



Case Report

Lessons from New York High Line Green Roof: Conserving Biodiversity and Reconnecting with Nature

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Abstract: The concept of sustainable urban design has appeared in different perspectives to minimize and reduce the negative impacts of urban expansion in terms of climatic and environmental drawbacks. One of the undeniable approaches of sustainable urban design is the adoption of green urban roofs. Green roofs are seen to have a substantial role in addressing and resolving environmental issues in the context of climate change. Research investigations have indicated that green roofs have a remarkable impact on decreasing rainwater runoff, reducing the heat island effect in urban spaces, and increasing biodiversity. Nevertheless, green roofs in urban spaces as a competent alternative to nature remains a standing question. To what extent can green roofs mimic the biodiversity that is seen in nature? Moreover, to what level is this approach practical for achieving a tangible reconnection with nature, or so-called biophilia? This study attempts to discuss the essence and impact of green roofs in urban spaces based on a case study approach. The study reflected lessons from the New York High Line Green Roof regarding biophilia and biodiversity in this case study. It concludes with key lessons that can be transferred to other urban spaces with similar settings.

Keywords: green roofs; biodiversity; biophilia; the high line; reconnection with nature; green urbanism



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1. Introduction

Over the last several decades, climate change has become one of the major issues for the contemporary world. Transforming thousands of square miles to urban grey spaces has influenced the ecosystem, wildlife existence and nature in the urban areas [1]. In 2018, the amount of CO₂ emission reached 33.5 Gt, driven by urbanization factors such as buildings, transportation, industry, electricity and heat generation [2]. Considerable research has been conducted regarding the climate change phenomenon; yet, most of this research is limited to the presentation of theoretical frameworks for conserving biodiversity in urban spaces [3–5]. The idea of sustainable urban design has appeared in different perspectives, all aiming to minimize and reduce the negative impacts of urban expansion on the biodiversity of urban spaces. One of the key approaches of sustainable urban design is the adoption of green urban roofs [6–8].

Green roofs are seen to have a substantial role in addressing and resolving environmental issues in the context of climate change. For instance, research investigations have indicated that green roofs have a significant impact on decreasing rainwater runoff, reducing the heat island effect in urban spaces, and conserving the ecosystem [9,10]. Green roofs are highly effective in reducing the carbon footprint and the heat island effect in urban spaces [11–13]. Additionally, green roofs positively enhance urban air quality by mitigating air pollution and purifying the urban atmosphere through their features and characteristics [14–16]. Large-scale green roofs provide an interactive ecological setting that is recognised as a source of relief for the urban scheme and a preserver of its biodiversity.

Moreover, these roofs are seen as a replacement for the existence of wildlife within urban contexts. Having such features in urban spaces not only preserves the natural biodiversity of the ecological system; it is a substantial element for reconnecting human beings with nature as well [17,18]. The human reconnection with nature has been addressed as a challenging aspect in the urban context due to the complexity of achieving a tangible connection as well as the nature of urban expansion, which tends towards building rather than preserving. However, green urbanism in general is seen to be a promising alternative for reconnecting the urban space with the nature while preserving eco-diversity within the urban context [19,20].

Nevertheless, the adoption of green roofs in urban spaces as a competent alternative for nature in the urban areas remains a standing question. To what extent can green roofs mimic the biodiversity that is seen in nature? Moreover, to what level is this approach practical for achieving a tangible reconnection with nature, so-called biophilia? Accordingly, this study attempts to discuss the essence and impact of green roofs in urban spaces based on a case study approach. The study will analyse the New York High Line Green Roof regarding biophilia and biodiversity aspects in urban areas. The study will conclude with key lessons that can be applied to other urban spaces with similar settings.

This paper takes a qualitative approach to discussing the concept of biophilia and biodiversity in urban spaces from previous studies in Section 2, then links the two main concepts to the application of green roofs in Section 3. Section 4 provides background about the High Line Green Roof, while Sections 5 and 6 reflect on the conceptual aspects of the project through visual analysis of pictures as well as through previous data and references. The study also derives key aspects learned from the High Line regarding the biodiversity and biophilia achieved in this case. Lastly, Section 7 concludes the study and suggests further research into the scope of sustainability in urban spaces.

2. Biophilia, Biodiversity and Urban Spaces

2.1. Biophilia

Biophilia is a hypothesis that emerged in the late 20th century. Wilson defined biophilia in 1984 as the preference and the pursuit of nature by humans, which is considered a genetic root inherited millions of years ago when humans were highly associated with the natural environment [21]. This old association might have influenced human behavior toward nature, and it has remarkable effects on human health in general. Kellert (2008) demonstrated that nature can significantly improve healing and recovery from illness, social problems, motivation, physiological problems, and the human brain [22]. Research associated with the impact of nature on the human species started with the beginning of the biophilia concept. Old research as far back as 1984 suggested that patients with a natural view can heal more quickly than those without [23]. Later research pointed out that walking in nature improves self-esteem by 90% [24]. This indicates that the human connection with nature has psychological benefits. This was deeply studied later on, and many scholars noticed that this connection leads to numerous health benefits and better quality of life [22]. Therefore, Beatley (2011) stressed that ‘we need nature in our lives; it is not optional but essential’ [25]. Moreover, it has been mentioned that as the world is becoming more urban, the human connection to nature is becoming more difficult [25]. Accordingly, human contact with nature is a basic need that should be reflected widely in urban environments, which probably has been neglected or less-considered for many years.

The benefits of biophilia can be achieved in urban spaces if cities are designed based on integrating nature into man-made environments. To adapt this Kellert, in 2011, suggested biophilic design; this was then promoted and applied by Beatley and Newman in 2011 and 2014 respectively, which means it is not an old concept compared to other design concepts [22,25,26]. Kellert and Calabrese (2015), in their *Practice of Biophilic Design*, suggested fundamental rules for the effective practice of such design [27]. They highlighted that biophilic design should sustain engagement with nature, encourage emotional attachment to place and setting, and promote an expanded sense of relationship and responsibility for

both human and natural communities. This, in the end, requires integrated architectural and urban solutions. Such ideas could be implemented, for example, through the fourteen “patterns of biophilic design” [28]. These patterns are fundamentally categorised under the headings of Nature in the Spaces, Natural Analogues, and Nature of the Space, as shown in Figure 1 [28]. Regarding Nature in the space, this approach emphasizes adding seven design patterns that connect humans with nature through scenes or feelings from nature, such as visual/non-visual connections, the presence of water, and the variability of nature in terms of lighting, thermal and airflow. On the other hand, patterns regarding Natural Analogues are added through biomorphic forms by using natural materials or mimicking nature’s complexity and order. Biophilic design pattern can complexify to further ideas and include Nature of the Space, such as the mystery of space, refuge, prospect, risk, and peril.

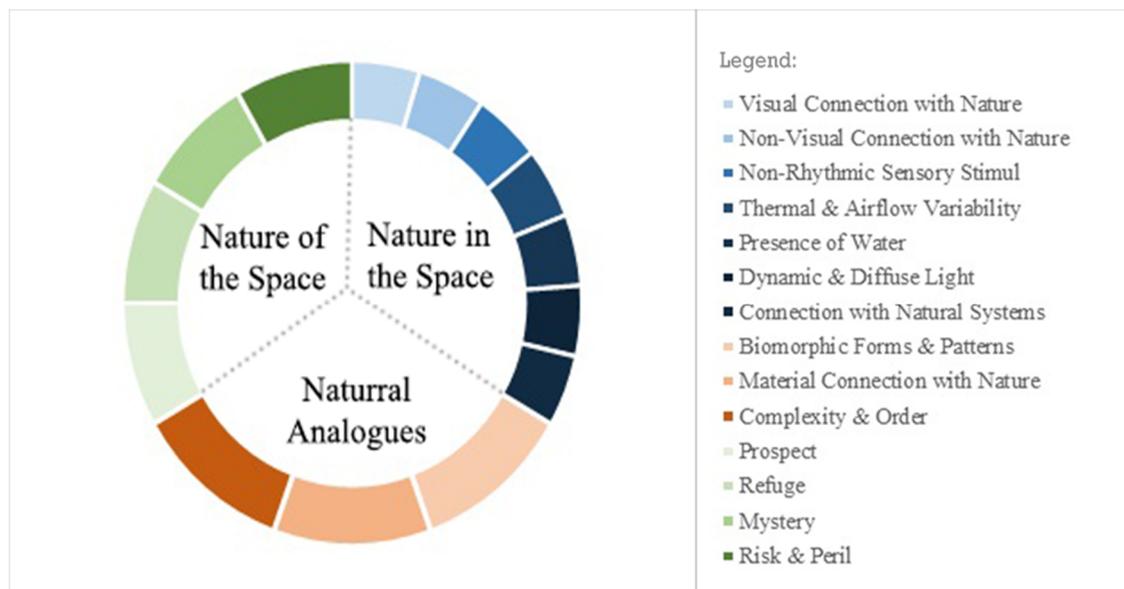


Figure 1. 14 Patterns of Biophilic design. Data from source: [28].

Urbanization has not only affected the connection between nature and human beings; it has affected the existence of wildlife features in urban areas, cities and living places as well. Thus, urbanization has impacted the biodiversity of the ecological system in urban spaces.

2.2. Biodiversity in Urban Spaces

Ecosystem and wildlife features are some of the significant environmental challenges that urban design confronts when designing urban areas. The ecosystem refers to a unique interaction between the living species and the physical environment that enables those species to sustain their lifecycle and maintain balance in nature [29]. Accordingly, any defect in the ecosystem will impact the lifecycle of living species [29]. On the other hand, urbanization has been seen as an extensive threat when it comes to breaking the ecological balance of the environment. Several studies [30–32] have clearly demonstrated the negative impact of transforming natural green areas into grey urban developments where the biodiversity of the ecosystem is adversely affected. Generally, urbanization has been pictured as in contrast with biodiversity; where the former increases, the latter decreases [30–32]. Therefore, architects, urban planners, and decision-makers have been seeking practical and innovative solutions that could preserve biodiversity in urban areas and lead to healthier and sustainable urbanization. These urban solutions are a key aspect in planning and designing urban areas while preserving the ecological diversity in these areas through a set of features and practices.

3. Green Roofs in Urban Spaces

Green roofs, also referred to as “Planted Roofs,” “Living Roofs,” “Eco-roofs,” or “Garden Roofs”, are roofs with vegetation on their final layers which are applied in urbanized spaces [33]. They are classified as extensive, intensive, and semi-intensive based on their depths [34]. Their depth starts with extensive types with a depth of less than 200 mm of growing media and grows to semi-intensive and intensive with more than 200 mm of growing substrate [34]. As the environmental outcomes of green roofs have been identified in the existing literature, this study investigates the contribution of green roofs in linking humans with nature and bio-diversification of the urbanized areas.

3.1. Green Roofs and Biophilia

Green roofs can play a substantial role in reconnecting humans with nature. As expanding urban areas translate to demolition of natural spaces, architects and urban designers recommend increasing garden roofs to compensate for those natural views removed by urban expansions. Biophilic Urbanism (BU) can be a solution when dense cities fail to increase green land, and Green Infrastructure (GI) can be used as an alternative approach including green walls, roofs, and balconies [35]. This is widely seen in Singapore, which has founded the SkyRise Greening Initiative (SRGI) to assess the quality of planted roofs in the early phases of building designs [26]. Therefore, green roofs are presented as a considerable dimension of Biophilic Urbanism, or BU [17]. The governments of Japan, Singapore, Belgium, and Germany highly encourage the use of green roofs in urban areas because of these benefits [36]. Moreover, studies have noticed a relationship between rooftop forests and psychological illness improvements in cities [37]. However, the studies which have investigated the contribution of a green roof for human reconnection with nature and well-being are limited [38], and further research is required as green roofs could be a notable method for increasing green space and reconnecting with nature in urbanized areas.

3.2. Green Roofs and Biodiversity

Studying the ability of green roofs to providing a suitable environment for wildlife existence appears to be controversial. The scholarly debate has focused on the possibility of including wildlife in urban spaces through the adoption of green roofs [9,39,40]. Some early investigations in Germany doubted the ability of green roofs to provide a rich biotic diversity paradigm [41,42]. The study questioned the possible depth of the substrate layers of the artificial roof, as the thinner the substrate layers are, the lower the cost of green roof construction. At the same time, this can negatively affect the opportunity to achieve an interconnected biodiverse paradigm. Nevertheless, later studies [7,40,43,44] have demonstrated that a wide spectrum of living species can thrive in green roofs when these roofs are properly designed with suitable substrate layers, landscape features, plants and natural elements. For instance, the green roof of Chicago City Hall has the capacity of accommodating nearly 20,000 plants and more than 150 different types of birds and invertebrate species living in an area of 2000 m² [45]. Accordingly, green roofs have been proposed as an appropriate alternative for adopting wildlife features in urbanized areas. The scholarly debate has considered the adoption of green roofs in urban spaces as an alternative to the existence of wildlife in these spaces; yet, more case studies need to be discussed in order to better understand the practicality and functionality of green roofs as a valid alternative for wildlife in urban areas.

For better understanding of the impact of green roofs on preserving biodiversity and achieving biophilia in urban spaces, the case of the High Line Green Roof will be discussed in this study to derive lessons on the adoption of large-scale green roofs in urban spaces. Due to the proper scale and the urban value of the High Line, this case has been selected for thorough investigation in this study.

4. The High Line

The High Line is a linear elevated urban park and greenway built on a former New York Central Railroad spur on the west side of the Manhattan in New York city. It has a length of 1.52 miles and an area of 27.499 m². The structure is mainly steel frames with reinforced concrete roof decking. The High Line is considered an iconic projects in New York City. Scientifically, the High Line can be considered a green roof, following the scientific definition that any top roof of a structure that contains vegetation on the final layer is regarded as a green roof [33].

The history of the High Line elevated railway has a significant role in the success of the project refurbishment. The structure was built in the 1930s, when the purpose of its construction was to improve the urban economy and transportation in the Lower Manhattan area of New York City [46]. The high line railway served to deliver and receive products from the Meat Packing District [47]. The last train movement on this track was in the 1980s, before a new generation of train were introduced [48]. The most significant part of the High Line's history starts in the year of 1980, when it stopped working until 1999. Throughout this 20-year timeframe, the High Line roof was abandoned and became a place for the growth of different types of wildlife plants and other species, showing the possibility of an emerging biodiverse environment where the required conditions are available [47]. Over the years, some parts of the train tracks were demolished to provide new areas for development on the site. However, in 1999, Robert Hammond created a group called Friends of The High Line to preserve the abandoned structure from becoming demolished [48].

In 2001, the New York City government decided to demolish the entire High Line site in order to accommodate a new development. The Friends of the High Line strongly opposed the demolition of the historic project, and provided remarkable financial support through donation campaigns in order to preserve and redevelop the structure. In 2004, a design competition was launched aiming to preserve and transform the High Line into a public urban space. Ultimately, the landscape architect James Corner won the competition in collaboration with the Field Operations Design Firm [49–52]. Figure 2 illustrates the main milestones in the history of the High Line.



Figure 2. History of the High Line in different historical stages. Data from source: [49].

5. Lessons on Biophilia

The concept of the High Line green roof design was based on the principles of biophilic design, seeking to engage people with nature while retaining the identity of the place. The proposal involved the creation of a sustainable urban ecology park integrating people with nature, and with the history of the site inspired by the years that the High Line was abandoned, resulting in the site becoming obscured by natural vegetation [ibid]. The designers kept the original rails along some parts of the roof in order to preserve its history. Trees and grass evoke the wildness of nature within the urban context of the New York City. The pathways have been designed to take different directions and provide various views of the location, as presented in Figure 3. The architect, James Corner, says that ‘The High Line is a different place from the rest of New York. There is a sense of slowness, distraction, and otherworldliness, and that is what we want to preserve’ [53]. Accordingly, the High Line renovation proposal has been designed based on the concept of biophilia to revive an old construction into a living green roof project.

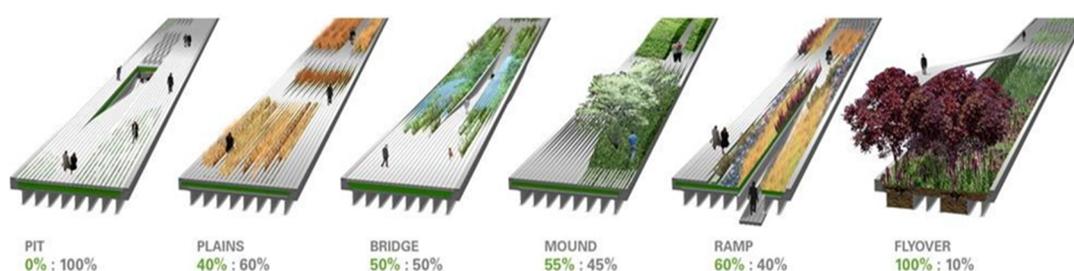


Figure 3. Design Proposal of the High Line. Reprinted from ref. [50].

Additionally, the High Line Project represents a successful example of green roofs that engage people with nature. The total number of visitors to the park jumped from 4 million people in 2011 to 7 million in 2018 [54]. This has led the project to become one of the most visited places in New York City and on the list of top New York City landmarks [ibid]. According to online public reviews, it is a highly recommended destination for visiting (www.tripadvisor.com) (accessed on 10 December 2021). According to the website, there are more than 60,000 reviews on the project at present; more than 42,000 reviews have given an excellent rating and 16,000 very good ratings. This amounts to 90% highly positive reviews on the site. The most popular comments on the site are related to the green spaces, pleasant walks, and elevated park, which shows the positive view of people about the space and how they are connected to nature when they walk through it. Following are samples of reviews of the highline project:

- R1: “The walk along the High line is full of lush greenery intermingled with the “concrete jungle” of high rise buildings. The walking path is well maintained, and is very accessible for all types of walkers, runners and families with children. The gardens are diverse, with a good selection of low lying, bush types and taller trees that provide lots of shade and fresh air and plenty of benches are available for those looking to rest or take in the scenery.”
- R2: “An urban green space built on an old railroad. You can still see the railroad structure remnants. The walk is very peaceful and a great place to reflect on life or have a conversation with a friend.”
- R3: “Not sure what’s all the fuss. Without a doubt, great for the neighborhood to have this green space in the middle of the city, but I’m not sure why a tourist would go out of their way to walk along the High Line. Also very crowded and not a relaxing stroll along a relatively narrow pathway.”

The public reviewers’ comments and the data provided lead to the conclusion that the Highline successfully connects people with nature by bringing nature to urban areas where minimal green regions exist. Transforming the old structure into an attractive green destination is a testament to the project’s success in mimicking nature by having various types of plants and providing fresh air and relaxation, as suggested by the reviewers.

To further investigate the project’s biophilic design aspect, a visual analysis of the project design was undertaken. The analysis was based on measuring the High Line’s views taking into account the biophilic design patterns discussed earlier in order to investigate the aspects of biophilia in the project. Hence, photos of the project were collected from the Friends of the High Line organization’s official website and the photos were visually analyzed to find biophilic design patterns (<https://www.thehighline.org/>) (accessed on 10 March 2021). It was observed that the project is highly successful in touching and applying all of the patterns from the three major categories, namely, Nature in Space, Natural Analogues and Nature of the Spaces. Figure 4 illustrates the visual analysis of biophilic patterns.

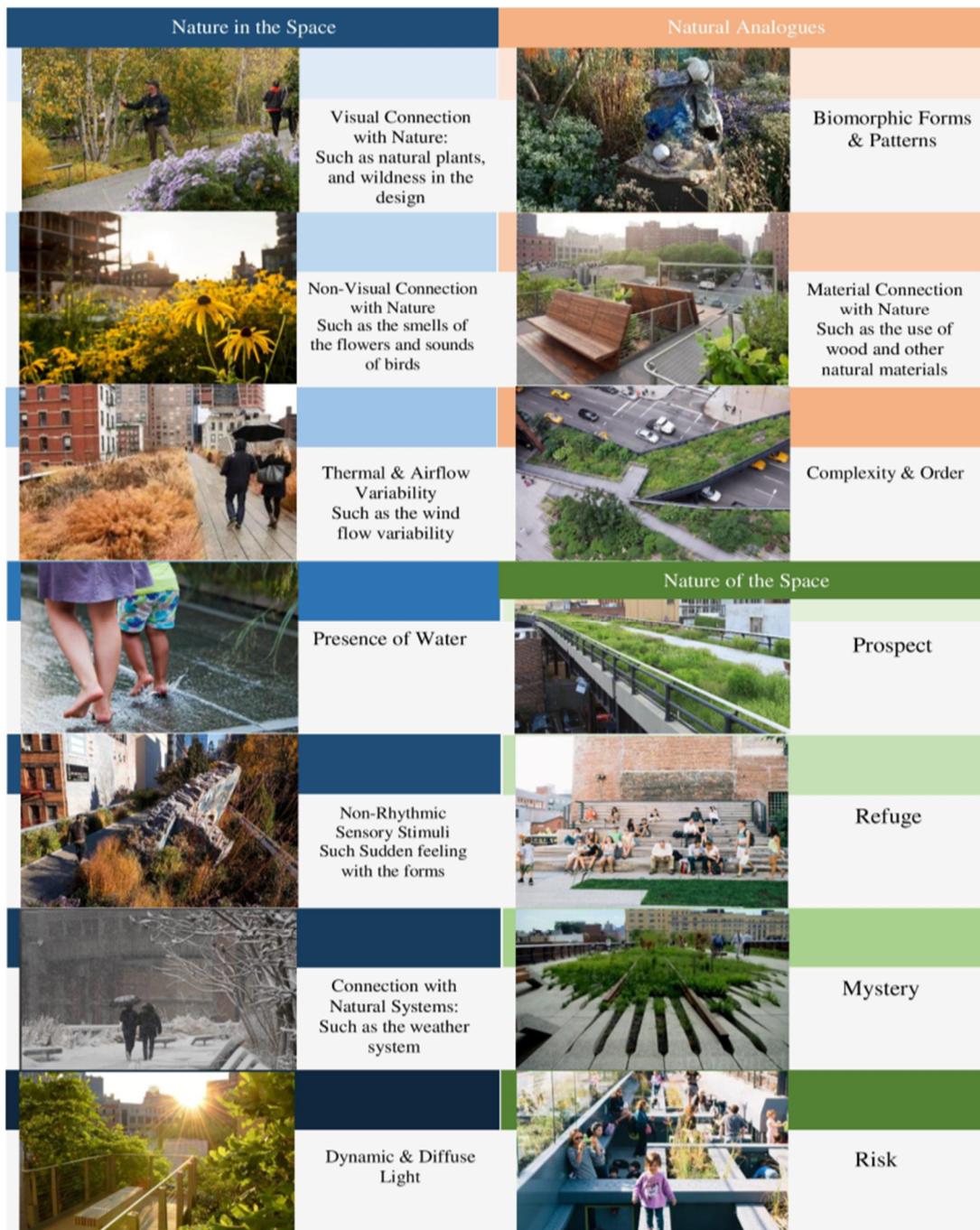


Figure 4. Biophilic patterns of the High Line. Diagram Source: Authors.

In studying the aspects of Nature in Space, the High Line shows a high reflection of visual and non-visual connection with nature, taking into account the wildness of the views, smells, and sounds of nature. The project evidently encompasses diversity in its selection of wild plants, the variability of the natural and artificial lights, the cycle of nature, and seasonal alteration in order to touch human desires related to natural systems and their variability. The project also incorporates water bodies and wild forms in its design as important patterns of nature. In terms of its Natural Analogues aspects, the project includes natural materials in the design of setting objects and excludes synthesized materials wherever possible. It has also considered the use of organic forms and patterns evocative of the biomorphic forms and its complicity and order at the same time. It can be noticed that the Nature of Space has been well-studied in the design of the High line. The visual analysis attracted the authors' attention to the design of different activities that take human attention in nature instinctively. This can be noticed in areas with risk-taking or the use of mysterious objects and designs that attract visitors to discover, as well as areas with sheltering and cover spaces to provide a feeling of inclusion to visitors, as presented in Figure 4.

Visual observation of people's interaction with the High Line, on the other hand, provides further evidence of how green roofs manage to simulate a natural environment. In [54] it was suggested that most of the visitors of the High Line come for walking and relaxation purposes, and the study detected a high satisfaction among people visiting the High Line. The reflections of visitors, as published online, demonstrates the success of the High line in providing a tangible connection with nature in various forms, as demonstrated by the remarkable number of visits to this distinguished urban roof. Figure 5 demonstrates the interaction between the visitors and the features and elements of the High Line green roof.



Figure 5. People engagement with nature on the top of the High Line. Data from source [49].

The case of the High Line has shown the importance of adopting green roofs as a substantial alternative to increase greenery in urban spaces and to reconnect people with nature. The project has shown the ability of green roofs in acting as a valid alternative to nature in urban areas. The High Line has been successful in attracting visitors to spend time for relaxation and walking to fulfill their instinctive desires for a connection with nature, even in urban spaces.

The example of the High Line can be replicated in other urban areas with a planned Biophilic Urbanism strategy, and green roofs can be a proper alternative for nature when dense cities fail to increase green land. In addition, the example of the High Line reflects the essence of Biophilic design patterns as a key measure for the successful design of green roofs. The more biophilic patterns are implemented, the more the connection with nature is seen to be sensible. The impact of the High Line in the urban space of New York City is not limited to reconnection with nature; the High Line has positively impacted the existence of a more wild and biodiverse environment within the congested urban scheme of New York City.

6. Lessons on Biodiversity

The emergence of a rich biodiverse environment on the abandoned rail line serves as a lesson on the possibility of the presence of natural wildlife features in a high-end urban area. The features of wildlife appeared gradually on the surface of the rail line, with increasing diversity over time. Looking at the timeline of the High Line, the elements of biodiversity thrived on the surface of the abundant rail line. This was the spark of insight for the High Line designers to preserve the emerging biodiverse elements and to redefine them in a proper design scheme, that placed them within the redevelopment scheme. Another lesson was the impact of strategic planning in preserving biodiversity in urban spaces. The designers of the High Line embraced a temporal strategy for attracting different forms of wildlife on the surface of the High Line, in different stages and with different features; thus, a natural and biodiverse ecosystem thrived. Figure 6 illustrates the emergence of wildlife features within specific timeframes. As demonstrated in the diagram, the diversity and integrity of wildlife features increases over the time to include a wider range of creatures. This process was exemplified in the case of the High Line. Consequently, the biodiverse environment that has been emerging on the abandoned rail line has inspired the community to preserve the structure and redesign the rail line in a way that maintains the biodiversity of the place and presents an interactive urban space for the citizens of New York City [49–51].

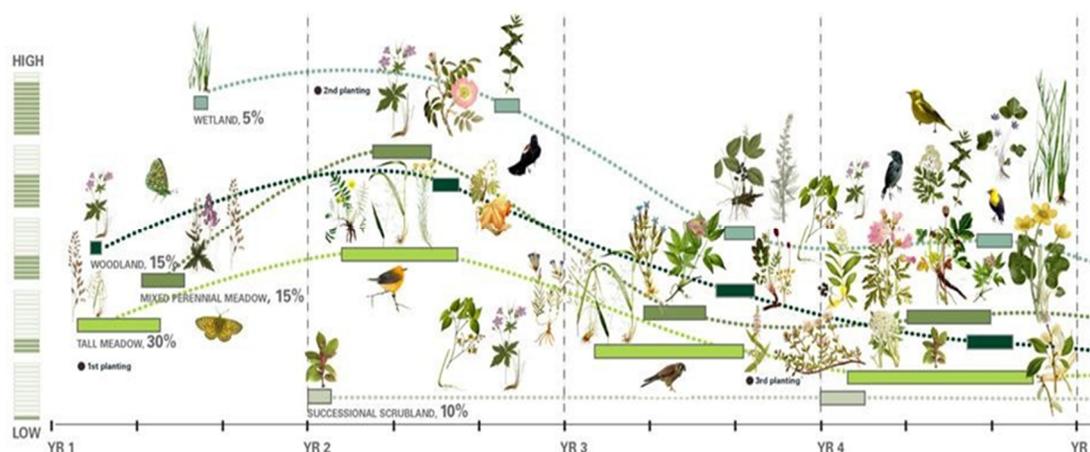


Figure 6. The emergence of a wild and biodiverse ecological system over the time. Reprinted from ref. [50].

One of the challenges in the redesign of the High Line was the ability to plant various species within the limited earth layer of the rail line. The Dutch Garden Designer Piet Oudolf addressed this problem by adopting specific plant types able to grow and thrive within the limited depth of the substrate layers. The average earth depth in the High Line is 450 mm, and reaches 900 mm in particular locations to accommodate wild trees. Figure 7 illustrates cross-sections for the High Line Garden Roof and shows different substrate layers from different locations on the roof [49–51].

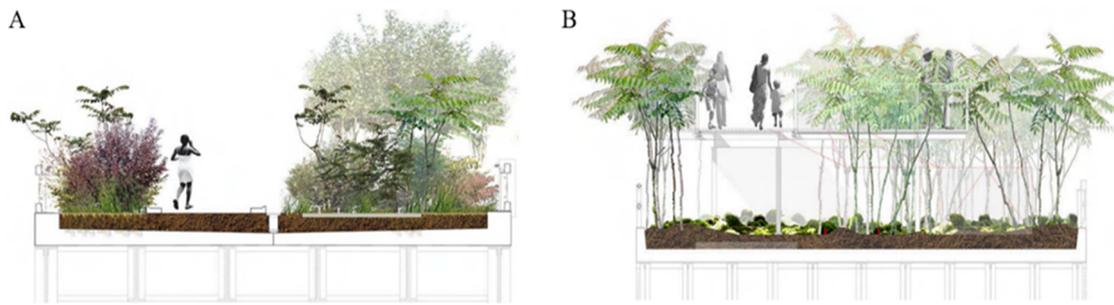


Figure 7. The High Line: (A) cross-section of the main pathway; (B) cross-section of a multi-level zone. Reprinted from ref. [50].

The design of the High Line demonstrates another lesson on the possibility of accommodating various types of wild plants within a limited substrate layer. The rational use of the available depth in the structure and the proper selection of wild plant types enabled the generation of a thriving and livable biodiverse environment on the top of the redesigned High Line. The design adopted seasonal plants of various types, with the aim of accommodating different living species that find in the seasonal plants a place to complete their lifecycle, even within a vibrant and crowded urban space. As a result, the High Line has become a suitable site for different types of migratory and local birds to grow, feed, and nest on the Green Roof. For instance, the American Kestrel, House Sparrow, Mourning Dove, Northern Mockingbird and Peregrine Falcon are among the types of birds living along the High Line. This demonstrates another lesson on the importance of adopting various planting strategies that match with all the seasons in order to achieve a rich ecological environment that accommodates different forms of wildlife in the urban space.

James Corner, the design architect, and the design team have outlined the High Line design to reflect different microclimatic conditions [52]. Along the linear landscape of the High Line, multiple climatic zones have been presented, each with the features and characteristics of that particular zone. For instance, the *Falcone Flyover* zone is a wet-shaded climatic zone that accommodates wild forest trees, while the *Sun lawn* zone is a dry-sunny climatic zone that accommodates wild high grasses and seasonal flowers, as shown in Figure 8. The variety of climatic zones in the High Line reflects the essence of mimicking different climatic conditions in the design of urban spaces to allow the flourishing of a biodiverse environment. The High Line design has successfully reflected various climatic conditions in the different zones of the design, presenting a holistic and comprehensive picture of biodiversity [49–52].



Figure 8. The High Line: (A) Sun Lawn Zone; (B) Falcone Flyover Zone. Data from source [49].

Today, the High Line Green Roof is seen as a successful paradigm for bringing wildlife into urban spaces. The artificial alternative greenspace has reflected an effective and practical approach for the emergence and thriving of a biodiverse environment within the urban scheme. Having adequate conditions and proper design elements, green roofs can substantially enhance the biodiversity of public urban spaces. The lessons reflected in this study on biophilia and biodiversity demonstrate the success factors behind the High Line Green Roof. These lessons can be transferred to and implemented in other urban areas where the aim is to reconnect with the nature and conserve biodiversity in the urban area.

7. Conclusions

Urbanization has notably impacted the connection of human beings with nature, as well as the existence of wildlife and biodiversity in urban spaces. The adoption of green roofs in urban areas is seen to be one of the substantial aspects of sustainable urban design that could significantly answer the call for tangible reconnection with nature as well as tackle the challenges of climate changes caused by urbanization. This study has attempted to reflect lessons on the implementation of green roofs in urban spaces based on a case study. The study has yielded the conclusions drawn below.

First, green roofs have proven to be a substantial alternative method for increasing greenery in urban spaces and reconnecting people with nature. The case study presented a successful project that is able to attract visitors to spent time in relaxation and walking and fulfill their instinctive desires for the natural environment in an urban space.

Second, the example of the High Line can be replicated through Biophilic Urbanism (BU) when dense cities fail to increase green land, by using alternative GIs such as green walls, roofs, and balconies. However, pre-planning is essential before any applications for the success of this strategy.

Third, biophilic design patterns can be used as a key measure to design green roofs, and should take the maximum number of biophilic patterns into design consideration, namely, Nature in Space, Natural Analogues, and Nature of Space. This, in return, will aid in reconnection with nature in urban areas.

Fourth, with a proper design strategy and adequate conditions green roofs can accommodate a thriving and biodiverse environment within urban areas. The variety of soil depth and different microclimate conditions in green roofs can help accommodate different types of plants, insects, birds, and other animals accordingly. Such design strategies are critical for the creation of a rich ecological area.

Fifth, although green roofs are human-made structures, these structures have shown the ability to mimic the features and characteristics of wild areas. The diversity of planting in the different site zones and the existence of living species actively depict the features of wildlife.

Finally, the adoption of green roofs in the design of urban areas can be a competent alternative to the existence of nature in the urban scheme. However, further research is recommended in order to investigate and discuss the challenges and barriers in transforming this approach to other urban areas.

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