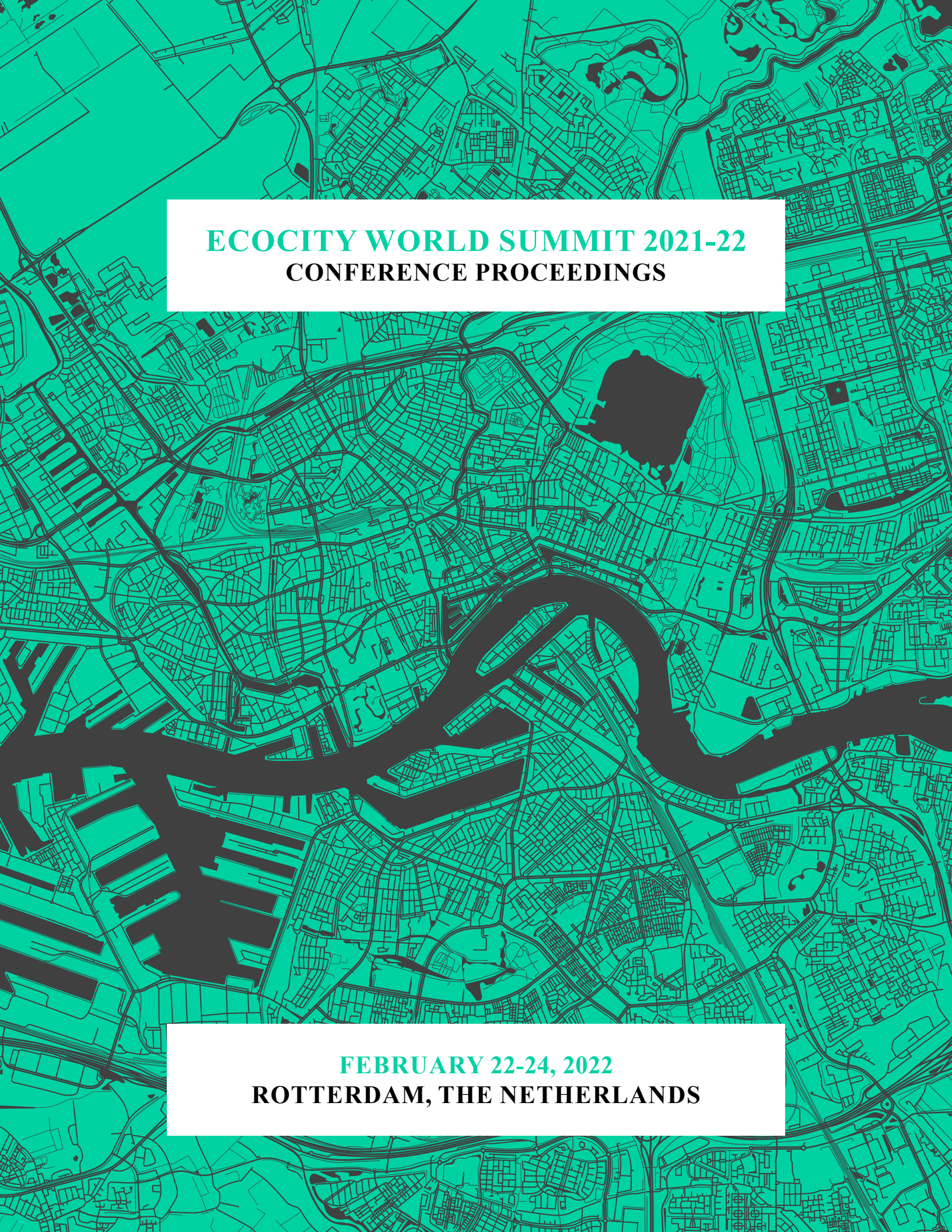

ECOCITY WORLD SUMMIT 2021-22

CONFERENCE PROCEEDINGS

FEBRUARY 22-24, 2022

ROTTERDAM, THE NETHERLANDS

ECOCITY WORLD SUMMIT 2021-22 HOSTING PARTNERS

TU Delft and SASBE

Summit Secretariat

Ecocity World Summit is an initiative of California USA-based nonprofit Ecocity Builders.

ECOCITY BUILDERS

1423 Broadway, 1015
Oakland, CA 94612 USA
www.ecocitybuilders.org
info@ecocitybuilders.org
EIN: 68-0285073

ISBN: 978-0-578-77618-7

ACHIEVEMENTS, FLAWS, AND FUTURE GOALS OF SCIENTIFIC RESEARCH ON GREEN ROOFS IN MEDITERRANEAN CITIES: FIRST FEEDBACK FROM ONGOING META-ANALYSIS

Salvatore Pasta
Italian National Research Council (CNR),
Institute of Biosciences and BioResources (IBBR), Palermo, Italy
salvatore.pasta@ibbr.cnr

Chiara Catalano
Zurich University of Applied Sciences (ZHAW),
Department of Life Sciences and Facility Management (LSFM), Wädenswil, Switzerland
cata@zhaw.ch

Francesca Bretzel
Italian National Research Council (CNR),
Institute on Terrestrial Ecosystems (IRET), Pisa, Italy
francesca.bretzel@cnr.it

Riccardo Guarino
University of Palermo, Department of Biological,
Chemical and Pharmaceutical Sciences and Technologies (STEBICEF), Palermo, Italy
riccardo.guarino@unipa.it

ABSTRACT

Current scientific research points out the low number of papers focused on the environmental patterns in Mediterranean urban areas, where green infrastructure is still strongly underrated by scientists as well as by politicians, planners and decision-makers. In this paper, the results of a simple meta-analysis on the topics treated in scientific literature about the Mediterranean green roofs (MGRs) are presented. Our review pointed out the strikingly higher attention paid to building materials, energy efficiency and hydraulics with respect to life sciences (including basic ecology, horticulture, soil, plant and animal sciences) in the target paper selection. In fact, despite the availability of plentiful information about the Mediterranean vascular flora and vegetation, this is not so informing the selection of plants for roof greening purposes. The role of soil-based substrates in local bio-geochemical cycles, plant and animal communities and their dynamics have also been poorly studied so far. Social and perceptive aspects are completely underrated too, whilst the management strategies and the dominant economic approach are informed more by energy-saving than by the finding innovative and sustainable materials and techniques. More investments are needed to: 1) diversify the techniques and materials for roof construction, respecting local ecoregional features and circular economy; 2) sustain the use of native plants, well adapted to stand environmental stress and anthropogenic disturbance; 3) avoid potentially invasive alien plants; 4) implement the cost-benefit effectiveness of MGRs in the medium- and long-term.

KEYWORDS

literature review; semi-arid habitats; urban ecosystems; Mediterranean Basin

INTRODUCTION

Although the oldest cities of Europe were built in the Mediterranean Basin, and some of them (e.g., Athens, Alexandria, Syracuse, Rome, Istanbul) have been very large and densely populated since antiquity and for long time, little attention has been paid to these in terms of urban ecology.

After 1960s the Mediterranean Basin has experienced the same socioeconomic and demographic processes that affected people worldwide [1]. The economic decline of agropastoral practices induced people to abandon inland areas and migrate toward the cities – mostly concentrated near the main rivers and the coasts – looking for new job opportunities (e.g., industry, tourism). Following this trend, Mediterranean cities (henceforth MCs) are experiencing ever increasing built (sealed) surface areas, resource consumption, carbon footprint and number of inhabitants [2]. In fact, 13 of them (mostly concentrated in North Africa and the Near East) host more than one million inhabitants, and the population of some more 40 cities exceeds 250,000 units (http://mc3.lped.fr/Les-caracteristiques-des-villes-Mediterraneennes?lang=en). As a result, many MCs are currently facing a dramatic social and ecological crisis, not only the largest and the medium-sized ones, but also the small ones are too densely inhabited (e.g., Valletta) or completely deprived of natural and semi-natural areas (e.g., Beirut), appearing just 'hostile' to their inhabitants basing on a wide spectrum of indicators (e.g., air quality, noise, green space/inhabitant).

In such an alarming scenario, it appears crucial to find out ways to improve the quality of urban spaces and to invert the above-mentioned landscape degradation/habitat fragmentation trend. The best option to make MCs more liveable places is to 'revive' local natural heritage, for instance by raising the citizens' awareness of the value of local landmarks, by protecting and restoring the remnant patches of urban soils and ecosystems, enhancing their connectivity (e.g., watershed, food webs, ecological corridors, steppingstones) to 're-start' natural processes. In this framework, the set-up of green roofs represents an effective strategy to improve the overall surface, structure and functionality of urban green infrastructure, a tool that has been overlooked by city planners, landscape architects, urban ecologists, and decision makers in the Mediterranean context [3].

This paper aims at providing a synthetic, yet preliminary view of the main results of the scientific research on Mediterranean green roofs (henceforth MGRs) and drafting the knowledge gaps and the questions which are still waiting to be experimentally addressed and answered. While some robust bibliometric studies already exist focusing on green roofs worldwide [4, 5]we found that the number of publications in this field increased in the last two decades at very similar pace to other pre-established academic disciplines. We also found that papers on green roofs were classified into 32 research areas. There was very little change in the frequency of most research areas through time. The percentages of plant sciences, forestry, marine and freshwater biology and biodiversity conservation of the total research areas classifications used each year increased significantly with time, while architecture decreased significantly with time signifying an increased interest in environmental issues and less focus on architectural issues. The distribution of publications between countries has been skewed, with the USA and the EU conducting 66% of the research, and thus allocation of research effort is focused in those continents and predominantly in temperate ecosystems. However, there has been a sharp increase in the number of countries that conduct green roof research. Our work provides a suite of indicators that can be combined to give a useful picture of the development of green roof research and identifies the challenges which lie ahead for this novel research area. (C, to the best of our knowledge, no previous research has identified and provided meta-analysis of the review on MGRs research in MCs.

MATERIAL & METHODS

This review is based on a study of papers about MGRs, retrieved peer-reviewed journals. A simple query was carried out by selecting in the Web of Science (WoS, last accessed: December 27, 2021) the peer-reviewed articles obtained by the search keys "green roof*", with and without "Mediterranean", in the topic field (i.e., searching in title, abstract and keywords). These were named "MED" and "NOT MED", respectively:

1. MED: TS=("green roof*") and TS=(Mediterranean) and Articles (Document Types) (https://www.webofscience.com/wos/woscc/summary/90b497f3-b1ce-4d09-b45c-4efe78ddea37-1d4073f3/times-cited-descending/1)

2. NOT MED: TS=("green roof*") NOT TS=(Mediterranean) and Articles (Document Types) (https://www.webofscience.com/wos/woscc/summary/35b9a6a8-8957-47f9-9f1b-d3d3ab85f015-1ef82312/times-cited-descending/1)

Additionally, we created and analysed the subset 'NOT MED (MED BASIN)' to have an idea of the number of articles included in the 'NOT MED' dataset which indeed are focused on MGRs.

3. NOT MED (MED BASIN): TS=("green roof*") NOT TS=(Mediterranean) and Articles (Document Types) and Articles or Early Access (Document Types) and ITALY or FRANCE or SPAIN or GREECE or TURKEY or EGYPT or ISRAEL or CYPRUS or SLOVENIA or LEBANON or ALGERIA or CROATIA or BOSNIA HERCEG (Countries/Regions) (https://www.webofscience.com/wos/woscc/summary/257267b8-7a81-407a-801a-690c45ab19bd-1ef82068/times-cited-descending/1).

To obtain a deeper insight on the focus of the 'MED' papers, we searched for several dozens of topics included (or not included) in the title, the key words and/or the abstract of our paper selection. These topics have been grouped as follows:

1. Technical Approaches & Building Materials (e.g., 'Building', 'Design', 'Construct*', 'Material'),
2. Energy, Water & Climate (e.g., 'Energ*', 'Climat*', 'Drainage', 'Runoff', 'Hydrol*', 'Heat'),
3. Ecology, Biogeography & Conservation (e.g., 'Community', 'Ecosyst*', 'Native', 'Disturbance'),
4. Soil Sciences & Agriculture/Horticulture (e.g., 'Substrate', Nitrogen', 'Soil Microorg*'),
5. Plant Sciences (e.g., 'Physiology', 'Vegetation', 'Metabolism', 'Life Form'),
6. Animal Sciences (e.g., 'Arthropod', 'Insect', 'Vertebrate', 'Bird'),
7. Social Sciences & Psychology (e.g., 'Well-Being', 'Recreat*', 'Awareness'),
8. Management Strategies & Economy (e.g., 'Cost-Benefit', 'Sustainab*', 'Management').

RESULTS

The global scale

The first automatic query carried out on the Web of Science for "green roof*" NOT "Mediterranean" in title, abstract, keywords (authors' keywords and keywords plus) yielded 1928 'NOT MED' papers published during last 25 years (1996-2021, Fig. 1), Wolch et al. [6] being the most cited (1351 citations) and Kralli et al. [7] the oldest work. According to the Web of Science categories, more than 70% of these papers belong to three main categories (Fig. 2), i.e., Environmental Sciences (731 items, 37.1%), Civil Engineering (361 items, 18.3%), Environmental Engineering (340 items, 17,3%). Most of these studies were carried out in USA, Europe and China (Fig. 3).

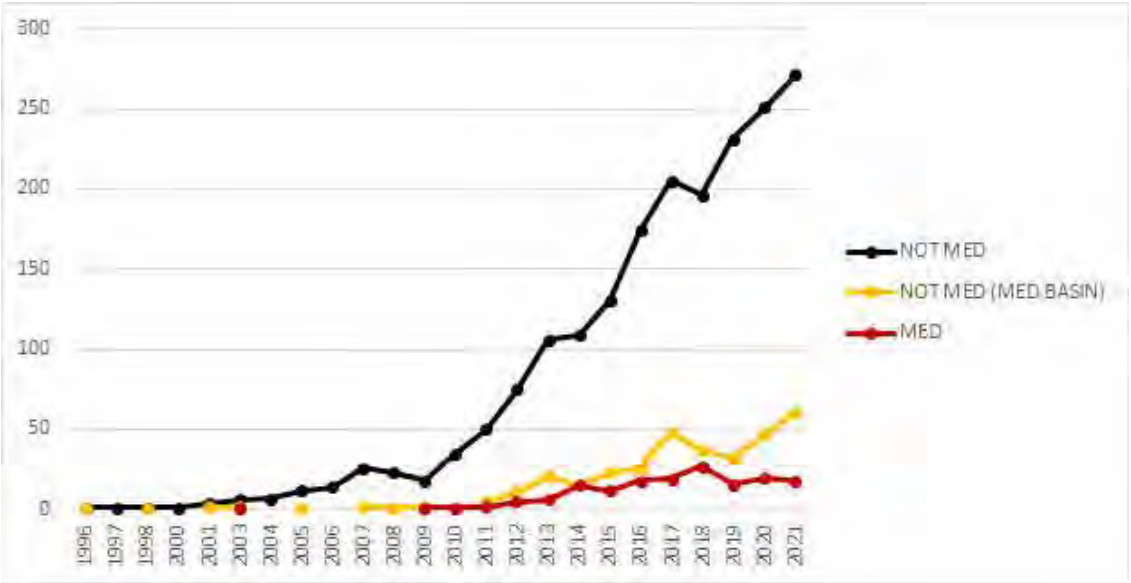

Figure 1. Diachronic comparison of the yearly publications of NOT MED (incl. NOT MED - MED BASIN) vs. MED papers.

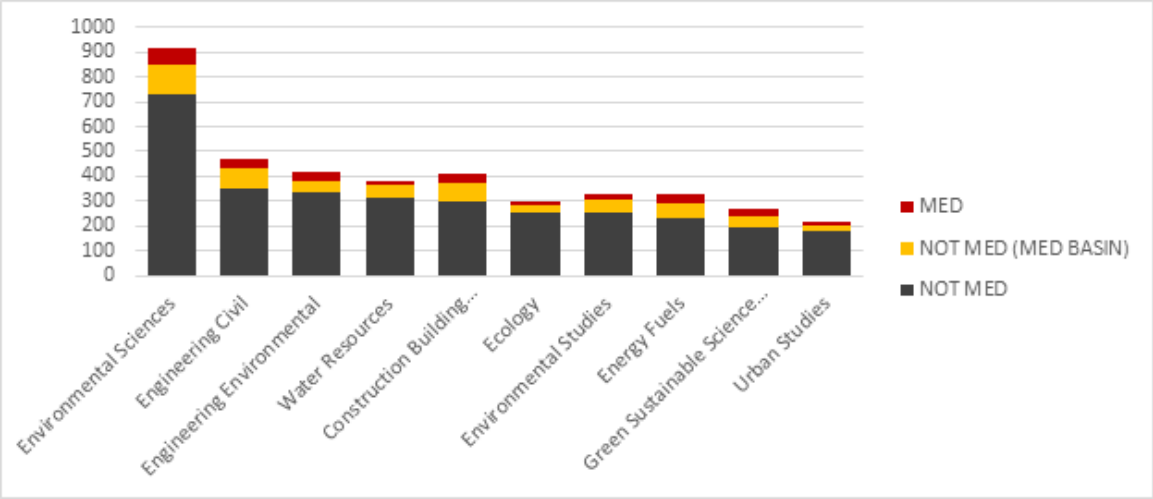

Figure 2. Top 10 categories (according to WoS classification scheme) of the NOT MED (incl. NOT MED - MED BASIN) vs. MED papers.

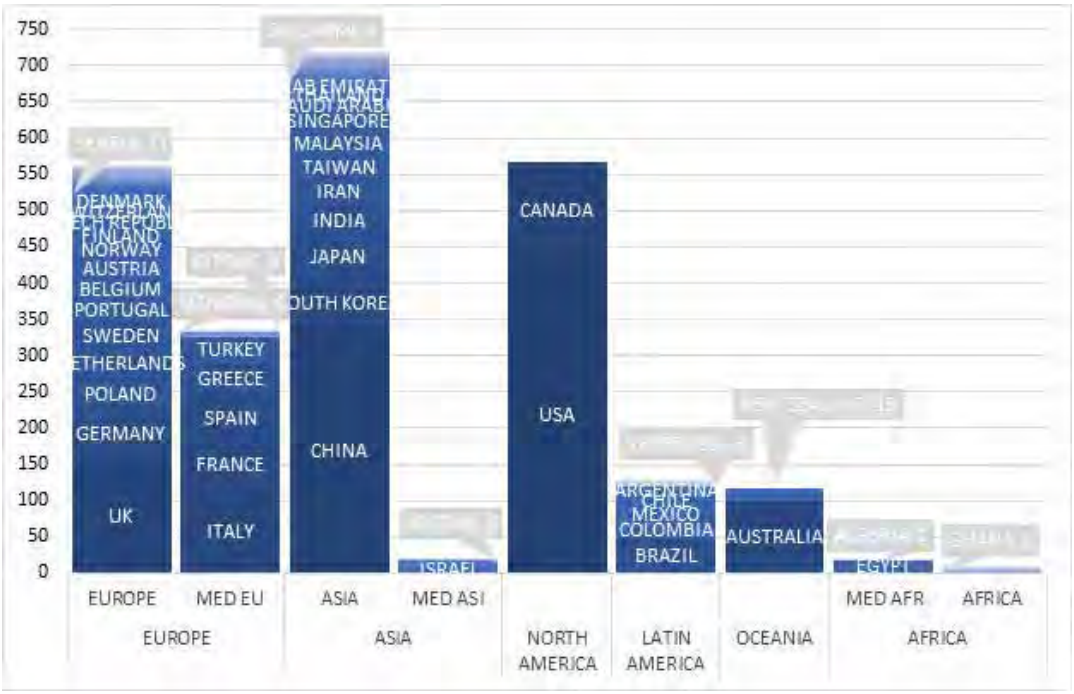

Figure 3. Geographical distribution and number of the NOT MED papers; only the most scientifically productive countries are mentioned. The Mediterranean countries of Europe, Asia and Africa (MED EUROPE, MED ASIA and MED AFRICA) are pointed out.

The second automatic query on the Web of Science for "green roof*" and "Mediterranean" title, abstract, keywords yielded 161 'MED' articles (Fig. 4) published in the last 19 years (2003-2021), with Zinzi and Angoli [8]as well as the intensification of the urban heat island effect. This trend is observed at several latitudes, including areas where overheating was unknown at building and urban levels. This phenomenon involves different issues: reduction of greenhouse gases, quality and comfort in outdoor and indoor environment, security of energy supply, public health. The building sector is directly involved in this change and adequate solutions can provide great benefit at energy and environmental levels. Roofs in particular are envelope components for which advanced solutions can provide significant energy savings in cooled buildings or improve indoor thermal conditions in not cooled buildings. Cool materials keep the roof cool under the sun by reflecting the incident solar radiation away from the building and radiating the heat away at night. Roofs covered with vegetation take benefits of the additional thermal insulation

provided by the soil and of the evapo-transpiration to keep the roof cool under the sun. These two technologies are different in: structural requirements, initial and lifetime maintenance costs, impact on the overall energy performance of buildings. This paper presents a numerical comparative analysis between these solutions, taking into account the several parameters that affect the final energy performances. By means of dynamic simulations, the paper depicts how cool and green roofs can improve the energy performance of residential buildings in different localities at Mediterranean latitudes. (C being the most cited (N=250) and Theodosiou [9] the oldest work, with 162 citations.

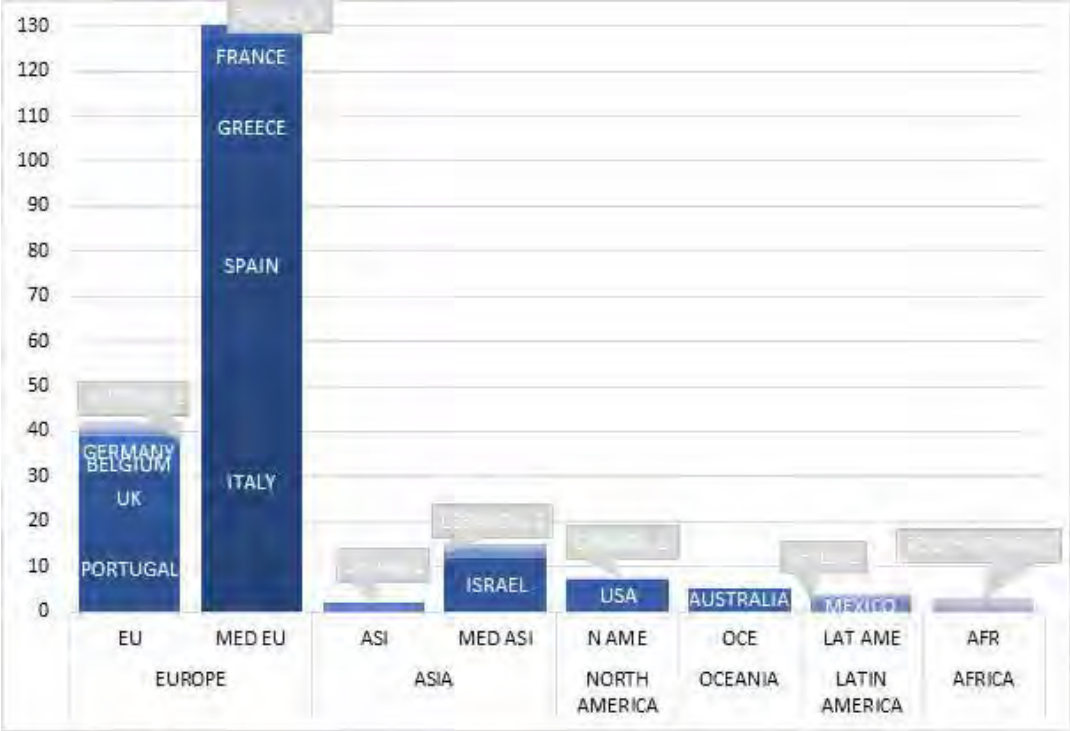

Figure 4. Geographical distribution and number of the MED papers; only the most scientifically productive countries are mentioned. The Mediterranean countries of Europe, Asia and Africa (MED EUROPE, MED ASIA and MED AFRICA) are pointed out.

The Mediterranean scale

Figure 5 illustrates the frequency of the words whose occurrence was checked throughout the MED paper selection.

As for the topic 'Technical Approaches & Building Materials' the word 'Building' is among the most cited ones, featuring 89 times, followed by 'Design' (N=49), 'Construct*' (N=31), 'Material' (N=29) and 'Techni*' (N=22). Much more attention seems to be paid to the different types of material (e.g., 'Concrete', 'Geotextiles', 'Rubber Crumb') used to build MGRs than on other important issues such as 'Engineering' options (N=4).

The term 'Energy' is featured 83 times, whilst the words 'Performance' and 'Efficiency' appear on 110 and 42 papers, respectively, their use being mostly referred, once again, to energy. Other frequently occurring words are 'Insulat*' (N=34), 'Energy Consumption' (N=28), 'Coating (N=6). With 89 citations, 'Water' features among the most important factors taken into consideration. Other frequently cited terms related with water are 'Irrigation' (N=46), 'Runoff' (N=36), 'Drought' (N=34), 'Drainage' (N=26), 'Arid' (N=23), 'Stormwater' (N=21), 'Hydrol*' and 'Moisture' (N=20), 'Hydraul*' (N=18). Strikingly less attention is paid to 'Water use/retention/storage' (N=14) and 'Water availability' (N=10).

With 111 occurrences, 'Climat*' is among the most cited words within the title, keywords and abstract of the selected papers. Other correlated and frequently mentioned terms are 'Heat' (N=66), 'Thermal' (N=63), 'Temperature' (N=48), 'Cooling' (N=41), 'Winter' (N=28), 'Heat Island' (N=24), 'Climate Change' (N=20), 'Thermal Insulation' (N=15), 'Thermal Comfort' (N=13). Very few papers mention and consider the two other yearly seasons, i.e., 'Spring' (N=8) and 'Autumn' (N=5), or other local climatic factors such as 'Wind' (N=6) and light conditions: for instance, 'Shad*' is mentioned only 6 times and 'Albedo' only 4.

Figure 5. 'Flower-shaped' cloud showing the frequency of the words whose occurrence was checked throughout the MED paper selection; created with the software Shapewordle (https://www.shapewordle.com/ref) [10].

The omni comprehensive (but perhaps too generic and misused) term 'Environment' is featured in 83 papers; moreover, 'Ecosyst*' and 'Habitat' were recorded on 25 and 14 papers, respectively, whilst 'Ecology' occurs only 6 times. The words 'Impact' (N=62) and 'Mitigation' (N=37) are mostly associated with extreme events such as rainstorms and heat waves. The word 'Stress' occurs 25 times and once again is mostly linked to climatic - thermal features. Among the non-climatic stress factors, salt stress and salt-tolerance feature among the few terms that are explicitly mentioned and considered in several papers. As for the themes dealing with biogeography and conservation, although the term 'Native' occurs in 35 papers, a very large number of other key themes and goals are still underrated or even totally neglected, like 'Conservation' (mentioned only on 9 papers), 'Nature-Based Solution*' (N=5), 'Resilience' (N=4), 'Functional Group' (N=2). Similarly, 'Biogeography', 'Alien/Exotic', 'Community', 'Niche', 'Facilitation', 'Corridor', 'Disturbance', 'Endemic' are all mentioned only once, while 'Steppingstone' and 'Food Web' never occur.

The importance of Soil Sciences in MGRs is clearly underestimated too, as well as that of Agriculture/Horticulture, mentioned only once. The term 'Substrate' (N=61) is more commonly recorded than 'Soil' (N=40); this is correct, also considering than only rarely real soil is used on the top of MGRs. The term 'Layer', mainly referring to standard materials and techniques, is mentioned 32 times, whilst much lower attention is paid on other important parameters such as 'Slope' (N=8), 'Layering' and 'Geometr*' (N=4). 'Pollution' is quoted 15 times and mainly refers to airborne pollution, but none of the selected papers concerns the depurative activity performed by soil microorganisms within the Mediterranean area. Although some attention is paid on the topics 'Substrate Type', 'Fertilisation/Amendment', 'Nitrogen' and 'Root Systems', other important themes such as 'Soil Biochemistry/Geochemistry' and 'Symbiotic Microorganisms' are completely absent among the topics of our paper selection.

As for Plant Sciences, even if the term 'Species' is featured 55 times, 'Plant Selection' occurs only 5 times. The terms 'Vegetation' and 'Vegetated' are used quite frequently (60 and 25 times respectively), but never to refer to natural plant communities. Increasing attention is paid to plant 'Physiology' (incl. 'Biomass', 'Photosynthesis', 'Succulent', 'Metabolism'), almost none to 'Life Form*', 'Mosses' and 'Lichens' and no mention is given for 'Growth Form'.

The attention paid to the animal component of the MGRs is surprisingly poor. In fact, no vertebrates are considered in the whole paper selection. As for invertebrates, Arthropods are mentioned only three times, and a few groups of Insects (ants, springtails, butterflies) are the focus of only two papers.

The terms 'Social' and 'Cultural' feature only in 15 and 7 papers, respectively, whilst altogether the words 'Awareness', 'Biophilia', 'Regeneration' and 'Recreation' are mentioned a handful of times. No mention is given neither to 'Psychology' 'Perception' nor to 'Well-Being'.

Surprisingly enough, economic aspects do not seem to be a focus of the studies concerning MGRs. Among the most cited terms dealing with this topic, the most cited resulted to be 'Econ*' (N= 36 times, i.e., only 22% of the whole paper selection) and 'Management' (N=33). However, both these terms, as well as many other strictly linked with economy, like 'Sustainab*' (N=51), 'Cost' (N=29), 'Energy saving' (N=28), 'Effective' (N=21), mostly refer to the initial construction costs, while the medium- and long-term perspective is somehow missing, as shown by the fact that each of the terms 'Cost-effective', 'Cost-benefit' and 'Recycl*' is mentioned roughly 10 times in our dataset. Although the term 'Monitor*' is quoted 31 times, the paper selection appears to 'hide' the need of regular and often expensive interventions during the whole green roof life-cycle; in fact, the term 'Removal' features only on 6 papers, 'Weed' only once and 'Eradication' never.

DISCUSSION

The datasets 'NOT MED' and 'MED' obtained automatically by querying the WoS turned to be partially biased. In fact, on the one hand many authors did not specify the biome where their study was carried out (e.g., 'temperate', 'Mediterranean') in the query field (title, keywords and abstract); on the other hand, the keyword 'Mediterranean' featured in papers illustrating non-Mediterranean study cases (e.g., inner USA, China, Portugal). A deeper insight on the subset NOT MED (MED BASIN) could only partially solve the first issue. In fact, several investigations done by researchers working in Mediterranean countries were focused on extra-Mediterranean territories (e.g., French scientists presenting study cases from Northern France or central Africa).

Most of the papers of the MED selection were focused on technical features and aim at optimizing energy consumption. In most of the selected papers improving green roof performance means just obtaining optimal thermal insulation, look for the best option to mitigate urban climatic conditions, namely heat waves in summer and excessive thermal dispersion during winter. Remarkably enough, very few papers considered spring and autumn, the two most important seasons for Mediterranean plant life cycles.

Water management is among the main topics, too. On the one hand, much of the selected works dealing with this topic are only focused on the most suitable materials and techniques to be adopted to improve drainage and/or avoid risks and damages due to extreme events. On the other hand, very few efforts have been made to inform the choice of MGR materials and living components to local climatic conditions.

Unable to get rid of the 'temperate archetype', many professionals are still convinced that the MGRs should be 'green' also in summer, and as many as 46 (28.5%) of the selected papers invoke 'Irrigation' as the best solution against the seasonal water shortage affecting the plants growing on MGRs. This idea is an unsustainable nonsense in the Mediterranean context, whose plant communities should instead be able to grow, spread and reproduce without any external water supply. To do that, designers should find out the best solutions to exploit local microclimatic conditions, for instance to capture overnight dew, an important water resource in Mediterranean coastal cities, and professionals should invest more in applied research on the making of uneven and patchy green roofs, hosting near-natural and self-sustaining Mediterranean habitats like winter-green annual swards, temporary ponds, etc.

The rather high frequency of the term 'Native' (featuring on more than 20% of the papers of our selection) suggests an increasing awareness of professionals about biogeographic features in the making of MGRs.

If left free to evolve following natural succession processes, plant communities growing on green roofs will form patches differing in terms of structure, species composition, functional spectrum, thus enhancing urban biodiversity [11–14]particularly through the planning and management of urban green spaces (UGS. In this way, MGRs may provide key-spaces and key-opportunities to mitigate and compensate human impact due to urban sprawl [15], and may represent key steppingstones and functional ecological corridors enhancing the dispersal and spread of plants, animals and habitats [16]and they offer promising additional opportunities to enhance biodiversity in cities. However, their ecological conditions remain poorly considered when planning wildlife corridors. To discuss the role of vegetated buildings in landscape connectivity, we reviewed the ecological and technical specificities of green walls and green roofs in light of the key factors concerning urban wildlife (patch size, quality, abundance, and isolation.

As far as soil science and agriculture are concerned, most of the current scientific research on MGRs is ruled - and biased - by the hegemony of the few existing companies promoting their commercial and standard substrates, yet fulfilling the most influential German guidelines [17]. Consequently, most of the papers concerning these topics are still focused on the abiotic (physical and chemical) properties of few standard substrates and layering-options, while little effort has been made to develop innovative techniques to better exploit the potential of soil organisms and plant communities to reduce soil pollution. For the same reasons, few resources have been invested to test new materials like volcanic ashes, that accumulate naturally on the roofs in the proximity of the Mediterranean active volcanoes, or to study the biogeochemical cycles of urban (landfill) soils and , or to develop innovative techniques inspired by the habitat template [18], like combining hay transfer [19] and soil transfer [20] to exploit local seedbank and microbiota at the same time.

Concerning plant sciences, only seldom plant selection is informed to nature- or expert-based criteria, and semi-automatised species lists are rare and even more rarely inspired by rigorous biogeographic and ecological criteria [21]. Being tested and used since decades by central-and north-European experts, Stonecrops (genus *Sedum*) are by far the most cited plants used in MGRs, featuring in topics of 23 papers. However, if the aim is to imitate and replicate the Mediterranean habitats, then the best suited plants for the extensive MGRs are not only those being able to face long-lasting drought periods (e.g., geophytes, hemicryptophytes and succulent chamaephytes), but also those adapted to avoid the harshest conditions., i.e. the short-lived therophytes whose life cycle ends up before the dry season begins [22], often underrated or even neglected in the already available plant lists for MGRs [e.g., 23]. As some of these species are rare, endangered and/or linked to conservation priority habitats, their use on MGRs may represent a possible strategy to ameliorate their conservation status. However, very poor experimental data are available on the ecology and biology of many annual plants during the first phases of their life cycle (e.g., germination and establishment). Hence, we cannot be sure that rare or endangered therophytes can be used for green roofs, as some of them may depend on still unknown microbiotic or microclimatic conditions.

Only few papers dealing with MGRs clearly correlate the generic term ‘Vegetation’ with ‘real’ and ‘local’ plant communities. The level of knowledge on the structure, the composition and the natural dynamics of plant communities growing on MGRs appears unsatisfactory. As far as we know, very few vegetation surveys on primary succession on MGRs have been done so far, and none has been published yet.

Moreover, many plants typical of the stress-tolerant Mediterranean vegetation units listed by Mucina et al. [24] could be successfully used on extensive MGRs with low to no management cost. Even better, as these vegetation units often correspond to Habitats identified by Annex I of the 92/43 EEC Directive as European conservation targets, their adoption as habitat templates on extensive MGRs may represent a powerful tool to 1) meet mitigation and compensation measures to contrast habitat fragmentation and disruption loss within and near construction sites, 2) restore habitats of high naturalistic interest and increase their connectivity, 3) reinforce the populations of rare/endangered taxa linked to Mediterranean xeric plant communities.

The term ‘Plant selection’ was recorded only five times. This result confirms that the criteria driving species selection and assemblage are still pretty much confused, and more efforts are needed to better fit species selection to local climate (e.g., drought duration) and to substrate traits (e.g., depth, texture, layering, pH, pollution, nutrient and salt content). Additionally, more attention should be paid to avoid the accidental or deliberate introduction of stress- and disturbance-tolerant, invasive, habitat-shaping alien plants. On the contrary, many papers claiming to adopt “sustainable” plant selection criteria suggest using few cosmopolitan alien plants which are well-known for their invasive behaviour worldwide such as *Carpobrotus* spp., *Paspalum vaginatum*, *Sedum spurium* and *Gaura lindheimeri.*

Our preliminary data analysis pointed out the very low attention paid to the faunistic component of MGRs. Knowledge on this topic needs strong improvement following good examples from central-European green roofs [e.g., 25]among other services, habitat for plants and animals, and stepping stones for mobile organisms, thereby enhancing permeability among habitat patches across densely built cities. In Switzerland, investigations over the past 20 years on more than one hundred distinct green roofs across six cities have provided an unprecedented dataset on ground beetles, albeit with information that is scattered across unpublished reports and local databases. We present here for the first time a synthesis of the state of knowledge of ground beetle communities from green roofs in Switzerland. We describe 91 ground beetles species (19,428 individuals and exploiting the huge amount of data concerning several taxonomic groups living in the Mediterranean cities [e.g., 26].

The number of studies focused on the possible connections between biodiversity, wilderness and citizens' perception of beauty and well-being is steadily increasing worldwide [27, 28]it is important to understand public perceptions of urban green spaces (UGSs. Yet, this topic appears poorly explored in the Mediterranean context, where semi-natural habitats like extensive MGRs may look 'yellow' for many months, and consequently are considered as 'untidy' and undesirable by many people [29]and floristic assemblage was consistent with the regional species pool. No significant levels of biotic homogenization were found. Local activists successfully campaigned to save the site from development, which resulted in its designation as an Urban Nature Reserve; however, it was essentially managed as a conventional neighbourhood park. As a consequence, vascular plant species richness decreased by 50%. The functional and biogeographic groups most typical of Mediterranean habitats saw the largest decrease (the steno-Mediterranean element decreased by 80%.

Only few papers pay attention to the need of regular interventions to manage the plants growing on MGRs, for instance emphasizing the impact of mowing regime on MGRs flower species diversity [30]the biodiversity dynamics during the two-years experiment, and the pollinating fauna, were analysed.\nEach plant group was able to efficiently colonize the surface of the roof though in different periods and with various modalities. Thermal insulation of green roof was connected to different development dynamics of leaf canopies. In particular, this cooling effect took place during the peak of the vegetation's growth pattern. As expected, each plant group had differing flowering periods, during which were observed coincided highest rate of pollinator' visits (domestic and solitary bees, bumblebees, lepidoptera, diptera both syrphidae and bombyliidae. Similarly, not so much research deals with building costs also due to the lack of built examples. Nevertheless, the feasibility to build (simple intensive) MGRs was investigated with reassuring results [31].

Very few papers consider the medium- and long-term rentability of the applied techniques and of the used (non-living and living) materials. Consequently, the striking unbalance between the frequency of the terms 'Experiment*' and 'Innovation' (69 vs. 10 in the 'MED' paper selection) is not surprising, yet we need to reverse it.

CONCLUSIONS

There is a clear need to establish a science-policy interface, involving soil and vegetation scientists, landscape architects and engineers, to implement and share best practices and collated knowledge on MGRs design and management [32]. Similarly, a traits-based framework from scientific studies to practical application should be encouraged. Here we refer not only to the vegetation functional traits, which differ between the Mediterranean and the temperate ecoregion, but also to the social-ecological traits of the urban environment, e.g., features of humans and other co-inhabiting species and their differing responses to local environmental pressures and drivers.

Despite ecological research on GRs is most advanced in the temperate ecoregions, its techniques and results cannot be taken for granted in the Mediterranean. Experimentation and adequate communication of the results are necessary so that, for example, the summer yellowing of Mediterranean vegetation is accepted unconditionally by the individual and collective perceptions of MGRs. This will support the development of a scientifically grounded, practically applicable framework to interrogate reciprocal feedback linkages, nature-human relationships and decision-making [33]we explore the potential of a traits framework for understanding social-ecological patterns, dynamics, interactions, and tipping points in complex urban systems. To do so, we discuss what kind of framing, and what research, that would allow traits to (1.

This paper represents a first trial to show some common traits and trends in the scientific literature focused on MGRs. To further check any appreciable shift of paradigm from the "construction materials + energetic efficiency + water runoff management" mainstream approach to a more holistic perspective, data should be analysed also from the diachronic perspective, through the lens of soil and vegetation scientists. This could help to verify if and to which extent professionals who build green roofs in the Mediterranean cities started to consider other factors, such as the increasing awareness of citizens about nature as a value *per se*, the physiology of living organisms, the natural dynamics and the functional complexity of the communities they build, the endurance of the materials used, the sustainability of the techniques adopted.

REFERENCES

1. King R, Proudfoot L, Smith B (1997) The Mediterranean: Environment and Society. Routledge, London

2. Baabou W, Grunewald N, Ouellet-Plamondon C, Gressot M, Galli A (2017) The Ecological Footprint of Mediterranean cities: Awareness creation and policy implications. Environ Sci Policy 69:94–104 . https://doi.org/10.1016/j.envsci.2016.12.013

3. Saaroni H, Amorim JH, Hiemstra JA, Pearlmutter D (2018) Urban Green Infrastructure as a tool for urban heat mitigation: Survey of research methodologies and findings across different climatic regions. Urban Clim 24:94–110 . https://doi.org/10.1016/j.uclim.2018.02.001

4. Blank L, Vasl A, Levy S, Grant G, Kadas G, Dafni A, Blaustein L (2013) Directions in green roof research: A bibliometric study. Build Environ 66:23–28 . https://doi.org/10.1016/j.buildenv.2013.04.017

5. Chafer M, Cabeza L, Pisello A, Tan C, Wong N (2021) Trends and gaps in global research of greenery systems through a bibliometric analysis. Sustain CITIES Soc 65:102608 . https://doi.org/10.1016/j.scs.2020.102608

6. Wolch JR, Byrne J, Newell JP (2014) Urban green space, public health, and environmental justice: The challenge of making cities 'just green enough.' Landsc Urban Plan 125:234–244 . https://doi.org/10.1016/j.landurbplan.2014.01.017

7. Kralli MN, Kambezidis HD, Cassios CA (1996) "Green roofs" policy in cities with environmental problems. Fresenius Environ Bull 5:424–429

8. Zinzi M, Agnoli S (2012) Cool and green roofs. An energy and comfort comparison between passive cooling and mitigation urban heat island techniques for residential buildings in the Mediterranean region. Energy Build 55:66–76 . https://doi.org/10.1016/j.enbuild.2011.09.024

9. Theodosiou T (2003) Summer period analysis of the performance of a planted roof as a passive cooling technique. ENERGY Build 35:909–917 . https://doi.org/10.1016/S0378-7788(03)00023-9

10. Wang Y, Chu X, Zhang K, Bao C, Li X, Zhang J, Fu C-W, Hurter C, Deussen O, Lee B (2020) ShapeWordle: Tailoring Wordles using Shape-aware Archimedean Spirals. IEEE Trans Vis Comput Graph 26:991–1000 . https://doi.org/10.1109/TVCG.2019.2934783

11. Aronson MF, Lepczyk CA, Evans KL, Goddard MA, Lerman SB, MacIvor JS, Nilon CH, Vargo T (2017) Biodiversity in the city: key challenges for urban green space management. Front Ecol Environ 15:189–196 . https://doi.org/10.1002/fee.1480

12. Catalano C, Marcenò C, Laudicina V, Guarino R (2016) Thirty years unmanaged green roofs: Ecological research and design implications. Landsc URBAN Plan 149:11–19 . https://doi.org/10.1016/j.landurbplan.2016.01.003

13. Van Mechelen C, Dutoit T, Hermy M (2015) Vegetation development on different extensive green roof types in a Mediterranean and temperate maritime climate. Ecol Eng 82:571–582 . https://doi.org/10.1016/j.ecoleng.2015.05.011

14. Vannucchi F, Pini R, Scatena M, Benelli G, Canale A, Bretzel F (2018) Deinking sludge in the substrate reduces the fertility and enhances the plant species richness of extensive green roofs. Ecol Eng 116:87–96 . https://doi.org/10.1016/j.ecoleng.2018.02.027

15. Lundholm JT (2016) Spontaneous dynamics and wild design in green roofs. Isr J Ecol Evol 62:23–31 . https://doi.org/10.1080/15659801.2015.1025511

16. Mayrand F, Clergeau P (2018) Green Roofs and Green Walls for Biodiversity Conservation: A Contribution to Urban Connectivity? Sustainability 10:985 . https://doi.org/10.3390/su10040985

17. FLL (2018) Dachbegrünungsrichtlinien – Richtlinien für die Planung, Bau und Instandhaltungen von Dachbegrünungen. Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau (FLL).

18. Lundholm JT, Walker EA (2018) Evaluating the Habitat-Template Approach Applied to Green Roofs. Urban Nat 39–51

19. Schröder R, Kiehl K (2020) Extensive roof greening with native sandy dry grassland species: Effects of different greening methods on vegetation development over four years. Ecol Eng 145:105728 . https://doi.org/10.1016/j.ecoleng.2020.105728

20. Best BB, Swadek RK, Burgess TL (2015) Soil-Based Green Roofs. In: Sutton RK (ed) Green Roof Ecosystems. Springer International Publishing, Cham, pp 139–174

21. Dvorak B, Bousselot J (2021) Theoretical Development of Ecoregional Green Roofs. In: Dvorak B (ed) Ecoregional Green Roofs. Springer International Publishing, Cham, pp 41–79

22. Vasl A, Shalom H, Kadas G, Blaustein L (2017) Sedum-Annual plant interactions on green roofs: Facilitation, competition and exclusion. Ecol Eng 108:318–329 . https://doi.org/10.1016/j.ecoleng.2017.07.034

23. Caneva G, Kumbaric A, Savo V, Casalini R (2015) Ecological approach in selecting extensive green roof plants: A data-set of Mediterranean plants. Plant Biosyst 149:374–383 . https://doi.org/10.1080/11263504.2013.819819

24. Mucina L, Bültmann H, Dierßen K, Theurillat J-P, Raus T, Čarni A, Šumberová K, Willner W, Dengler J, García RG, Chytrý M, Hájek M, Di Pietro R, Iakushenko D, Pallas J, Daniëls FJA, Bergmeier E, Santos Guerra A, Ermakov N, Valachovič M, Schaminée JHJ, Lysenko T, Didukh YP, Pignatti S, Rodwell JS, Capelo J, Weber HE, Solomeshch A, Dimopoulos P, Aguiar C, Hennekens SM, Tichý L (2016) Vegetation of Europe: hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities. Appl Veg Sci 19:3–264 . https://doi.org/10.1111/avsc.12257

25. Pétremand G, Chittaro Y, Braaker S, Brenneisen S, Gerner M, Obrist MK, Rochefort S, Szallies A, Moretti M (2018) Ground beetle (Coleoptera: Carabidae) communities on green roofs in Switzerland: synthesis and perspectives. Urban Ecosyst 21:119–132 . https://doi.org/10.1007/s11252-017-0697-7

26. Zara L, Tordoni E, Castro-Delgado S, Colla A, Maccherini S, Marignani M, Panepinto F, Trittoni M, Bacaro G (2021) Cross-taxon relationships in Mediterranean urban ecosystem: A case study from the city of Trieste. Ecol Indic 125:107538 . https://doi.org/10.1016/j.ecolind.2021.107538

27. Atiqul Haq SM, Islam MN, Siddhanta A, Ahmed KJ, Chowdhury MTA (2021) Public Perceptions of Urban Green Spaces: Convergences and Divergences. Front Sustain Cities 3:755313 . https://doi.org/10.3389/frsc.2021.755313

28. Gao T, Zhu L, Zhang T, Song R, Zhang Y, Qiu L (2019) Is an Environment with High Biodiversity the Most Attractive for Human Recreation? A Case Study in Baoji, China. Sustainability 11:4086 . https://doi.org/10.3390/su11154086

29. Filibeck G, Petrella P, Cornelini P (2016) All ecosystems look messy, but some more so than others: A case-study on the management and acceptance of Mediterranean urban grasslands. Urban For Urban Green 15:32–39 . https://doi.org/10.1016/j.ufug.2015.11.005

30. Benvenuti S (2014) Wildflower green roofs for urban landscaping, ecological sustainability and biodiversity. Landsc Urban Plan 124:151–161 . https://doi.org/10.1016/j.landurbplan.2014.01.004

31. Yıldırım S, Özden Ö (2018) Positive effects of vegetation: Biodiversity and extensive green roofs for Mediterranean climate. Int J Adv Appl Sci 5:87–92 . https://doi.org/10.21833/ijaas.2018.10.012

32. Grace M, Balzan M, Collier M, Geneletti D, Tomaskinova J, Abela R, Borg D, Buhagiar G, Camilleri L, Cardona M, Cassar N, Cassar R, Cattafi I, Cauchi D, Galea C, La Rosa D, Malekkidou E, Masini M, Portelli P, Pungetti G, Spagnol M, Zahra J, Zammit A, Dicks LV (2021) Priority knowledge needs for implementing nature-based solutions in the Mediterranean islands. Environ Sci Policy 116:56–68 . https://doi.org/10.1016/j.envsci.2020.10.003

33. Andersson E, Haase D, Anderson P, Cortinovis C, Goodness J, Kendal D, Lausch A, McPhearson T, Sikorska D, Wellmann T (2021) What are the traits of a social-ecological system: towards a framework in support of urban sustainability. Npj Urban Sustain 1:1–8 . https://doi.org/10.1038/s42949-020-00008-4