OKU Fen Bilimleri Enstitüsü Dergisi
9(1): 565-581, 2026

OKU Journal of The Institute of Science and Technology, 9(1): 565-581, 2026

Osmaniye Korkut Ata Üniversitesi Fen Bilimleri Enstitüsü Dergisi

Osmaniye Korkut Ata University Journal of The Institute of Science and Technology

Parametric and Symbiotic Approaches in Landscape Architecture: New Urban Space Paradigms

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Reviews

Article History:
Received: 01.06.2025
Accepted: 10.10.2025
Published online:13.01.2026

Keywords:
Landscape architecture
Parametric design
Symbiotic city
Sustainability

ABSTRACT

Environmental, social and spatial problems faced by today's cities necessitate new design paradigms in landscape architecture. This study investigates how the parametric design approach in landscape architecture can be evaluated within the framework of the symbiotic city concept. The aim is to conceptually and theoretically reveal the intersection point of these two concepts by supporting the symbiotic city vision, which aims to establish a mutually beneficial relationship between nature and the city, with parametric design tools. In the study based on a qualitative research method, literature review, conceptual analysis and thematic synthesis techniques were used. The findings obtained show that these two approaches play a complementary role in the process of producing not only formal but also functional, systemic and sustainable design decisions in landscape architecture. The study revealed that the symbiotic city approach is a systematic planning model that advocates the integration of natural and built environments on the basis of mutual benefit, and that parametric design is a powerful tool that enables the integrated modeling of these systems with environmental and social data. It is also emphasized that landscape architecture plays a spatial and systemic unifying role that can combine both approaches. The results reveal that landscape architects can develop integrated designs at ecological, social and technical levels by making symbiotic relationships more readable, simulatable and measurable through parametric tools. In this context, the discipline of landscape architecture is being redefined as a strategic actor in the sustainable transformation of cities.

Peyzaj Mimarlığında Parametrik ve Simbiyotik Yaklaşımlar: Yeni Kentsel Mekân Paradigmaları

Derleme

Makale Tarihçesi:
Geliş tarihi: 01.06.2025
Kabul tarihi:10.10.2025
Online Yayınlanma:13.01.2026

Anahtar kelimeler:
Peyzaj Mimarlığı
Parametrik Tasarım
Simbiyotik Kent
Sürdürülebilirlik

ÖZ

Günümüz kentlerinin karşı karşıya kaldığı çevresel, sosyal ve mekânsal sorunlar, peyzaj mimarlığında yeni tasarım paradigmalarını gerekli kılmaktadır. Bu çalışma, peyzaj mimarlığında parametrik tasarım yaklaşımının simbiyotik kent kavramı çerçevesinde nasıl değerlendirilebileceğini araştırmaktadır. Amaç, doğa ve kent arasında karşılıklı faydaya dayalı bir ilişki kurmayı hedefleyen simbiyotik kent vizyonunu, parametrik tasarım araçlarıyla destekleyerek bu 2 kavramın (simbiyotik kent ve parametrik tasarım) kesişim noktasını kavramsal ve kuramsal olarak ortaya koymaktır. Nitel araştırma yöntemine dayanan çalışmada, literatür taraması, kavramsal çözümleme ve tematik sentez teknikleri kullanılmıştır. Elde edilen bulgular, bu iki yaklaşımın peyzaj mimarlığı içinde yalnızca biçimsel değil, aynı zamanda işlevsel, sistemsel ve sürdürülebilir tasarım kararları üretme sürecinde tamamlayıcı rol oynadığını göstermektedir. Çalışma simbiyotik kent yaklaşımının doğal ve yapılı çevrelerin karşılıklı fayda temelinde bütünleşmesini savunan sistematik bir planlama modeli olduğunu, parametrik tasarımın ise bu sistemlerin çevresel ve sosyal verilerle bütünleşik olarak modellenmesini sağlayan güçlü bir araç olduğunu ortaya koymuştur. Ayrıca peyzaj mimarlığının her iki yaklaşımı birleştirebilecek mekânsal ve sistemsel birleştirici rolü üstlendiği vurgulanmıştır. Sonuçlar peyzaj mimarlarının parametrik araçlar sayesinde simbiyotik ilişkileri daha okunabilir, simüle edilebilir ve ölçülebilir hale getirerek ekolojik, sosyal ve teknik düzeyde entegre tasarımlar geliştirebileceğini ortaya koymaktadır. Bu bağlamda, peyzaj mimarlığı disiplini, kentlerin sürdürülebilir dönüşümünde stratejik bir aktör olarak yeniden tanımlanmaktadır.

To Cite: Sipahi M. Parametric and Symbiotic Approaches in Landscape Architecture: New Urban Space Paradigms. Osmaniye Korkut Ata Üniversitesi Fen Bilimleri Enstitüsü Dergisi 2026; 9(1): 565-581.

1. Introduction

Cities in the 21st century are faced with the necessity of developing resilient, adaptable and sustainable solutions to global problems such as climate change, rapid urbanization and ecological destruction (Beatley, 2011; Newman and Jennings, 2012). The discipline of landscape architecture has undertaken the responsibility of developing holistic and innovative approaches to re-establish this balance. In this context, the concept of the symbiotic city, which proposes an interaction based on mutual benefit between nature and the city, has become one of the fundamental areas of interest not only in urban planning but also in landscape architecture (Mostafavi and Doherty, 2010; Mang and Reed, 2012). Symbiotic cities aim to ensure that natural systems and urban systems co-exist and evolve together by reorganizing the relationships that the city establishes with its biotic and abiotic environment (Zhang et al., 2013). These approaches require multi-scale and multi-functional solutions in terms of both landscape design and urban formation.

Symbiotic cities are conceptually not only an ecological restoration project, but also a systemic reconstruction proposal. This approach treats nature not only as an area to be protected, but also as a system to be integrated with the city (Olivieri, 2022). Therefore, the discipline of landscape architecture, with its ability to read natural processes and urbanization processes simultaneously, plays an important role in the spatial representation of symbiotic city theory (McHarg, 1969; Forman, 1995). Traditional urban design methods are often insufficient in providing this holistic view. At this point, parametric design stands out, especially with its ability to read and analyze multivariate data simultaneously (Kolarevic, 2001; Schumacher, 2009). Parametric approaches enable the production of symbiotic urban strategies in a digital environment by offering the opportunity to model city components not only formally but also at a functional and relational level (Januszkiewicz and Kowalski, 2017).

Parametric design, especially in landscape architecture, has the potential to model complex relationships between variable environmental data (climate, topography, water cycle, etc.) and user behavior (Hensel, 2010; Allen and McQuade, 2011; Charalampidis and Tsalikidis, 2015). In this way, integrating symbiotic relationships into design can cease to be a mere theoretical approach and turn into applicable projects (Ripley, 2023). At the intersection of these two approaches, the city becomes an organism that does not compete with nature but establishes a symbiotic partnership with it (Gaha, 2023). Thanks to parametric methods, sustainability criteria such as energy cycles, water management, biodiversity protection, and microclimatic effects can be made a dynamic part of the design (Hudson, 2010; López López et al., 2023). The integration of the concepts of symbiotic city and parametric design offers not only a method proposal on how to produce urban space, but also a vision on how this production can be more ethical, sustainable and resilient (Han et al., 2023). By combining these two paradigms, landscape architecture has the potential to reconstruct the nature-city relationship not only spatially but also culturally and politically. In this context, the main purpose of this study is to reveal how the parametric design approach in landscape architecture can be interpreted within the framework of symbiotic city theory at a theoretical and conceptual level. The study aims to discuss the intersection of these two approaches through the discipline of landscape architecture by supporting the symbiotic city vision, which aims to establish mutually beneficial relationships between nature and the city, with the digital tools offered by parametric design. In this direction, it will be examined how symbiotic relationships can be constructed not only spatially but also at ecological, social and technical levels; and it will be evaluated how parametric design methods make these relationships more readable, simulatable and measurable. Thus, the theoretical foundations of a new design paradigm in the discipline will be opened to discussion by highlighting the transformative and strategic role that landscape architecture can play in sustainable urban design.

2. Method

The study, which aims to associate parametric design with symbiotic city theory, is based on qualitative research method and consists of two main stages. In the first stage, symbiotic city and parametric design theories were examined by conducting a literature review. In this context, how the design flexibility offered by parametric systems and data-based decision mechanisms intersect with symbiotic city components was evaluated at a theoretical level. In the second stage, a conceptual matching was made between parametric and symbiotic approaches in the light of the information obtained from the literature review. A framework was created on the strengths, intersections and possible syntheses of parametric and symbiotic approaches. This matching was examined under 3 main headings (Symbiotic city, parametric design, integrated role of symbiotic and parametric approaches in landscape architecture) (Table 1). While revealing the integrated role of symbiotic and parametric approaches, conceptual harmony and practical limitations were revealed, and a comparative analysis was made on comparison criteria. The aim is to reveal in which aspects these two approaches complement each other, where they diverge and how their combination can contribute to landscape architecture.

Table 1. Theoretical framework

	Theoretical Framework	
1	Symbiotic city	
	1.1. Structural features of symbiotic cities	
2	Parametric design	
	2.1. Analytical potential of parametric design	
3	Integrated role of symbiotic and parametric approaches in landscape architecture	
	3.1. Conceptual Consistency and Practical Limitations; Common Conceptual Ground, Complementary Qualities, Common Purpose in Sustainability, Implementation Gap	*3.2. Comparative Analysis Performance-Based Comparison; Future Scenarios with Time-Space Simulations, Multidisciplinary Integration: Socio-Ecological Systems, Formal and Morphological Comparison*

3. Discussion and Results

The study was evaluated under 3 main headings (Symbiotic cities, Parametric design, Integrated role of symbiotic and parametric approaches in landscape architecture).

3.1. Symbiotic Cities

Today's cities are increasingly complex not only in terms of population but also in terms of being at the center of the ecological, economic and cultural metabolism of societies (The World Bank, 2010). The fact that approximately 80% of energy consumption takes place in cities (Seydioğulları, 2013) shows that these spaces are not only centers of consumption but also centers of transformation and innovation. The growing ecological footprint of cities reveals that traditional urban development models are no longer sustainable; therefore, approaches that aim to establish mutually beneficial, symbiotic relationships between the city and nature are coming to the fore (Boyacıoğlu, 2010; Stuiver, 2022).

Historically, cities have been likened to living organisms. In Plato's work "Politeia", the city is defined as a “macro-anthropos”, that is, a large human body (Šijaković and Perić, 2018). This analogy continues today, and urban tissue is explained with terms such as city epidermis, nervous systems and vascular structures (Solà Morales, 2008). This organic perspective emphasizes that cities are not static objects; they are living structures that constantly develop, breathe and change and establish symbiotic relationships. The concept of symbiosis, as a biological concept, was first defined by Anton de Bary as “the cohabitation of different organisms” and has been adapted to disciplines such as urban planning, architecture and sociology over time (Sapp, 1994; Paracer and Ahmadjian, 2000). Japanese architect Kisho Kurokawa was one of the first names to bring this biological concept to architecture and urban planning, developing the concept of the “symbiotic city”. According to Kurokawa, architecture is not only physical structures; it is a process of interaction between nature, society, culture and the individual based on mutual benefit (Kurokawa, 1994; Lee, 2015).

The concept of the symbiotic city refers to a new planning vision that focuses on increasing efficiency by creating synergy between city functions, improving the quality of life by cooperating with nature, and sustainability (Cansever, 2019). In this context, symbiotic cities aim to protect ecosystem services by establishing symbiotic bonds between both natural and built environmental elements, and to increase resource efficiency in areas such as health, energy, and transportation (Mulder and Delft, 2017; Minh et al., 2021). Kurokawa's approach is based on the balance established between seemingly opposing elements such as tradition and modernity, east and west, nature and humans. In this context, symbiotic architecture represents an architectural approach that is in harmony with nature rather than in conflict with it, observes cultural continuity, provides temporal flexibility, and encourages social integration (Kurokawa, 1994; Xue et al., 2011). This approach suggests transformation not only at the physical but also at the social and cultural level for sustainable urban life (Zamperini and Lucenti, 2015).

The symbiosis theory consists of three basic elements: symbiotic unit (U), symbiotic form (M) and symbiotic environment (E). The interaction of these elements determines the sustainability and direction of the symbiotic system. When this structure is applied to urban design, it proposes a new urban model in the nature-human-technology triangle by establishing a balance between physical space and social systems (Zhang et al., 2013).

Urban symbiosis emerges as an innovation strategy for sustainable urban transformation through the integration of emission reduction, waste management, resource sharing and infrastructure systems (Mulder and Delft, 2017). Public spaces stand out as the basic ground where these symbiotic relationships take place. The “human ecosystem” structure, which consists of mutual relationships between humans, nature and society, can provide benefits such as reducing energy consumption and increasing economic welfare by considering historical and cultural continuity (Minh et al., 2021). Frederick Law Olmsted’s “Emerald Necklace” project in Boston can be considered an early example of the contemporary symbiotic city approach in that it addresses nature as a partner in human design (Stuiver, 2022). This example shows that the urban landscape can be designed not only as an aesthetic element, but also as a functional and symbiotic system.

3.1.1. Structural Features of Symbiotic Cities

Symbiotic cities stand out with their structural organizations inspired by nature. These cities have a system approach that aims to ensure that different urban components work in harmony with each other (Kurokawa, 1994). This organic approach emphasizes that cities should be designed as dynamic and evolutionary structures, not static. Stuiver (2022) argues that symbiotic cities should be in harmony with both natural and built environments, and that this structural feature should be reflected not only at the physical level but also at the cultural level.

Symbiotic relationships overlap with the basic principles of sustainability. Managing resources such as energy, water and waste in cities with cyclical systems, reducing emissions and increasing infrastructure efficiency are directly related to this type of relationship (Mulder and Delft, 2017). In this context, a symbiotic city is not only a formal structure, but also a functioning sustainability mechanism. When the features of symbiotic cities are examined; The design and operation of cities are seen to have a multi-layered structure that aims to benefit from ecosystem services, ensure resource cyclicality and increase environmental sustainability (Table 2).

Table 2. Symbiotic city features

Feature	Description	Literature
Ecological Integration	Integration of natural systems into the urban fabric; elements such as green infrastructure, ecological corridors.	McHarg (1969); Waldheim (2006)
Resource Circularity and Waste Reduction	Evaluation of waste as a resource, establishment of cyclical systems.	Newman and Jennings (2012)
Metabolic Approach	Design of the urban system as a living organism that manages energy and material flows.	Register (2006)
Mutual Benefit (Symbiosis) Principle	Establishment of functional relationships based on mutual benefit between urban components.	Kurokawa (2001)
Local Context and Cultural Adaptation	Context-based design approach that is sensitive to local climate, culture and geography.	Kurokawa (1994); Lee et al., (2018)
Data-Driven, Dynamic Planning	Scenario-based planning processes with parametric and data-driven methods.	Kolarevic (2001); Schumacher (2009); Edmonds et al., (2022)
Interdisciplinary and Holistic Approach	Holistic design model with integration of fields such as ecology, sociology, economy, etc.	Spirn (2005)

3.2. Parametric Design

Parametric design is a data-driven and algorithmic design approach that has been increasingly applied in recent years, especially in the disciplines of architecture and urban design. This approach is a systematic process that includes not only the production of form but also the interactive analysis of environmental, social and economic variables (Kolarevic, 2001; Januszkiewicz and Kowalski, 2017). Unlike traditional design methods, parametric design allows the production of multiple solutions within the framework of certain rules or parameters; thus, the designer can create flexible, dynamic and adaptive solutions by controlling the relationships between variables (Schumacher, 2009).

The application of parametric methods to urban planning and landscape architecture provides critical advantages, especially in the modeling of complex ecosystems. More sustainable and livable spaces can be designed by processing variables such as the city's topography, sunshine durations, wind direction, population density, heat islands and green space distribution together (Yoffe et al., 2020).

Schumacher (2016) defines parametric design as “a new global style in architecture” and argues that this approach is based on a relational system logic that constantly redefines the urban fabric. Therefore, parametric design offers both a philosophical and technological basis in terms of establishing a symbiotic bond between nature and the built environment. At the same time, analyzing socio-technical data such as user behavior, energy consumption and transportation needs through simulation enables cities to become flexible and adaptable. The possibilities offered by parametric design are particularly useful in the management of complex systems and the production of future scenarios. For example, algorithmic models integrated with environmental data can be used to develop sustainability strategies such as reducing heat island effects or optimizing wind guidance systems (Lee et al., 2018). Thus, parametric design contributes to cities becoming more livable and resilient (Gaha, 2023; López López et al., 2023). On the other hand, with the development of digital design tools, not only technical data but also social and cultural data have begun to be taken into account in parametric models. This shows that parametric design can be considered not only as a formal tool but also as a cultural and ethical framework (Birkeland, 2008). Thus, parametric design has a strong potential to establish symbiotic relationships between nature and humans, the user and the environment, and the past and the future.

3.2.1. Analytical Potential of Parametric Design

Parametric design has the potential to produce effective solutions to complex environmental and social problems with its capacity to process a large amount of data simultaneously (López López et al., 2023). Parametric design is a versatile approach supported by digital technologies and can be integrated into urban and landscape design processes with different methods. These methods include data-based design, where environmental data is directly converted into design input, computational modeling, where geometric relationships are shaped by algorithms, and multi-scenario simulation analyses (Gaha, 2023). Performance-oriented optimization processes allow the design to be guided by measurable outputs such as energy efficiency, microclimate, or permeability (Edmonds et al., 2022). In addition, form-finding and interdisciplinary integration techniques allow the parametric approach to produce more effective solutions in both technical and ecological contexts (Table 3).

Table 3. Parametric design methods

Method	Description	Literature
Data-Based Design	Using environmental and structural data directly as design input.	Edmonds et al., (2022)
Algorithmic and Computational Design	Geometric and environmental variables produce form through algorithms.	Gaha (2023)
Simulation and Scenario Analysis	Modeling factors such as climate, user behavior and energy to test alternative scenarios.	Roudavski (2009)
Optimization Processes	Directing the design to the best solution according to specific performance targets.	Kolarevic (2001); Schumacher (2009)
Form-Finding	Reconstructing forms derived from natural forces in a digital environment.	Han et al., (2023)
Multi-Disciplinary Integration	Directing the design by integrating engineering, ecology and social data in the same model.	Schumacher (2009)

3.3. The Integrated Role of Symbiotic and Parametric Approaches in Landscape Architecture

Landscape architecture is a discipline that creates a physical and functional interface between nature and the built environment, mediating both the protection and redesign of multi-layered ecosystems. The intersections of parametric design and the symbiotic city approach are particularly evident in landscape architecture. In this context, the mutually beneficial structure proposed by symbiotic cities (Kurokawa, 1994; Stuiver, 2022) and the data-driven modeling tools offered by parametric design become an integrated strategy in landscape architecture. This integration offers a new paradigm in terms of urban sustainability, especially through ecosystem-based design strategies and data-driven process management.

Applications such as transferring natural processes to digital media, topographic analyses, permeability tests, and biodiversity simulations enable these two approaches to work together (Allen and McQuade, 2011).

In the literature, it is emphasized that landscape is not only a spatial result but also a dynamic process and system (Waldheim, 2006). The symbiotic city approach defines this dynamism through the metabolic relationship between the city and nature. Parametric design offers the opportunity to simulate, optimize and scenarioize this metabolism with concrete data and algorithms (Edmonds et al., 2022). Parametric design enables multiple environmental data (climate, water cycle, soil analysis, sunshine durations, etc.) to be brought together in a digital environment and transformed into functional space decisions (Kolarevic, 2001; Hudson, 2010). This becomes an important tool in the development of symbiotic cities (Allen and McQuade, 2011). Environmental variables such as permeable surface ratios, water retention capacity, and sunshine durations can be modeled with parametric tools and design decisions that consider the ecological balance can be produced. This enables landscape architects to move away from traditional form-oriented design and transform into performance-based, adaptable and system-based design producers (Hudson, 2010). Software such as Grasshopper, Rhino, and Dynamo play a significant role among the algorithmic methods used in parametric design. These tools allow for numerical modeling and performance analysis of environmental data such as the urban heat island effect, sunshine duration, wind directions, and permeable surface ratios. Thus, the nature-city relationships envisioned by the symbiotic city approach become quantitatively measurable (Kolarevic, 2003; Woodbury, 2010; Oxman, 2017).

In addition, the basic principles of the symbiotic architecture approach, integrity, continuity and mutual benefit, can be implemented not only formally but also functionally with parametric landscape design. In this context, landscape architecture is not only an aesthetic intervention, but also a strategic reconstruction of urban ecosystems.

Landscape architecture also plays a critical role in the production of hybrid systems such as intermediate areas where cities establish symbiotic relationships, such as green corridors, ecological spines and public transition spaces. The formation of these areas should not only be based on formal preferences, but also on parametrically analyzed socio-ecological relationships (Han et al., 2023). Thus, the design process can create new spatial arrangements that produce mutual benefits between the cycles of nature and urban life practices. In addition, parametric-symbiotic landscape design is an important tool in the development of infrastructure systems that are resilient to climate change. For example, designs shaped in light of data such as permeable surface ratios, flood risk maps and carbon dioxide absorption potential do not only provide spatial aesthetics; they also create functional areas that reduce natural disaster risks and lower carbon footprints (Birkeland, 2008).

3.3.1. Conceptual Compatibility and Practical Limitations

Parametric design and symbiotic city approach stand out as two powerful methods that complement each other on a conceptual level. Both aim to develop sustainable, flexible and environmentally sensitive design solutions based on a systemic thinking structure. While the parametric approach offers a technical tool in data-based form production, the symbiotic approach gives these forms an ecological and ethical aspect. Despite this theoretical compatibility, the reflections of both approaches in landscape architecture practice are still limited. In this context, the compatibility and limitations of both concepts are explained under 4 subheadings.

• *Common Conceptual Ground*: Parametric design and symbiotic city approach are both based on systemic thinking and aim to produce spatial solutions that can adapt to dynamic environmental conditions. This partnership brings data-driven but nature-compatible design models to landscape architecture.

• *Complementary Qualities*: While parametric design offers a powerful tool in terms of form production, data analysis and multivariable system establishment, the symbiotic city approach provides content that directs these systems in ecological, ethical and social terms. Therefore, when form (parametric) and content (symbiotic) are combined, holistic landscape strategies can be developed.

• *Common Purpose in Sustainability*: Both approaches adopt sustainability as a goal; however, while parametric design pursues sustainability with performance-oriented models, the symbiotic approach interprets it through ecosystem integrity and continuity of life. This difference enables the development of multifaceted sustainability strategies in landscape design.

• *Application Gap*: Although both approaches are theoretically strong, they are represented with limited examples in landscape architecture practice. This situation can be associated with the lack of interdisciplinary knowledge and the inadequacy of the use of digital design tools.

3.3.2. Comparative Analysis

Using parametric design to compare symbiotic cities from different perspectives provides a more comprehensive assessment of the potential of these two approaches. Below, how parametric design enables multi-dimensional comparative analyses with symbiotic cities based on literature is examined under four headings:

• *Performance-Based Comparison*

Parametric design allows urban systems to be evaluated not only formally but also functionally. In this context, symbiotic cities can be compared numerically through performance criteria such as energy efficiency, carbon footprint, access to green areas, and water cycle management. In this context, it is possible to measure the scalability of symbiotic cities, their adaptation capacity in the process, and the degree of interaction with ecological systems with parametric analyses.

• *Future Scenarios with Time-Space Simulations*

Parametric design allows for the prediction of how symbiotic systems may develop by modeling the temporal evolution of cities. This approach has the ability to visualize what kind of responses the city will give according to future climate scenarios, population changes, and infrastructure requirements. Edmonds et al., (2022) argue that parametric tools can work not only with current data but also with hypothetical futures. This way, the long-term resilience capacity of symbiotic cities can be calculated.

• *Multidisciplinary Integration: Socio-Ecological Systems*

Parametric design allows modeling symbiotic cities as a multi-dimensional system, as it can integrate data from different disciplines such as ecology, sociology, engineering, and economics. Schumacher (2016) defines parametric design as not only a form production tool but also an information-oriented "interdisciplinary thinking tool". This approach addresses socio-ecological systems together, enabling space to be processed not only physically but also culturally and socially.

This integration, for example, makes it possible to model the relationship between the health of an ecosystem and the well-being of a community on a parametric level. Thus, the potential of symbiotic urban structures to produce social benefits can also be quantified.

• *Formal and Morphological Comparison*

Parametric design is also a powerful tool for comparing the spatial formations of symbiotic cities. In particular, it can be analyzed how spatial components such as urban morphology, transportation schemes, and green infrastructure connections evolve under different local conditions. Parametric approaches emerge as an ideal method for modeling morphological differences, particularly focusing on the behavior of the form (Yoffe et al., 2020). In this context, landscape architecture has the potential to spatially represent symbiotic relationships and optimize these relationships with parametric tools. This situation shows that landscape architects are positioned as process designers as well as form designers. In addition, landscape architecture serves as a bridge that can transform the system-level urban vision of symbiotic city theory into local-scale, measurable and sustainable design practices with parametric design tools. This bridge plays a central role in both the ecological and technological transformation of 21st-century cities.

4. Conclusion

The study examined the concepts of parametric design and symbiotic city, two innovative approaches that are gaining importance in landscape architecture, at a theoretical level and evaluated the potential interaction areas between these approaches. Findings based on literature review and conceptual comparison revealed that these two approaches have complementary qualities.

Parametric design offers landscape architects the opportunity to develop adaptive, dynamic and scenario-based designs by processing multiple data (Schumacher, 2016). This feature provides great advantages in terms of producing fast and flexible responses to the complex environmental conditions of today's cities. However, the content of parametric design can often be limited to form production and numerical optimization.

The symbiotic city approach focuses more on ecological integrity, harmony with natural processes and mutually beneficial living systems (Register, 2006; Beatley, 2011). This approach advocates that human settlements evolve in an integrated manner with nature and that cities should be considered as ecosystem components.

While traditional urban planning and landscape design approaches often offer linear and fixed solutions, the algorithmic thinking offered by parametric design offers landscape architects the opportunity to model dynamic processes. In particular, basic parameters of the landscape such as microclimate, water management, soil permeability and plant diversity become measurable, comparable and scriptable through parametric systems (Hudson, 2010; Hensel, 2010). As emphasized in the literature, parametric design is a powerful tool for measuring and comparing environmental parameters (Oxman, 2017; Woodbury, 2010). In this context, the integration of parametric tools with the symbiotic approach proposed in this study enables sustainable design decisions based not only on formal diversity but also on climatic data. Modeling current environmental problems, particularly urban heat islands, plays a critical role in translating theoretical frameworks into practice. The combination of both approaches has the potential to produce powerful and holistic solutions in landscape design in terms of both formal flexibility and ecological depth. Parametric tools can serve as a tool for analyzing and modeling the multi-layered environmental relationships required by symbiotic cities. This unity is especially promising in terms of developing innovative responses to contemporary problems such as climate change, biodiversity loss and urban resilience.

Since landscape architecture functions as a spatial interface between nature and the city, it is one of the most powerful tools for spatially representing symbiotic cities. However, this representation should not only be structured at an aesthetic level, but also in the form of functional networks that support ecosystem services. At this point, parametric design strengthens the role of the landscape architect as a spatial strategy developer and system designer (Allen and McQuade, 2011; Charalampidis and Tsalikidis, 2015).

In this context, landscape architects’ role extends beyond green space design; they can also act as contributors to cities’ ecological performance, support nature–city interactions, and explore alternative scenarios with digital tools. The algorithmic measurement capacity of parametric design supports the practical applicability of the symbiotic city approach. As emphasized in this study, quantitatively demonstrating nature-city interactions through parametric tools contributes to the development of next-generation design paradigms. Future studies are recommended to apply this finding to the field and test it through experimental projects. For example, comparing the heat retention capacity of different surface materials through parametric models will fill the gap between theory and practice and add methodological strength to the study. This comparative perspective highlights how different design approaches, when analyzed together, reveal both their individual limitations and the opportunities they create when integrated. The comparison table illustrates the fundamental differences and complementarities between traditional design, parametric design, and the symbiotic approach, while also highlighting the potential of an integrated model. Traditional design primarily relies on intuition and visual aesthetics, often lacking systematic data-driven analyses. Parametric design, on the other hand, offers algorithmic processing of multiple variables, enabling advanced simulation and optimization processes, yet it remains highly technology-dependent and still limited in its practical applications. The symbiotic approach emphasizes the mutual relationship between nature and the city, advocating for ecological integrity and ethical responsibility. However, while strong in theory, it has not yet been widely realized in practice. Finally, the integrated model proposes a synthesis: by applying parametric tools to model symbiotic relationships, it becomes possible to achieve both theoretical depth and practical applicability. This comparative framework underscores the necessity of moving beyond isolated approaches, towards more holistic and measurable design strategies that align urban development with ecological imperatives (Table 4).

Although direct intersections between parametric design and the symbiotic city approach remain limited in the literature, this very limitation constitutes the original contribution of the present study. The few existing intersections point to fundamental features that require further development. In this context, three key dimensions can be identified: measurability, integration, and a new paradigm. Measurability refers to the capacity of parametric tools to model nature–city relations quantitatively, thereby transforming the abstract principles of the symbiotic approach into concrete and verifiable data. Integration denotes the incorporation of environmental parameters into the principles of the symbiotic city, providing a multidimensional perspective within the design process. The new paradigm demonstrates that this intersection is not merely a technical overlap but also marks the beginning of a methodological transformation in urban design and landscape architecture.

Table 4. Comparison of traditional, parametric, and symbiotic approaches

Approach	Characteristics	Limitations	Strengths
Traditional Design	Intuition-based, focused on visual aesthetics and historical continuity.	Lacks quantitative analysis, adaptation to environmental variables is weak.	Strong in cultural and historical continuity (e.g., preserving traditional forms).
Parametric Design	Uses algorithmic tools (e.g., Grasshopper, Rhino, Dynamo) to simulate solar radiation, wind flow, urban heat island effects.	Technology-dependent; results may vary depending on data input quality.	Provides measurable outputs (e.g., solar exposure reduced by 25% with shading structures).
Symbiotic Approach	Focuses on nature–city integration, enhancing ecosystem services (e.g., biodiversity, carbon sequestration).	Still mostly theoretical, with limited real-world applications.	Strong in ecological integrity (e.g., potential to reduce CO_2 emissions by 15% in green corridors).
Integrated Model	Combines parametric simulations with symbiotic principles to optimize both performance and ecological balance.	Few pilot projects exist; requires interdisciplinary collaboration.	Can demonstrate quantifiable improvements (e.g., 20% reduction in surface temperature + enhanced habitat diversity).

The intersections highlighted in this study can be further summarized in more concrete terms as follows:

- *Data-Driven Measurability:* Through parametric simulations, the nature–city relationships envisioned by the symbiotic city approach can be supported with quantitative data, thereby grounding the theoretical framework in concrete criteria.
- *Ecological and Systemic Integration:* The incorporation of parameters such as climate, water cycles, and biodiversity into urban design enhances the practical applicability of the symbiotic city concept.
- *Sustainability-Oriented New Paradigm:* The convergence of the two approaches generates a holistic design perspective that relies both on performance-based evaluations and ecological values.
- *Form–Content Coherence:* The formal flexibility enabled by parametric tools, when combined with the symbiotic city perspective, endows design outcomes with ecological and ethical substance.
- *Identification of the Implementation Gap:* While both approaches are theoretically robust, their limited real-world applications highlight the original contribution of this study and pave the way for future applied research.

Although the theoretical framework of this study reveals significant strengths, addressing the existing implementation gap remains crucial. In order to bridge this gap, pilot projects and experimental applications are recommended as essential steps toward validating the proposed approach. For instance, the application of parametric simulations and measurability analyses of symbiotic relationships on a selected urban public space would enable the empirical verification of the method. Such practice-based validation would not only strengthen the methodological rigor of the study but also provide a tangible contribution to the transformation of theoretical insights into practical design strategies. By doing so, the study would move beyond the limits of a literature-based exploration and actively support the integration of symbiotic and parametric approaches into real-world urban and landscape design practices.

In the study, it is seen that the concept of symbiotic city is addressed more at a "representative" or "symbolic" level in landscape architecture literature, and it is emphasized that this concept has now become applicable, calculable, and evaluable with parametric methods. This requires the discipline to move towards more data-based decision-making models, as well as to collaborate more effectively with public policy and urban management.

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As a result, the parametric design approach can be considered a powerful tool in realizing the symbiotic city vision. Parametric design and the symbiotic city approach offer not only technical tools and conceptual frameworks, but also a new way of thinking for landscape architecture. This synthesis can enable cities to be reimagined as systems that live together with nature. Future studies can deepen the impact of this approach with more application analysis and user experience-focused evaluations.

Conflict of Interest

The author of the article declares that she has no conflict of interest.

Author's Contributions

The author declares that she has contributed 100% to the article.

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