diversity

MDPI

Opinion

Beyond Urban Forests: The Multiple Functions and the Overlooked Role of Semi-Natural Ecosystems in Mediterranean Cities

Riccardo Guarino [1], Chiara Catalano [2,3,*] and Salvatore Pasta [4]

[1] Department STEBICEF, University of Palermo, 90133 Palermo, Italy; riccardo.guarino@unipa.it
[2] Institute of Research on Terrestrial Ecosystems (IRET), National Research Council (CNR), 05010 Porano, Italy
[3] National Biodiversity Future Center (NBFC), 90133 Palermo, Italy
[4] Institute of Biosciences and BioResources (IBBR), National Research Council (CNR), 90146 Palermo, Italy; salvatore.pasta@cnr.it
* Correspondence: chiara.catalano@cnr.it

Abstract: In recent times, the misleading belief that the indiscriminate planting of a million trees is the panacea to some of the most serious and urgent environmental problems of our planet (such as soil erosion, climate change, etc.) has gained increasing popularity. However, the idea of "reforesting the planet" does not seem to adequately consider the fact that forests most often represent the last successional stage of terrestrial ecosystems, thus requiring—at least in the first years after planting within urban contexts—some care (hence time and money resources) to become large enough to fulfil the functions (climate mitigation, particulate capture, air purification, etc.) expected by public opinion. Starting from these critical considerations, this paper aims to highlight the need to carry out in-depth multidisciplinary investigations on the most suitable species and communities, underlining the fact that, to improve the environmental quality in urban areas, it is necessary to make appropriate choices, also considering the biogeographical contexts in which such interventions are made.

Keywords: design; habitat template; mediterranean ecosystems; nature-based solutions; urban green infrastructure

Citation: Guarino, R.; Catalano, C.; Pasta, S. Beyond Urban Forests: The Multiple Functions and the Overlooked Role of Semi-Natural Ecosystems in Mediterranean Cities. *Diversity* **2024**, *16*, 447. https://doi.org/10.3390/d16080447

Academic Editor: Michael Wink

Received: 30 June 2024
Revised: 24 July 2024
Accepted: 24 July 2024
Published: 29 July 2024

1. Introduction: The Growing Popularity of Urban Forests

Urban forests can be defined as "networks or systems comprising all woodlands, groups of trees, and individual trees located in urban and peri-urban areas; they include, therefore, forests, street trees, trees in parks and gardens, and trees in derelict corners" [1]. In the face of the massive shifting of human populations to cities, with over half of mankind residing in urban areas [2], people have become increasingly aware of the essential role played by these green spaces. They are vital components of urban landscapes and a cornerstone of green infrastructure, offering a wide array of ecological, social, and economic benefits, connecting rural and urban green areas.

The ecosystem services of urban forests include the improvement in air quality because trees act as natural air filters, absorbing pollutants and particulates [3,4]. Additionally, urban forests provide habitats for a diverse range of species, promoting urban biodiversity, and acting as ecological corridors, allowing wildlife to move through fragmented urban landscapes [5,6]. Trees sequester carbon dioxide, mitigate climate change, and regulate local temperatures by providing shade, thus reducing the urban heat island effect [7,8]. Trees also absorb rainwater, reducing surface runoff, minimising the risk of floods, preventing soil erosion, and sustaining the soil microbiota [9–11].

Access to green spaces, including urban forests, has been linked to improved mental health, reduced stress, and increased physical activity [12,13], while from a social and cultural perspective, the same spaces offer recreational areas, community gathering spaces, and contribute to the aesthetic value of cities [14]. In Japanese cities, Shinto shrine forests are positively correlated with the "Happiness Ranking" [15] and have a crucial role in providing spiritual and communal connectivity, preserving traditional heritage, offering vital aesthetic values, and making visitors connected with nature [16,17].

The "Guidelines on Urban and Peri-Urban Forestry" by the Food and Agriculture Organization [1] provide comprehensive insights into planning and managing urban forests. These guidelines raise awareness of urban forests' benefits and serve as a key resource for policymakers and practitioners working to conserve and enhance urban forests. However, they may overly emphasise urban forests as the preferred form of urban green space.

In recent times, the misleading belief that the indiscriminate planting of trees is the panacea to some of the most serious and urgent environmental problems of our planet (such as soil erosion, climate change, etc.) has gained increasing popularity. This oversimplified approach ignores the nuanced interactions between various forms of vegetation in urban and peri-urban areas and, in the end, fails to recognise the unique services provided by the spontaneous vegetation occurring in the cities.

Urban forests are by no means the only green spaces providing essential ecosystem services in urban areas. On the contrary, many other forms of urban vegetation, including those regarded as "weedy" plants that grow naturally in vacant lots, roadsides and pavement cracks, railroad tracks, embankments, wastelands, and brownfields offer a wide array of ecosystem services. These spontaneous vegetation stands also play an important ecological role in urban areas. They contribute to biodiversity, provide habitat and food for urban animal wildlife, exhibit resilience in challenging conditions, and may include plant species from nearby (semi-)natural habitats that can even be conservation targets [18].

Unfortunately, the idea of "reforesting the planet" today appears not only a mantra of many environmentalists and planners, but it also figures among the mitigation strategies proposed by ministry officials and encounters the unexpected support of many influential researchers. This unrealistic project, however, does not seem to adequately consider the fact that trees and forests represent the last successional stage of terrestrial ecosystems, thus requiring—at least in the first years or decades after planting within urban contexts—some care (hence time and money resources) to become large enough to fulfil the functions expected by public opinion. If we opt for less demanding and faster-growing tree species, the problem is not reduced but exacerbated. In fact, the use of very performant (and often alien) trees increases the risk to favour the spread of species adapted to tolerate disturbance and stress; these will end up behaving as invasive organisms, capable of deeply altering the habitats where they are introduced, as has already happened with many pioneer exotic trees in different parts of the globe [19,20].

The aim of this paper is to discuss why urban forests may not always be the best option for Mediterranean cities, highlighting the need for developing adaptive management strategies, thereby enhancing the adaptability of species and ecosystems. Adaptive management that leverages ecological and evolutionary processes to increase the resilience of Mediterranean ecosystems to land use and climate change should go beyond the indiscriminate application of urban forests.

2. NbS or Not? That Is the Question

The term nature-based solution (henceforth: NbS) was introduced in the first decade of the 2000s by the World Bank to embed biodiversity considerations in climate change adaptation and mitigation. Later, the European Commission used this umbrella term to define "solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic intervention". Recently, the definition of NbS has evolved into [21] "[. . .] actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience and biodiversity benefits [. . .]".

By confronting the two most widely used definitions, there emerges a shift from a concept based on the broad perspective of the three pillars of sustainability to one that emphasises the role of NbS for nature conservation and restoration [22]. Moreover, the latest definition [21] responds to the necessity to distinguish NbS from nature-derived (e.g., wind, wave, and solar energy) and nature-inspired solutions (e.g., innovative design and material production modelled on biological processes such as biomimicry) and also in a broader sense what is an NbS from what is not [23,24]. In this regard, the IUCN global standard for NbS provides a common ground for defining, designing, assessing, and upscaling NbS outcomes based on eight criteria referring to the IUCN NbS principles of the Word Conservation Congress [25] and 28 indicators (Figure 1).

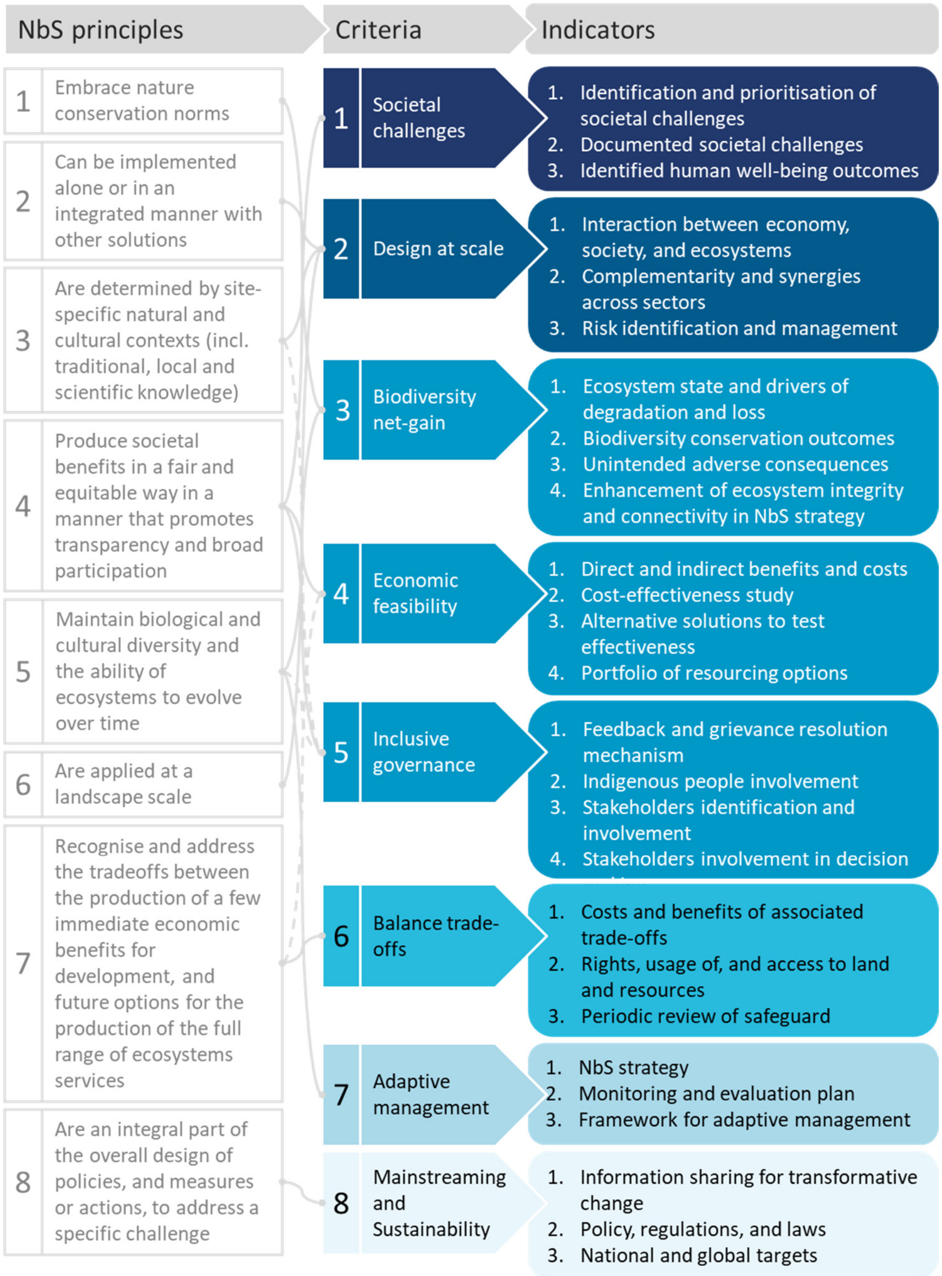

Figure 1. IUCN global standard criteria, indicators, and links with NbS principles as defined in the World Conservation Congress in 2016. Adapted from [23,26]. Dotted lines connecting the principles to the criteria are newly identified by the authors.

Examples of the application of the IUCN standard criteria self-assessment tools are specifically related to marine aquaculture [26] and also to a wider array of NbS [27] as well as being included in the guide for practitioners of the World Wildlife Fund [28].

Recently, NbS have been distinguished among spatial or technological units whether containing green space or green-blue technology; what is relevant is that an Nbs, to be considered as such, must employ nature, namely implying the presence of vegetation [22]. In this regard, urban forests are often considered a key component of NbS. However, in Mediterranean cities, labelling urban forests as NbS without careful consideration of species selection and vegetation structure can be problematic. In fact, this region is characterised by unique climatic and environmental conditions that impose specific limitations on the suitability of urban forests as a universal solution.

For instance, many Mediterranean cities often face significant water shortages, especially during the summer months. Peri-urban areas close to the Mediterranean Sea often have strong hydric stress in summer, reflected in a dry landscape in which forest is often replaced by scrubland or Mediterranean maquis. Urban forests typically require substantial water to establish and maintain, which may not be sustainable or practical given the limited water resources [29]. Without careful selection, the species planted in urban forests may not be resilient to the Mediterranean climate, requiring intensive management and resources [30], or they might become invasive, disrupting local ecosystems [31].

Forests play a crucial role in the hydrological cycle, influencing groundwater recharge, streamflow, and overall water availability [32]. Evapotranspiration rates, which vary by species, age, and density of trees, are a primary driver [33]. Fast-growing species very common in Mediterranean tree plantations, like eucalyptus and pines, tend to consume more water compared to native or mixed-species forests [34]. The revegetation of degraded ecosystems in water-limited areas may create potentially conflicting demands for water between green areas and humans [35].

Mediterranean ecosystems are prone to wildfires, and the introduction of dense urban forests can increase this risk, particularly if they include species that are highly flammable, such as conifers [36]. Increased temperatures, prolonged droughts, and changes in precipitation patterns are contributing to more frequent and severe forest fires all over the Mediterranean region and beyond [37,38]. The interplay between climatic factors and forest composition in driving fire regimes [39], the synergic impact of repeated fires and invasive alien plants [40], and the relationship between socioeconomic drivers, tree mortality, and fire severity [41,42] are crucial issues, yet poorly explored for urban forest planning in Mediterranean cities.

Planting urban forests can lead to the displacement of native vegetation that is better adapted to the local conditions, limiting the ability of local ecosystems to evolve over time. This can reduce the overall biodiversity and resilience of the local ecosystems, thereby going against the very principles and standard criteria for which NbS are designed [43].

Traditional Mediterranean landscapes are a mosaic of ecosystems that have been shaped by human activity over centuries [44,45]. These landscapes include rural and agroforestry systems that are species-rich and have historically demonstrated resilience to various pressures. However, climate and land-use changes pose a new challenge, questioning their long-term resilience. In recent times, Mediterranean cities have experienced significant erosion of semi-natural areas in suburban and peri-urban zones. This degradation has led to the loss of many ecosystem services, including water regulation, species and habitat richness, and soil protection. Many Mediterranean species lack long-distance dispersal strategies, hence their ability to adapt to new environments is limited, making them vulnerable to shifts in temperature and precipitation patterns [46]. This highlights the need for adaptive management strategies that can sustain the resilience of these species and the ecosystems they inhabit. While urban forests can offer significant benefits as part of NbS, their indiscriminate application in Mediterranean cities can be problematic. By harnessing the heterogeneity of Mediterranean landscapes and focusing on ecological and evolutionary processes, it is possible to increase ecosystem resilience to climate and land-use changes through the adoption of solutions tailored to local vegetation dynamics, which do not always involve the planting of urban forests as the best possible option.

3. Patchy Is Beautiful: Shifting from the Tree Plantation Paradigm to Habitat-Rich and Multifunctional Urban Landscapes

Mediterranean cities often fall within territories of paramount biological interest, many of them being featured among the hotspots of plant biodiversity at the global scale [47]. The floristic richness of these territories is the result of strong environmental discontinuity and heterogeneity (microclimate, substrate, morphology; see [48]). With very few conspicuous exceptions, like the small holm-oak wood fragments of La Favorita near Palermo [49] and Portici near Naples [50], many of the most valuable and interesting ecosystems found in Mediterranean cities do not correspond to forests but to open plant communities spreading over scattered and often small-sized surfaces. These can be extremely rich in species, especially those adapted to tolerate harsh environmental conditions (thermal and water stress) and frequent disturbances (cutting, grazing, fire, etc.; see [51]). The vegetation of these ecosystems appears to be "adapted" to anthropogenic pressure, which over the last millennia has shaped its composition, structure, and functioning [52,53]. In fact, Mediterranean semi-natural ecosystems, such as rangelands, garrigues, and maquis, currently covering large amounts of Mediterranean lands, are resilient and count several hundred species capable of coexisting with humans [54]. Recent paleo-ecological investigations [55] pointed out that even under cooler climatic conditions and long before cities were built, central Europe was already home to a complex patchwork where numerous vegetation units—certainly not only forests—coexisted and interacted. The same conditions occurred also under the more stressful climatic conditions of the Mediterranean Basin.

Shaped by human activities, many of the Mediterranean urban, suburban, and peri-urban contexts currently host peculiar assemblages, often very rich in widespread and economically interesting plant species that are classified as crop wild relatives [56]; many other plants, known as archaeophytes, were intentionally or accidentally introduced by humans a long time ago [57]. In the recent past, with the intensification of international plant trade, urban green areas have become focal areas for the establishment and spread of many other exotic species [58,59]. Not surprisingly, most of the phytosociological research concerning Mediterranean urban areas concerns ruderal wall vegetation (*Parietarietea judaicae*), the pioneer communities occurring in brownfields and marginal areas (*Stellarietea mediae* and *Artemisietea vulgaris*) and trampled sites (*Polygono arenastri-Poetea annuae*), and the xerophytic vegetation of nutrient-rich fallows and xeric vegetation often characterising former suburban pasturelands (*Onopordetea acanthii*). These ruderal, pioneer, and opportunistic assemblages benefit from soil disturbance, which has often led to irreversible land degradation, associated with the alteration of the soil microbiota and the disappearance of forest ecosystems and other natural plant communities. This should be considered before planning reforestation measures. In some cases, favouring less complex plant communities, dominated by herbaceous species, appears more sustainable from both an ecological and economic point of view. For the same reason, brownfields may be amended and used for recreational and agricultural (urban gardens) purposes instead of pretending to obtain an "urban forest" by planting fast-growing trees on poorly structured soils. To do so, vegetation ecologists and specialised consultants on "sustainable urbanisation" should be invited to participate in decision-making processes that are currently skewed by agricultural and forestry scientists.

3.1. Will Italians Do It Better?

In Italy, 11.8 million hectares of forests now cover 40% of the national territory, a figure that has doubled since the early twentieth century due to decreased human activity in mountainous and peripheral areas [60]. Given this, reforestation efforts make sense only near metropolitan districts to address rising air pollution and the urban heat island effect.

In coherence with the EU Biodiversity Strategy for 2030, which also includes a pledge to plant 3 billion trees in European territory "in full respect of ecological principles" [61], the Italian National Recovery and Resilience Plan (PNRR) includes planting 6.6 million trees in 14 metropolitan districts between 2022 and 2026. However, the initial goal to plant 1.6 million trees by 2022 was not met in cities like Milan, Bologna, and Florence due to funding access issues related to population density constraints. Despite 84 million euros being allocated to 11 districts, procedural problems and inconsistencies could jeopardise the entire project.

A paradox arises as the EU mandates the planting of native species and a minimum area of one hectare for new forests. Most of the 14 Italian metropolitan cities involved in the plan mentioned above will be unable to apply to the call because they do not have enough free space to do that due to urban development and agricultural land use, making reforestation where it is most needed challenging.

In contrast, the "Forestami" project in Milan, launched in 2018/2019 by local authorities and private foundations, successfully planted 427,000 trees in three years [62], saturating all spaces that could have been available for the PNRR initiative. Although Milan is not a Mediterranean city, it is a large city in a Mediterranean country. The "Forestami" project, independent of the PNRR, highlights the potential for significant urban greening efforts within a short timeframe. However, it also underscores the difficulty in sourcing appropriate plant materials and scaling up nursery production to meet PNRR demands [63,64].

To ensure the success of such initiatives, it is essential to avoid using invasive species and select plants that minimise cultivation and water costs. Addressing green gentrification is also crucial, as creating green spaces can lead to increased property values and the displacement of lower-income residents. To prevent this, efforts should focus on creating smaller, more frequent green patches across urban areas, making green spaces accessible to a broader population and mitigating the risk of displacement. Creating smaller but more frequent and diffuse urban green patches is by far more feasible thinking at herb-rich annual swards and grasslands.

3.2. Rely on (and Pander to) Urban Nature

The above-mentioned measure of the PNRR focuses on cultivation care—planned over a period of no less than 5 years—to facilitate the rooting and growth of young trees, mostly born from seeds, to overcome the shortage of 1–2-year-old seedlings in nurseries. Over 90% of the funding should be used for such care, not for the purchase of the plants. Indeed, only the adequate care of the plantlets may guarantee the future resilience of the new plantations and reduce the number of failures. But are we sure that much more—or at least better—could not be done with the same money by using plant species that are less demanding in terms of water, soil, and space, i.e., by creating plant communities consisting of annual and perennial grasses and small- and medium-sized shrubs?

Semi-natural vegetation units that already occur in the unbuilt gaps and in the surroundings of many Mediterranean cities, such as grass-dominated annual swards (class *Stipo-Trachynietea distachyae*), perennial xeric grasslands (*Lygeo-Stipetea*), garrigue communities (*Rosmarinetea* and *Cisto-Micromerietea*), and evergreen sclerophyllous scrub (*Pistacio-Rhamnetalia alaterni*) represent many habitat templates to be used in Mediterranean urban green infrastructure (Figure 2) and, possibly, pave the way for the establishment of urban forests [65]. Moreover, promoting a patchy, species- and habitat-rich urban landscape may represent the most effective way to foster and promote plant and animal diversity [66] and self-organised ecosystem structure and function. Unfortunately, little attention is paid to the spontaneous mechanisms of ecological succession in urban areas, and no experiments exist on the potential use of natural vegetation dynamics for NbS to improve urban resilience.

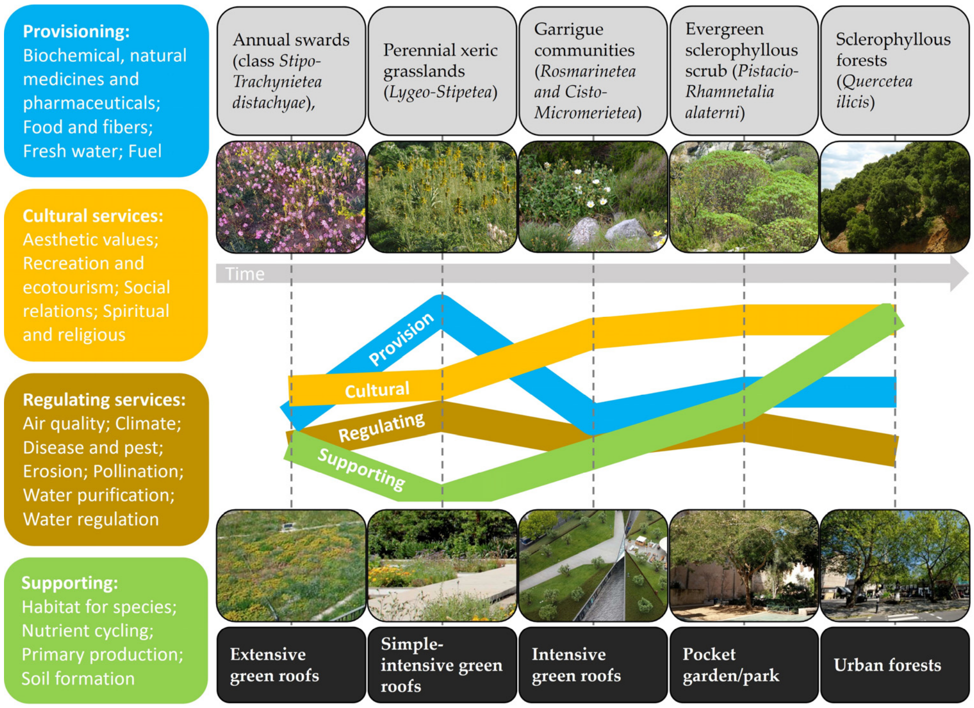

Figure 2. Urban NbS, their ecosystem services, and structural types of potential habitat templates from Mediterranean-type ecosystems. Habitats are ordered following the standard chronosequence of ecological succession. Ecosystem services of Nbs were derived from [22], available at https://github.com/icra/nbs_list (accessed on 23 July 2024). Natural habitat photos credit: Riccardo Guarino; NbS Photos credit https://nbs-explorer.nature4cities-platform.eu/ (accessed on 23 July 2024).

Additionally, green infrastructure built with a habitat template approach, besides requiring low maintenance and being cost-effective, can be usefully employed to create urban stepping stones for rare and endangered plant and animal species [67] and create new sites hosting the target habitats listed in the EU 92/43 Directive [68].

4. Conclusions

Addressing the challenges of urban green infrastructure (UGI) requires a holistic approach that recognises the complexity of ecosystem functioning. Instead of a singular focus on tree species and reforestation, comprehensive strategies should encompass preserving existing natural habitats and engaging in conservation efforts that consider the whole natural scenario and really mirror and comply with the local vegetation dynamics [69].

Administrators and technical consultants should decide on a case-by-case basis, selecting the best options for green infrastructure, i.e., forming plant communities that are expected to grow, spread, and self-sustain over time. Non-woody plant communities can play an important ecological role and may provide plenty of services as well, even in cities.

At the moment of writing, over 22.6 million trees have already been planted in the European territory [70], with little transparency on tree location, planting methods, and direct and indirect effects on the habitats of these reforestation and afforestation actions [71]. By understanding the vegetation dynamics of ecosystems and adopting habitat-based, informed approaches, we can pave the way for sustainable solutions that stand the test of time.

Often overlooked but ecologically vital, Mediterranean spontaneous vegetation may challenge the conventional notion that urban forests are the sole providers of essential ecological functions. If adequately designed and implemented, grass- or shrub-rich urban green spaces can serve as invaluable sanctuaries for urban wildlife, fostering local biodiversity and ecological succession processes. If properly managed, these spaces can also lead to the development of self-established urban forests designed “for” nature [72].

Enhancing habitat-based, informed approaches to UGI design involves integrating ecological principles with urban planning to create resilient and sustainable green spaces that align with local vegetation dynamics. Site-based ecological knowledge is a prerequisite to ensure that UGI projects support native biodiversity and ecosystem services. This requires gathering data on the local vegetation, soil types, hydrology, and historical vegetation patterns, to establish adaptive management frameworks that allow for the continuous monitoring, evaluation, and adjustment of UGI projects based on changing ecological conditions and vegetation dynamics.

Author Contributions: Conceptualisation, R.G., C.C., S.P.; writing—original draft preparation, R.G., C.C., S.P.; writing—review and editing, R.G.; figures, C.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research has been supported by the Ministero dell'Istruzione e del Merito (grant no. PRIN 2022 PNRR P20228T8TJ_003; CUP B53D23032530001), through the NextGenerationEU funds. C.C. acknowledges the support received from the National Recovery and Resilience Plan (NRRP), Mission 4 Component 2 Investment 1.4—Call for tender No. 3138 of 16 December 2021, rectified by Decree n.3175 of 18 December 2021 of the Italian Ministry of University and Research funded by the European Union—NextGenerationEU; Project code CN_00000033, Concession Decree No. 1034 of 17 June 2022 adopted by the Italian Ministry of University and Research, CUP, H43C22000530001 Project title "National Biodiversity Future Center—NBFC".

Institutional Review Board Statement: Not applicable.

Data Availability Statement: No new data were created.

Acknowledgments: Daniele La Rosa and Marisa Meli, from the University of Catania, are gratefully acknowledged for sharing ideas and participating in the discussions about the contents of this paper.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

1. *FAO Guidelines on Urban and Peri-Urban Forestry*; Forestry Paper No. 178; FAO: Rome, Italy, 2016.
2. Johnson, M.T.; Munshi-South, J. Evolution of life in urban environments. *Science* **2017**, *358*, eaam8327. [CrossRef] [PubMed]
3. Nowak, D.J.; Hirabayashi, S.; Bodine, A.; Greenfield, E. Tree and forest effects on air quality and human health in the United States. *Environ. Pollut.* **2014**, *193*, 119–129. [CrossRef] [PubMed]
4. Ramon, M.; Ribeiro, A.P.; Theophilo, C.Y.S.; Moreira, E.G.; de Camargo, P.B.; de Bragança Pereira, C.A.; Saraiva, E.F.; dos Reis Tavares, A.; Dias, A.G.; Nowak, D.; et al. Assessment of four urban forests as environmental indicator of air quality: A study in a Brazilian megacity. *Urban Ecosyst.* **2023**, *26*, 197–207. [CrossRef]
5. Dearborn, D.C.; Kark, S. Motivations for conserving urban biodiversity. *Conserv. Biol.* **2010**, *24*, 432–440. [CrossRef] [PubMed]
6. Dickinson, D.C.; Ramalho, C.E. A balancing act: Biodiversity and human wellbeing considerations in the management of urban forest in a global biodiversity hotspot. *Urban For. Urban Green.* **2022**, *74*, 127656. [CrossRef]
7. Marando, F.; Heris, M.P.; Zulian, G.; Udías, A.; Mentaschi, L.; Chrysoulakis, N.; Parastatidis, D.; Maes, J. Urban heat island mitigation by green infrastructure in European Functional Urban Areas. *Sustain. Cities Soc.* **2022**, *77*, 103564. [CrossRef]
8. Muluneh, M.G.; Worku, B.B. Contributions of urban green spaces for climate change mitigation and biodiversity conservation in Dessie city, Northeastern Ethiopia. *Urban Clim.* **2022**, *46*, 101294. [CrossRef]
9. Majidi, A.N.; Vojinovic, Z.; Alves, A.; Weesakul, S.; Sanchez, A.; Boogaard, F.; Kluck, J. Planning nature-based solutions for urban flood reduction and thermal comfort enhancement. *Sustainability* **2019**, *11*, 6361. [CrossRef]
10. Mills, J.G.; Bissett, A.; Gellie, N.J.; Lowe, A.J.; Selway, C.A.; Thomas, T.; Weinstein, P.; Weyrich, L.S.; Breed, M.F. Revegetation of urban green space rewilds soil microbiotas with implications for human health and urban design. *Restor. Ecol.* **2020**, *28*, S322–S334. [CrossRef]
11. Viezzer, J.; Schmidt, M.A.R.; dos Reis, A.R.N.; Freiman, F.P.; de Moraes, E.N.; Biondi, D. Restoration of urban forests to reduce flood susceptibility: A starting point. *Int. J. Disaster Risk Reduct.* **2022**, *74*, 102944. [CrossRef]
12. Bratman, G.N.; Anderson, C.B.; Berman, M.G.; Cochran, B.; De Vries, S.; Flanders, J.; Folke, C.; Frumkin, H.; Gross, J.J.; Hartig, T.; et al. Nature and mental health: An ecosystem service perspective. *Sci. Adv.* **2019**, *5*, eaax0903. [CrossRef] [PubMed]
13. Marselle, M.R.; Hartig, T.; Cox, D.T.; De Bell, S.; Knapp, S.; Lindley, S.; Triguero-Mas, M.; Böhning-Gaese, K.; Braubach, M.; Cook, P.A.; et al. Pathways linking biodiversity to human health: A conceptual framework. *Environ. Int.* **2021**, *150*, 106420. [CrossRef] [PubMed]

14. Weinbrenner, H.; Breithut, J.; Hebermehl, W.; Kaufmann, A.; Klinger, T.; Palm, T.; Wirth, K. "The forest has become our new living room"—The critical importance of urban forests during the COVID-19 pandemic. *Front. For. Glob. Chang.* **2021**, *4*, 672909. [CrossRef]
15. Marks, A.M.; Kitatani, K.; Bhagwat, S.A. Shinto shrine forests and happiness in Japan. In *Religion and Nature Conservation*; Routledge: Abingdon, UK, 2022; pp. 143–157.
16. Ishii, H.T.; Manabe, T.; Ito, K.; Fujita, N.; Imanishi, A.; Hashimoto, D.; Iwasaki, A. Integrating ecological and cultural values toward conservation and utilization of shrine/temple forests as urban green space in Japanese cities. *Landsc. Ecol. Eng.* **2010**, *6*, 307–315. [CrossRef]
17. Melaku, A.; Pastor Ivars, J. Urban sacred forests support human well-being through cultural ecosystem services. *J. Cult. Herit. Manag. Sustain. Dev.* 2024; *preprint*. [CrossRef]
18. Turo, K.J.; Gardiner, M.M. The balancing act of urban conservation. *Nat. Commun.* **2020**, *11*, 3773. [CrossRef] [PubMed]
19. Rejmánek, M.; Richardson, D.M. Trees and shrubs as invasive alien species–2013 update of the global database. *Divers. Distrib.* **2013**, *19*, 1093–1094. [CrossRef]
20. Campagnaro, T.; Brundu, G.; Sitzia, T. Five major invasive alien tree species in European Union forest habitat types of the Alpine and Continental biogeographical regions. *J. Nat. Conserv.* **2018**, *43*, 227–238. [CrossRef]
21. UNEA. Resolution Adopted by the United Nations Environment Assembly on 2 March 2022 (UNEP/EA.5/Res.5). United Nations. 2022. Available online: https://www.unep.org/resources/resolutions-treaties-and-decisions/UN-Environment-Assembly-5-2 (accessed on 23 July 2024).
22. Castellar, J.A.C.; Popartan, L.A.; Pueyo-Ros, J.; Atanasova, N.; Langergraber, G.; Säumel, I.; Corominas, L.; Comas, J.; Acuña, V. Nature-based solutions in the urban context: Terminology, classification and scoring for urban challenges and ecosystem services. *Sci. Total Environ.* **2021**, *779*, 146237. [CrossRef]
23. IUCN. *Guidance for Using the IUCN Global Standard for Nature-Based Solutions: A User-Friendly Framework for the Verification, Design and Scaling up of Nature-Based Solutions*, 1st ed.; IUCN: Gland, Switzerland, 2020. [CrossRef]
24. Sowińska-Świerkosz, B.; García, J. What are Nature-based solutions (NBS)? Setting core ideas for concept clarification. *Nat. Based Solut.* **2022**, *2*, 100009. [CrossRef]
25. Cohen-Shacham, E.; Andrade, A.; Dalton, J.; Dudley, N.; Jones, M.; Kumar, C.; Maginnis, S.; Maynard, S.; Nelson, C.R.; Renaud, F.G.; et al. Core principles for successfully implementing and upscaling Nature-based Solutions. *Environ. Sci. Policy* **2019**, *98*, 20–29. [CrossRef]
26. Le Gouvello, R.; Cohen-Shacham, E.; Herr, D.; Spadone, A.; Simard, F.; Brugere, C. The IUCN Global Standard for Nature-based Solutions™ as a tool for enhancing the sustainable development of marine aquaculture. *Front. Mar. Sci.* **2023**, *10*, 1146637. [CrossRef]
27. Mehta, D.; Pandey, R.; Kumar Gupta, A.; Juhola, S. Nature-based solutions in Hindu Kush Himalayas: IUCN global standard based synthesis. *Ecol. Indic.* **2023**, *154*, 110875. [CrossRef]
28. De Kock, M.; Del Pino, D.P. (Eds.) *How to Design High-Quality NbS Field Projects: A Guide for Practitioners*; World Wildlife Fund: Gland, Switzerland, 2022. Available online: https://wedocs.unep.org/bitstream/handle/20.500.11822/42356/WWF_2.pdf?sequence=1&isAllowed=y (accessed on 23 July 2024).
29. García-Ruiz, J.M.; López-Moreno, J.I.; Vicente-Serrano, S.M.; Lasanta–Martínez, T.; Beguería, S. Mediterranean water resources in a global change scenario. *Earth Sci. Rev.* **2011**, *105*, 121–139. [CrossRef]
30. Teixeira, C.P.; Fernandes, C.O.; Ahern, J. Adaptive planting design and management framework for urban climate change adaptation and mitigation. *Urban For. Urban Green.* **2022**, *70*, 127548. [CrossRef]
31. Moricca, S.; Bracalini, M.; Croci, F.; Corsinovi, S.; Tiberi, R.; Ragazzi, A.; Panzavolta, T. Biotic factors affecting ecosystem services in urban and peri-urban forests in Italy: The role of introduced and impending pathogens and pests. *Forests* **2018**, *9*, 65. [CrossRef]
32. Jones, J.; Ellison, D.; Ferraz, S.; Lara, A.; Wei, X.; Zhang, Z. Forest restoration and hydrology. *For. Ecol. Manag.* **2022**, *520*, 120342. [CrossRef]
33. Oishi, A.C.; Oren, R.; Novick, K.A.; Palmroth, S.; Katul, G.G. Interannual invariability of forest evapotranspiration and its consequence to water flow downstream. *Ecosystems* **2010**, *13*, 421–436. [CrossRef]
34. Shi, Z.; Xu, D.; Yang, X.; Jia, Z.; Guo, H.; Zhang, N. Ecohydrological impacts of eucalypt plantations: A review. *J. Food Agric. Environ.* **2012**, *10*, 1419–1426.
35. Feng, X.; Fu, B.; Piao, S.; Wang, S.; Ciais, P.; Zeng, Z.; Li, Y.; Jiang, X.; Wu, B. Revegetation in China's Loess Plateau is approaching sustainable water resource limits. *Nat. Clim. Chang.* **2016**, *6*, 1019–1022. [CrossRef]
36. Pausas, J.G.; Llovet, J.; Rodrigo, A.; Vallejo, R. Are wildfires a disaster in the Mediterranean basin?—A review. *Int. J. Wildland Fire* **2008**, *17*, 713–723. [CrossRef]
37. Meng, M.; Harrison, S.P.; Jie, D.; Li, N.; Liu, B.; Li, D.; Gao, G.; Niu, H. Climate and fire drivers of forest composition and openness in the Changbai Mountains since the Late Glacial. *For. Ecosyst.* **2023**, *10*, 100127. [CrossRef]
38. MacCarthy, J.; Tyukavina, A.; Weisse, M.J.; Harris, N.; Glen, E. Extreme wildfires in Canada and their contribution to global loss in tree cover and carbon emissions in 2023. *Glob. Chang. Biol.* **2024**, *30*, e17392. [CrossRef]
39. Hagmann, R.K.; Hessburg, P.F.; Prichard, S.J.; Povak, N.A.; Brown, P.M.; Fulé, P.Z.; Keane, R.E.; Knapp, E.E.; Lydersen, J.M.; Metlen, K.L.; et al. Evidence for widespread changes in the structure, composition, and fire regimes of western North American forests. *Ecol. Appl.* **2021**, *31*, e02431. [CrossRef]

40. Guarino, R.; Cerra, D.; Zaia, R.; Chiarucci, A.; Lo Cascio, P.; Rocchini, D.; Zannini, P.; Pasta, S. Remote sensing reveals fire-driven enhancement of a C 4 invasive alien grass on a small Mediterranean volcanic island. *Biogeosciences* **2024**, *21*, 2717–2730. [CrossRef]
41. Chergui, B.; Fahd, S.; Santos, X.; Pausas, J.G. Socioeconomic factors drive fire-regime variability in the Mediterranean Basin. *Ecosystems* **2018**, *21*, 619–628. [CrossRef]
42. Berčák, R.; Holuša, J.; Trombik, J.; Resnerová, K.; Hlásny, T. A Combination of Human Activity and Climate Drives Forest Fire Occurrence in Central Europe: The Case of the Czech Republic. *Fire* **2024**, *7*, 109. [CrossRef]
43. Seddon, N.; Smith, A.; Smith, P.; Key, I.; Chausson, A.; Girardin, C.; House, J.; Srivastava, S.; Turner, B. Getting the message right on nature-based solutions to climate change. *Glob. Chang. Biol.* **2021**, *27*, 1518–1546. [CrossRef] [PubMed]
44. Florenzano, A. The History of Pastoral Activities in S Italy Inferred from Palynology: A Long-Term Perspective to Support Biodiversity Awareness. *Sustainability* **2019**, *11*, 404. [CrossRef]
45. Florenzano, A.; Zerboni, A.; Carter, J.C.; Clò, E.; Mariani, G.S.; Mercuri, A.M. Environmental and land use changes in a Mediterranean landscape: Palynology and geoarchaeology at ancient Metapontum (Pantanello, Southern Italy). *Quat. Int.* **2022**, *635*, 105–124. [CrossRef]
46. Aurelle, D.; Thomas, S.; Albert, C.; Bally, M.; Bondeau, A.; Boudouresque, C.-F.; Cahill, A.E.; Carlotti, F.; Chenuil, A.; Cramer, W.; et al. Biodiversity, Climate Change, and Adaptation in the Mediterranean. *Ecosphere* **2022**, *13*, e3915. [CrossRef]
47. Médail, F.; Myers, N. Mediterranean Basin. In *Hotspots Revisited: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions*; Mittermeier, R.A., Robles Gil, P., Hoffmann, M., Pilgrim, J., Brooks, T., Mittermeier, C.G., Lamoreux, J., da Fonseca, G.A.B., Eds.; CEMEX: Monterrey, Mexico; Conservation International: Washington, DC, USA; Agrupación Sierra Madre: San Salvador, Mexico, 2004; pp. 144–147.
48. Thompson, J.D. *Plant Evolution in the Mediterranean*; Insights for Conservation; Oxford University Press: Oxford, UK, 2020; p. 439.
49. Gianguzzi, L.; Caldarella, O.; Campisi, P.; Ravera, S.; Scalenghe, R.; Venturella, G. Plant diversity in old-growth woods: The case of the forest edges of the Favorita Park in Palermo (north-western Sicily, Italy). *Plant Sociol.* **2024**, *61*, 1–29. [CrossRef]
50. Teobaldelli, M.; Cona, F.; Stinca, A.; Saulino, L.; Anzano, E.; Giordano, D.; Migliozzi, A.; Bonanomi, G.; D'Urso, G.; Mazzoleni, S.; et al. Improving resilience of an old-growth urban forest in Southern Italy: Lesson(s) from a stand-replacing windstorm. *Urban For. Urban Green.* **2020**, *47*, 126521. [CrossRef]
51. Guarino, R.; Vrahnakis, M.; Rojo, M.P.R.; Giuga, L.; Pasta, S. Grasslands and shrublands of the Mediterranean region. In *Encyclopedia of the World's Biomes*; Elsevier: Amsterdam, The Netherlands, 2020; Volume 3, pp. 638–655.
52. Mercuri, A.M.; Sadori, L.; Uzquiano Ollero, P. Mediterranean and north-African cultural adaptations to mid-Holocene environmental and climatic changes. *Holocene* **2011**, *21*, 189–206. [CrossRef]
53. Mercuri, A.M.; Florenzano, A.; Burjachs, F.; Giardini, M.; Kouli, K.; Masi, A.; Picornell-Gelabert, L.; Revelles, J.; Sadori, L.; Servera-Vives, G.; et al. From influence to impact: The multifunctional land use in Mediterranean prehistory emerging from palynology of archaeological sites (8.0–2.8 ka BP). *Holocene* **2019**, *29*, 830–846. [CrossRef]
54. Blondel, J.; Aronson, J. *Biology and Wildlife of the Mediterranean Region*; Oxford University Press: Oxford, UK, 1999.
55. Pearce, E.A.; Mazier, F.; Normand, S.; Fyfe, R.; Andrieu, V.; Bakels, C.; Balwierz, Z.; Bińka, K.; Boreham, S.; Borisova, O.K.; et al. Substantial light woodland and open vegetation characterized the temperate forest biome before Homo sapiens. *Sci. Adv.* **2023**, *9*, eadi9135. [CrossRef] [PubMed]
56. Heywood, V.H.; Zohary, D. A catalogue of the wild relatives of cultivated plants native to Europe. *Flora Mediterr.* **1995**, *5*, 375–415.
57. Brullo, S.; Guarino, R. The Mediterranean weedy vegetation and its origin. *Ann. Di Bot.* **2007**, *7*, 101–110.
58. Kowarik, I. Novel urban ecosystems, biodiversity, and conservation. *Environ. Pollut.* **2011**, *159*, 1974–1983. [CrossRef]
59. Branco, M.; Nunes, P.; Roques, A.; Fernandes, M.R.; Orazio, C.; Jactel, H. Urban trees facilitate the establishment of non-native forest insects. *NeoBiota* **2019**, *52*, 25–46. [CrossRef]
60. Falcucci, A.; Maiorano, L.; Boitani, L. Changes in land-use/land-cover patterns in Italy and their implications for biodiversity conservation. *Landsc. Ecol.* **2007**, *22*, 617–631. [CrossRef]
61. European Commission. Commission Staff Working Document. The 3 Billion Tree Planting Pledge for 2030. Accompanying the New EU Forest Strategy for 2030. 2021. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021SC0651 (accessed on 23 July 2024).
62. Available online: https://forestami.org (accessed on 23 July 2024).
63. Martini, S.; Maltoni, A.; Monteverdi, M.C.; De Dato, G.; Salbitano, F.; Marchetti, M.; Mariotti, B. Indagine sulla produzione vivaistica forestale pubblica in Italia. *For. J. Silvic. For. Ecol.* **2022**, *19*, 18–30. [CrossRef]
64. Mariotti, B.; Mezzalira, G.; Allasia, E.; Fazio, F.; Fiorentin, R.; Maltoni, A.; Marchetti, M.; Matteucci, G.; Mori, P.; Motta, R.; et al. La vivaistica forestale in Italia al bivio: Sfide e strategie. *For. J. Silvic. For. Ecol.* **2022**, *19*, 85–94. [CrossRef]
65. Catalano, C.; Pasta, S.; Guarino, R. A plant sociological procedure for the ecological design and enhancement of urban green infrastructure. In *Urban Services to Ecosystems. Future City*; Catalano, C., Andreucci, M.B., Guarino, R., Bretzel, F., Leone, M., Pasta, S., Eds.; Springer: Cham, Switzerland, 2021; Volume 17, pp. 31–60.
66. Caula, S.A.; Sirami, C.; Marty, P.; Martin, J.L. Value of an urban habitat for the native Mediterranean avifauna. *Urban Ecosyst.* **2010**, *13*, 73–89. [CrossRef]
67. Ives, C.D.; Lentini, P.E.; Threlfall, C.G.; Ikin, K.; Shanahan, D.F.; Garrard, G.E.; Bekessy, S.A.; Fuller, R.A.; Mumaw, L.; Rayner, L.; et al. Cities are hotspots for threatened species. *Glob. Ecol. Biogeogr.* **2013**, *25*, 117–126. [CrossRef]

68. Van Mechelen, C.; Dutoit, T.; Hermy, M. Mediterranean open habitat vegetation offers great potential for extensive green roof design. *Landsc. Urban Plan.* **2014**, *121*, 81–91. [CrossRef]
69. Zhao, J.; Davies, C.; Veal, C.; Xu, C.; Zhang, X.; Yu, F. Review on the Application of Nature-Based Solutions in Urban Forest Planning and Sustainable Management. *Forests* **2024**, *15*, 727. [CrossRef]
70. Available online: https://mapmytree.eea.europa.eu (accessed on 23 July 2024).
71. Pérez Gómez, Á.; Repeto Deudero, I.; Ojeda Copete, F.; Gómez González, S. Poor communication jeopardizes biodiversity. *Conserv. Biol.* **2023**, *37*, e14181. [CrossRef]
72. Catalano, C.; Meslec, M.; Boileau, J.; Guarino, R.; Aurich, I.; Baumann, N.; Chartier, F.; Dalix, P.; Deramond, S.; Laube, P.; et al. Smart sustainable cities of the new millennium: Towards design for nature. *Circ. Econ. Sustain.* **2021**, *1*, 1053–1086. [CrossRef]