becoming the most potential demand field [41]. At present, China is still in the stage of rapid urbanization, and the concept and method of biodiversity conservation are gradually developing from the core of species genetic protection to the core of landscape planning and design protection. Therefore, how to protect and restore urban biodiversity through landscape design will develop into an important research and practice field of landscape architecture. Recently, biodiversity has been taken as one of the goals in the planning and design of many domestic and foreign projects. However, there are still many ways to improve biodiversity in practice, and further exploration is needed in theory and technical methods.

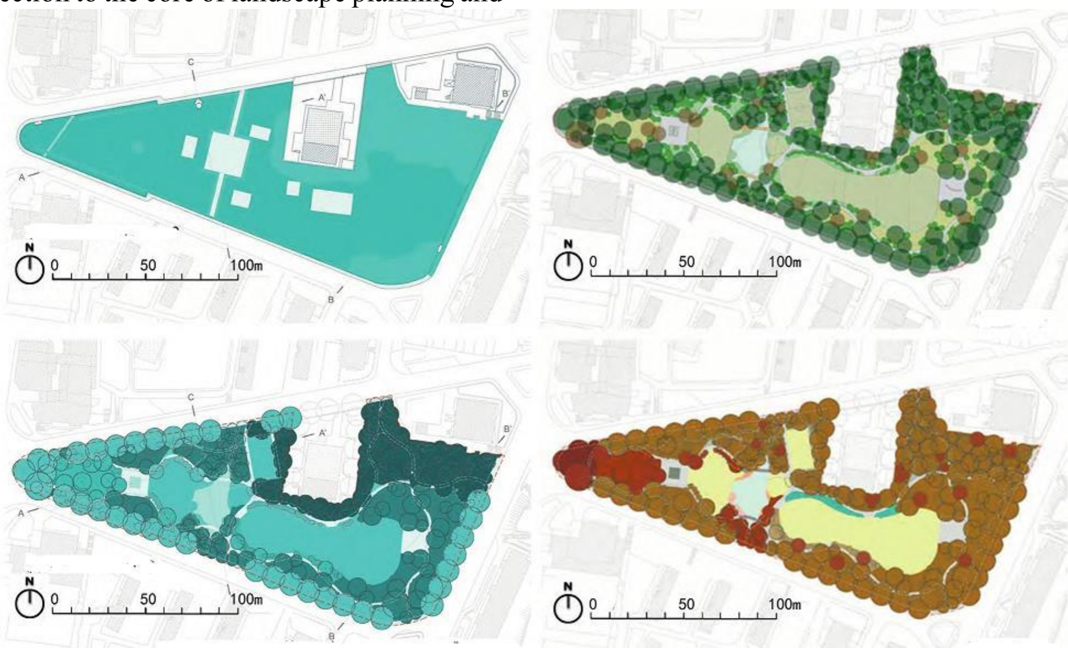


**Figure 5.** Application of LBPDS in Porto's Paolo Varada Garden (adapted from reference [41])

**Table 3.** Summary of steps and methods of ecological model design [37]

| Phase | The target | Parameter chemical tool | The data source |
|---|---|---|---|
| Surveying and mapping | Create a comprehensive digital model of the site, including current conditions, environmental parameters, and existing plant species | 1.uavs (DJI Mavic)<br>2.PIX4D Capture App<br>3.Agisoft Photoscan<br>4.Rhinoceros3d | Google Earth<br>Openstreetmaps<br>Epwmap |
| Environmental simulation analysis | Quantitative data are obtained based on digital model analysis and simulation of current conditions and environmental constraints: solar radiation, wind and water accumulation | 1.Rhinoceros3d<br>2.Grasshopper (with Ladybug)<br>3.Excel | Epwmap |
| The data stack | Organize, reclassify and overlay different analysis layers in order to determine the climatic zoning of the site | 1.Rhinoceros3d<br>2.Grasshopper | - |
| Ecological model design | Relate the climatic zoning of the site to plant species that match the properties of each block | 1.Rhinoceros3d<br>2.Grasshopper<br>3.Excel | - |

## 3.2. Strengthen the multi-scale, multi-type and multi-disciplinary research on biodiversity

Due to the complexity of the structure of the biodiversity and ecosystem, between its own functions and processes, as well as there is complex relationship between economic social culture, only from a single scale and type of thinking is not enough, need to study the individual space to urban green space structure of green space network, even multi-scale nested g. Full discussion and argument [42]. In addition, landscape approaches to biodiversity conservation mainly focus on the selection of adaptive plant species, and the composition of more complex habitats still needs to be further considered. At the same time, a broader view of biodiversity strategies should be advocated, emphasizing integrated ecosystem service benefits such as carbon sequestration, water quality improvement, mitigation of urban heat island effects, and other socio-cultural benefits. This requires interdisciplinary and professional integration. For example, landscape planning and design should be integrated with water conservancy projects, transportation infrastructure projects, agricultural and forestry activities, and urban development and construction to improve the breadth and universality of landscape approaches for biodiversity protection [43].

### 3.3. Improve the evaluation and supervision mechanism of biodiversity protection

Biodiversity protection is a systematic and long-term project, not only need to establish a stable and effective design model and system, more need to improve the evaluation and supervision mechanism [44], form the elasticity, the dynamic feedback regulation system, and gradually developed a set of suitable for China's national conditions and characteristics of regional climate environment assessment concept framework and monitoring management mode. The current assessment system still needs to be improved. For example, in the practical application of landscape biodiversity planning and design system, it is difficult to establish a reference habitat to calibrate indicators to guide biodiversity design when the urban landscape has undergone great changes. In addition, most of the current assessment systems focus on vegetation, and most of the proposed design methods for biodiversity of different species, such as insects, birds and fish, are based on vegetation diversity, without paying enough attention to the species themselves. At the same time, how to parameterize the score of social and cultural factors, how to make use of key social factors to achieve adaptive and collaborative landscape management, and provide a way for the public to participate in the assessment and supervision, these issues still need to be improved in the future development.

### 3.4. Parametric application research of biodiversity conservation in the context of big data is advocated

In the era of big data, parametric technology is developing vigorously. Parameterized landscape approach to urban biodiversity conservation brings not only the innovation of research methods, but also the transformation of thinking mode. From the above research cases, it can be seen that the application of biodiversity parameterization is still limited to biodiversity assessment, coding and ecological environment simulation, and there are still many limitations and adaptability problems in the evaluation index system and model methods. Therefore, strengthening real-time monitoring and feedback, predicting more accurate future trends of urban biodiversity based on climate change simulation, formulating positive and appropriate coping strategies and doing a good job in demonstration application can make future urban landscape more scientific, forward-looking and sustainable.

## Conflict of interest

The authors declare no conflict of interest.

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