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NATURE BASED SOLUTIONS SUMMIT URBAN EDITION

MAY 23rd-24th 2024 - SUPER BOCK ARENA
PORTO – PORTUGAL

Book of abstracts of Nature Based Solutions Summit - Urban Edition 2024

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Book of Abstracts

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NBS SUMMIT 2024 | 23 - 24 May, 2024 | GREENROOFS® by ANCV, Porto (Portugal)

Edited by: GREENROOFS® Innovated by Associação Nacional de Coberturas Verdes

ISBN: 978-989-33-6951-7

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CONTENT

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THE CONFERENCE

Following two days of intense debate and sharing, the NBS Summit Urban Edition concluded its inaugural event with great success at the Super Bock Arena in Porto. The event, which drew over 500 attendees, featured numerous international experts and leaders in urban sustainability, creating a platform for discussion and innovation focused on the future of cities.

The NBS Summit Urban Edition opened with Porto's Deputy Mayor, Filipe Araújo, reaffirming the city's commitment to Nature-Based Solutions (NBS) and green infrastructure. This was followed by Rúben Fernandes from Águas e Energia do Porto, who highlighted successful applications of these solutions. Keynote speakers included Francisco Rocha Antunes, Menno Lammers, Luigi Petito, Paulo Palha, Steven L. Peck, Kevin Halpenny, João Torres, and José Miguel Lameiras. Additionally, Filipe Mesquita (This is Pacifica) unveiled the new brand GREENROOFS® Innovated by the National Green Roofs Association.

On the second day, speakers Martin Kostal, Edmund Maurer, Jürgen Preiss, and Filipe Araújo shared practical examples of urban sustainability from Brno, Vienna, and Porto. Additionally, Per Malmos, Laura Gatti, Valentina Galiulo, João Vaz, and João Jesus highlighted the pivotal role of design in promoting urban sustainability.

Throughout the event, masterclasses by Kongjian Yu and Nuno Brandão Costa stood out, marked by the depth of discussions and insights shared. Brandão Costa, an architect from Porto, shared valuable reflections on integrating NBS into urban architecture, highlighting his award-winning Campanhã Intermodal Terminal as an example of successful urban regeneration. In turn, Kongjian Yu, one of today's most influential landscape architects, stressed the urgency of creating greener, more resilient urban environments. By presenting recent examples from Dubai and Rio Grande do Sul, Yu showcased a range of innovative solutions that effectively balance contemporary architectural needs with the resilience necessary for sustainable urban landscapes. His presentation concluded with a standing ovation, inspiring a new generation of professionals to embrace sustainable practices.

The closing remarks emphasized the renewed commitment of all participants to drive the transition toward a more sustainable and resilient urban future.

On the afternoon of May 24, the NBS Summit Urban Edition extended its discussions to the field with technical visits organized for the event's participants and speakers. Three

routes were held, each showcasing innovative applications of Nature-Based Solutions (NBS) and urban sustainability in Porto. Route A included visits to Escola do Falcão, Horta da Oliveira, Parque da Alameda de Cartes, and Parque Oriental, guided by Architect José Miguel Lameiras from the Faculty of Sciences at the University of Porto (FCUP). Route B explored Parque da Asprela and Nó do Regado, led by Landscape Architect David Campos, also from FCUP. Finally, Route C featured the Intermodal Terminal of Campanhã and Parque Oriental, with insights provided by Architects Luís Carreno and Bianca Schiavoni from Brandão Costa Arquitetos. These immersive experiences allowed participants to witness firsthand the integration of NBS in urban spaces, enriching both the practical and academic aspects of the event.

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NBS SUMMIT ORGANIZATION

The organizing team, composed of GREENROOFS® by ANCV, the Porto City Council through Águas e Energia do Porto, and STAGE, expressed their satisfaction with the results of this first edition, celebrating its success and looking ahead with optimism to a more sustainable future.

GREENROOFS® Innovated by Associação Nacional de Coberturas Verdes (ANCV) is a non-governmental, non-profit organization dedicated to promoting green infrastructure in urban environments. Its mission focuses particularly on green roofs for both new and existing buildings, which play a crucial role in fostering healthy, sustainable, biodiverse, and resilient urban ecosystems.

The Porto City Council, represented by Águas e Energia do Porto, served as the official sponsor of the event. Águas e Energia do Porto, a municipal company dedicated to essential public services such as water and energy management, plays a vital role in advancing the economic, environmental, and social sustainability of the community.

STAGE, a company specializing in tailored event management solutions, brought its innovative approach to ensure the seamless organization of the symposium.

Together, these entities joined forces to create a successful and impactful event, reinforcing their shared commitment to a greener and more sustainable future.

MESSAGE FROM THE VICE-PRESIDENT OF THE PORTO CITY COUNCIL

Filipe Araújo, Vice-President of Porto City Council, responsible for Environment and Climate Transition, and Innovation and Digital Transition

I truly believe that cities are the major drivers of change in the context of sustainability. They are closely connected to citizens—the primary vectors of behavioral change—and can leverage their physical and human geography to accelerate progress and overcome the inertia and bureaucratic burdens of national governments. Challenges such as sustainability, neutrality, and adapting our territories to climate change cannot be solved within four-year political cycles. Therefore, these issues require strong political commitments from local governements, but also from European institutions, adhering to a consistent and ambitious roadmap that transcends electoral timelines.

Let me emphasize the role of Nature-Based Solutions (NBS) in addressing these demanding scenarios. NBS have proven to be one of the most effective approaches to mitigate some of the greatest environmental challenges, including climate change.

In Porto, we are spearheading a genuine "Nature-Inspired Revolution," committing to the expansion of NBS to tackle significant climate challenges. For instance, the city has more than 130 green roofs and vertical gardens covering more than 11 hectares. NBS constitute nearly 80% of the initiatives outlined in Porto's municipal strategy for climate adaptation, with a notable impact being the new ecological framework in our City Master Plan. We used European funding to construct "sponge parks," like Parque Urbano da Asprela and Parque da Alameda de Cartes, designed to retain, store, and infiltrate 100% of incoming water. Additionally, "bio-solar roofs" have been installed on primary schools to collect and reuse rainwater in nearby community gardens. Our tree nursery has cultivated and nurtured over 60,000 native trees, which have been donated to neighboring municipalities for ecological restoration of burned areas and to expand Porto's native forest. We are also tackling energy poverty and safeguarding the vulnerable by encouraging private developers to integrate nature-based and bioclimatic strategies into buildings, facilitated by fee waivers and tax incentives under the forthcoming Porto Environmental Index.

I could elaborate further, but these initiatives underline why we believe an international summit dedicated to NBS should not only receive our unwavering support but also be hosted in no other city but Porto—a city inspired by nature.

The inaugural NBS Summit surpassed all its objectives, serving as a highly sought-after platform for sharing best practices among leading national and international experts on NBS. I hope this summit becomes an essential forum for raising awareness among

academics, designers, policymakers, and real estate developers about the benefits of Nature-Based Solutions (NBS). It should accelerate their incorporation into more projects and policies, ensuring that people and nature remain at the heart of all decisions.

Vice-President of Porto City Council

Filipe Araújo.

MESSAGE FROM THE PRESIDENT OF GREENROOFS® INNOVATED BY ASSOCIAÇÃO NACIONAL DE COBERTURAS VERDES

Paulo Palha, President of the European Federation of Green Roofs and Vertical Gardens (EFB),

President of GREENROOFS® by ANCV

It is with great pleasure that we present the Book of Abstracts for the NBS Summit urban edition, Porto ’24.

This collection encapsulates the diverse and innovative research presented at our conference, highlighting the critical role that nature-based solutions play in addressing the pressing urban environmental and societal challenges of our time.

The conference aims to bring together a multidisciplinary community of scientists, practitioners, policymakers, and stakeholders dedicated to exploring and advancing the application of nature-based solutions in our cities. Over the course of this event, we have engaged in fruitful discussions, shared groundbreaking research, and forged new collaborations that will help pave the way toward a more sustainable and resilient urban future.

This compilation of abstracts provides a snapshot of the topics covered during the conference, from sustainable urban planning and ecosystem restoration to climate change mitigation and biodiversity conservation. Each abstract represents the hard work, creativity, and dedication of researchers committed to positively impacting our world through nature-based approaches.

The importance of research in this field cannot be overstated. As we confront climate change, habitat loss, and environmental degradation, the scientific community’s contributions are invaluable in developing effective and sustainable solutions. The insights gained from these studies inform policies, guide practical implementations, and inspire further innovation.

We extend our deepest gratitude to all the contributors for their exceptional work and willingness to share their findings. Your efforts are at the heart of our mission to promote nature-based solutions as a key strategy for achieving ecological balance and enhancing human well-being.

Additionally, we would like to thank Porto’s Municipality, our sponsors, partners, and the organizing committee for their unwavering support and dedication. Without your efforts, this summit would not have been possible.

As you explore the abstracts in this book, we hope you find inspiration, knowledge, and a renewed commitment to advancing urban nature-based solutions. Let this collection catalyze continued research, collaboration, and action in our shared quest for a sustainable and resilient urban future.

Thank you for your participation and contribution to the success of this first NBS Summit.

President of the European Federation of Green Roofs and Vertical Gardens (EFB)

President of GREENROOFS® by ANCV

Paulo Palha.

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ABSTRACTS

Urban heat island mitigation: a computational approach for NBS modelling

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This paper proposes a methodological approach to improve the effectiveness of the simulations to quantify NBS performance in relation to outdoor thermal conditions, by working on plant modelling. In particular, the parameters considered are: foliage albedo, transmittance, emissivity of leaves, and the height and the width of plants. In this research we model for one urban case study selected plant species considering the parameters listed above and compare the results of three simulation approaches for the analysis on outdoor comfort: 1) a simplified model in stationary conditions which considers only geometric parameters, 2) a CFD model with same geometry parameters considered in step 1 and default radiative parameters, and 3) a CFD model with updated radiative parameters.
The analysis and comparison of the results will allow understanding how the thermodynamic parameters of plants affect their performances and if the consideration of geometries only allows obtaining significant results (i.e. comparing thermodynamic and stationary conditions modeling).
The results of the experiment allow a critical understanding of the role of NbS in climate change adaptation and more in particular of the possible computational approaches that can be included in the design process. Although the greatest contribution in terms of reducing thermal stress is due to the shading provided by plants, radiative parameters can also have a positive or negative impact on their performance. In particular, they can be of interest in situations of particular stress or in situations where it is not possible to introduce many plants, as is often the case in densely built urban contexts.
The analysis and comparison of the results allow understanding how the radiative parameters used to describe evapo-transpiration processes of plants affect their performances and if the consideration of geometries only allows obtaining significant results (i.e. comparing thermodynamic and stationary conditions modeling).

Keywords: urban heat island mitigation, trees modelling, climate adaptation, local microclimate.

Ectomycorrhizal fungi as a green solution to improve urban trees' health and preserve urban ecosystem biodiversity

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The provisioning of ecosystem services by urban trees is of utmost importance in the actual context of everchanging climate conditions. These trees are recurrently exposed to austere conditions that impair its general health, negatively impacting the delivery of ecosystem services. Ectomycorrhizal (EcM) fungi are symbiotic organisms that improve the health of its host trees in less-than-ideal conditions with proved beneficial effects in forestry and agriculture, hence its great potential to improve the health of trees in urban context. The application of EcM fungi to urban trees was performed and the monitoring of branch contraction/expansion was conducted with the main goal of understanding the effect of EcM fungi on the improvement of trees' tolerance to water-stress and on promotion of growth. Two years after inoculation, inoculated trees exhibited lower diurnal shrinkage of branches, suggesting a higher tolerance to water-stress. The growth of the trees was improved as well. The fungal community, including the mycorrhizal fungi, associated to trees provides benefits such as protection to biotic and abiotic stresses and improvement of water and nutrient uptake. The study of the trees' microbiome indicated that the fungal community of trees was significantly different between the pairs inoculated/non-inoculated and trees with good/bad health, suggesting that the introduction of an external EcM fungus had an impact not only on the performance of the tree but also on the dynamics of its fungal community. The results obtained in this work allow us to advocate the use of EcM fungi as a green solution to improve the health of urban trees, contributing positively to its general health status, and increasing its tolerance to stresses, which ultimately will contribute to a more sustainable and resilient urban environment and to the preservation of biodiversity of urban ecosystems both above and below ground.

Keywords: Ectomycorrhizal fungi; urban trees; water-stress; biodiversity; green solution.

Funding and Acknowledgements:

This work was supported by the 2015–2016 BiodivERsA COFUND call for research proposals, with the national funders: Belgian Science Policy (BelSPo), Research Foundation Flanders (FWO), Agence Nationale de la Recherche (ANR) and Fundação para a Ciência e a Tecnologia (FCT) (grant number BR/175/A1/URBANMYCOSERVE).
The authors would like to acknowledge the PhD grant of Cindy Serafim (SFRH/BD/146755/2019) and Centro de Biotecnologia e Química Fina (CBQF) scientific collaboration under the Fundação para a Ciência e a Tecnologia (FCT) project UIDB/ 50016/ 2020

Constructed wetland for the treatment of olive mill wastewater

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The olive oil sector is one of the most important agro-industrial activities in the Mediterranean region, and in the last years the olive oil production and consumption have increased worldwide. However, with the demand for olive oil increasing, also the concerns about the environmental problems posed by olive mill wastewater (OMW) are growing. Annually, millions m^3 of OMW are produced, particularly between November and February, with high organic loads and complex phytotoxic and antimicrobial compounds, making the treatment and management of these wastewaters a complex issue. Despite the great research investment in the last decades, the main approaches that have been proposed to treat OMW, are still far from being solved realistically, mainly due to financial constraints. , Taking into account that most of these companies are small family business, without the necessary capital to invest in such approaches, this issue becomes even more complex. In this context, Constructed Wetlands (CW) can be a suitable alternative to conventional treatments, especially for small and scattered business in peri-urban and rural areas, due to the low maintenance, implementation and operational costs. This nature-based solution can not only treat several types of wastewaters resulting into less harmful by-products or nutrients, which can be recovered and reused, but also provide other ecosystem services. In this study, a pilot scale system based on a CW was developed and installed near a press mill, with the main goal of reducing the environmental impact of the wastewaters generated. Preliminary results already showed an improvement in the quality of the final effluent. Further analysis will be carried out over time to attest the efficiency of the system in improving the physical and chemical properties of the final effluent, but also the performance in reducing the toxicity to aquatic organisms, towards water reuse.

Keywords: nature-based solutions, wastewater management, organic load removal, toxicity, phytoremediation

Roof rainwater harvesting and aquifer recharge in an urban environment: Dry and wet infiltration wells comparison

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In urban environments there is a severe reduction of infiltration and groundwater recharge due to the presence of large impervious areas. At rain events, large volumes of water that could have enriched groundwater are diverted into the drainage system and lost from the freshwater storage. Moreover, extreme rain events impose high peak flows, which increase the risk of city floods. This paper focuses on the use of rainwater harvesting from rooftops, for managed aquifer recharge purposes. While the benefits of this approach are well understood, research on its hydrological, and water quality aspects is limited. This study examined the use of infiltration wells for groundwater recharge with harvested rainwater collected from building rooftops under Mediterranean climate. Two types of wells with similar technical properties were examined: a well that reaches the groundwater (wet well); and a well that discharges the water into the unsaturated zone (dry well). Infiltration capabilities of the wells were compared in controlled experiments during summer, and in operational uses, during winter. Both dry and wet wells were found to be suitable for purposes of groundwater recharge. The wet well infiltration capacities were found to be much higher than those of the dry well. However, the latter has notable advantages in respect to water quality, as the unsaturated zone acts as a filter that absorb solutes and other contaminates that may be present in the harvested roof-water. Considering Tel-Aviv, Israel, as a case study for a dense modern city in Mediterranean climate, it is demonstrated herein that the use of infiltration wells may reduce urban drainage by ~40 %.

Keywords: Rainwater harvesting; Managed aquifer recharge; Water quality; Injection wells

Small-scale Ecological Sewage Treatment Plant: TEWetland, an innovative system

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Some regions of Brazil require more efforts from managers in order to preserve water quality and maximize its use, in face of scarcity. Failure to adequately treat sewage in developing countries contributes to the deterioration of the quality of aquatic ecosystems. In this context, the generation of treated effluent for reuse becomes doubly beneficial, preserving the quality and quantity of water in the sources, as well as human health. TEWetland, an innovative treatment model, designed by the Brazilian research team at the UFPB Aquatic Ecology Laboratory, is a nature-based solution, which combines the Evapotranspiration Tank (TEVAP) and the Constructed Wetland. This technology is designed to receive both greywater and toilet water, producing effluent for reuse and food in its structure. Two prototypes were installed in the municipality of Ingá-PB, Brazil, with different dimensions. Operational and effluent quality parameters were monitored in TEVAP. Average concentrations of BOD (27 mg L^{-1} and 25 mg L^{-1}), COD (75 mg L^{-1} and 67 mg L^{-1}), coliforms (6.8 x 10^3 CFU and 8.9 x 10^3 CFU) were observed. The system presented a high performance in terms of pollutants removal, when compared to traditional WWTP including treatment plants with Activated Sludge processes. Regarding the removal of coliforms, the system is not yet stable. However, for water reuse based on COEMA Resolution 02/2017 framework, of the state of Ceará, TEWetland_UPA in 86% of the results is suitable for reuse for environmental purposes, 73% for urban purposes, and 20% for agricultural and aquaculture purposes. The quality of the effluent will certainly improve after treatment in the constructed wetland, which has not yet released effluent for analysis. TEWetland Small-scale Sewage Treatment Plants is a low-cost technology that contributes to the development of fairer, healthier and more resilient territories, in line with the Sustainable Development Goals of the UN.

Keywords: sustainability, biotreatment, ecological sanitation, decentralised WWTP, constructed wetland

InsectScan: Preserving Nature's Architects in Urban Landscapes

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Insects are vital components of ecosystems, offering crucial services such as pollination and nutrient recycling. Yet, data on insect populations beyond iconic species like butterflies and bees are scarce, hampering accurate monitoring and understanding of their roles in ecosystems. Cities can play a pivotal role in sustaining insect populations by providing shelter, food, and interconnected habitats through green infrastructures like parks, green roofs, and urban gardens. These green spaces hold the ability to support insect life cycles, enhance urban biodiversity, and improve air quality, temperature regulation, and overall well-being for urban residents. To address this challenge the InsectScan was developed. This innovative tool employs environmental DNA (eDNA) to swiftly and non-invasively identify and monitor insect biodiversity. By analyzing genetic material from vegetation and flowers of green spaces, the InsectScan provides high-resolution monitoring of a wide range of insects, surpassing traditional methods in speed and frequency. Globally launched by SGS, it has demonstrated its effectiveness in promoting sustainable practices and biodiversity conservation in many terrestrial landscapes. When applied to urban settings, the InsectScan not only monitors biodiversity and allow to visually depict its complexity, but also provide sound-scientific data on net-positive gains and nature-based solutions. Hence, this tool can support decision-making for sustainable urban developers like architects, municipalities and companies that aim to achieve the Sustainable Development Goals, while fostering healthier and more vibrant urban ecosystems.

Keywords: InsectScan, Environmental DNA, Biodiversity monitoring, Urban environments, Sustainable development goals (SDGs).

Promoting sustainability in green facades with Cork-based panels and drought-tolerant Portuguese native species

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The utilization of climbing plants in indirect green facades as nature-based solutions in cities offers numerous benefits, including thermal stability, energy savings, and biodiversity enhancement. However, long-term building damage and maintenance issues, and the use of traditional supporting materials, such as metals, raise concerns about sustainability and environmental impact.

Moreover, the predominant use in green facade cultivation leans towards exotic varieties, and the water consumption of these species is not in accordance with the climatic conditions of the region, but information is lacking on the applicability of native species for green facades.

Thus, by identifying these obstacles, an experiment was conducted at the Ajuda Botanical Garden in Lisbon, Portugal, where low-cost cork panels on a brick and cement wall were installed, as a sustainable alternative for supporting native ivy species (*Hedera iberica* and *H. hibernica*) in indirect green facades. Preliminary results indicate that ivies adapted well to the cork panels, exhibiting slow but steady growth and demonstrating a preference for climbing the panels and these proved to be an adequate medium for ivy growth. Although this structure will be considered an opportunity for a long-term experiment, the primary results highlight the suitability of cork as a vegetation support material, offering advantages such as water retention and environmental sustainability.

The slow and steady growth of ivies and the advantages of cork panels to maintain moisture further encouraged an innovative mixed green facade system that includes the planting of the agricultural rapid-growth species (*Phaseolus lunatus*), providing initial green coverage, combined with slow-growing, low water users ornamental species (*Hedera iberica* - Monsanto ecotype), installed at the School of Agriculture campus of the University of Lisbon.

Monitoring the long-term performance of ivy, bean, and the use of cork panels in indirect green facades under Mediterranean conditions is ongoing, and promising results are expected.

Keywords: Recyclable material; urban agriculture; low-water consumption; nature-based solutions;

Evaluating the Contribution of Green Roofs/Walls for cities' Biodiversity with the support of Citizen Science

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Nature-Based Solutions address urban challenges in a multifunctional way. Green roofs and walls are some of the most promising alternatives as urban space is scarce. Yet, their merit is not generally known and accepted, mainly due to difficulties in valuing intangible benefits as biodiversity.
Biodiversity guarantees an important amount of ecosystem services, such as food supply, soil composition, air quality or climate regulation. Therefore, public policies have pursued answers to protect biodiversity, namely based on international agreements, such as the United Nations Sustainable Development Goals. However, despite the growing concern, the loss of biodiversity has continued, particularly in urban areas.
The work presented here is part of the ongoing research project GRAVITY. The strategy of the project is to: i) define a city case study and catalogue existing green roofs/walls that are already installed; ii) collect a comprehensive and systematic data basis of green roofs/walls contributions to the biodiversity of the city using citizen participation; iii) develop a model to assess the contribution of green roofs/walls to the urban biodiversity and to understand the explanatory variables (e.g., how does proximity to other green spaces or type of green roof/wall influence its contribution to urban biodiversity?); and iv) understand how this demonstration project can be up-scaled in other cities. GRAVITY follows a transdisciplinary approach where citizen science takes on a central and crucial role
Lisbon was chosen as a case study due to its up-scale potential. So far, results of monitoring and modelling of existing green roofs/walls in Lisbon show important biodiversity data, varying e.g. according to the time of the year.Project GRAVITY is funded by FCT - Portuguese Foundation for Science and Technology, project 10.54499/2022.02093.PTDC, DOI https://doi.org/10.54499/2022.02093.PTDC. The authors also acknowledge the support from CERIS Research Centre, Instituto Superior Técnico, Universidade de Lisboa, in the framework of project UIDB/04625/2020.

Keywords: green roofs, green walls, biodiversity, citizen science.

Nature Based Solutions in the rehabilitation of the Leça River

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The Leça River Valley presents traces of human occupation since the Palaeolithic period, currently corresponding to an anthropic landscape with a characteristic distribution of urban sprawl, where residential, industrial, agricultural, and forest areas coexist with large road and railway infrastructures. It is deeply altered and contaminated by human activities, but also contains several elements of cultural and heritage value to preserve because they are representative of human action in the landscape. The Leça River crosses the municipalities of Santo Tirso, Valongo, Maia, and Matosinhos over a length of 48km.

The project aims to develop a multifunctional Green Corridor associated with a water and mobility system contributing to the consolidation of the intermunicipal green infrastructure of the Porto Metropolitan Area while also harnessing ecosystem services to fortify resilience against climate change effects. Interventions should be based on a regenerative process and Nature-Based Solutions, such as the implementation of natural water retention measures, restoration of the riparian gallery, improvement of contaminated soil. Additionally, it aims to mitigate carbon emissions through natural mechanisms such as carbon sequestration and habitat restoration.

The developed methodology is based on a set of analyses, diagnostics and field work that guided proactive actions to promote ecosystems adapted to current conditions of the river and its valley, resilient to climate change and capable of improving the current environmental condition and fostering new relationships between humans and natural elements.

The first phase of the project is already built and establishes a versatile Green Corridor, incorporating water and mobility systems, to strengthen intermunicipal green and grey infrastructure in the Porto Metropolitan Area. The intervention is viewed as a process based on regenerative and strategic nature-based solutions for climate adaptation and mitigation, aiming to minimize maintenance needs and enhance resilience, notably evidenced by its endurance through several of the recent flood events.

Keywords: River; Green Corridor; Regeneration; Mobility; NBS

Green walls for greywater treatment to increase water circularity in urban areas

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The scarcity of water resources has emerged as a global challenge of extreme importance. Urban areas have a special relevance, due to the high demand in terms of resources to face a growing population, since it is estimated by OEDC that 68% of the world population will be living in urban areas by 2050. Climate changes also brings a water crisis due to the reduction in water availability, making water a double challenge in urban areas. In order to fa this challenge new water sources have gained increasing interest, in order to increase water circularity and reduce the pressure over natural water sources. The reuse of gray water is an increasingly interesting alternative in urban areas since it represents 65% of total domestic wastewater production and, compared to black water, has relatively lower levels of contaminants, thus presenting a better possibility of reuse for non-potable purposes. At the same time, the European Commission has defined guidelines for the integration of Nature-Based Solutions (NBS) in cities, with the aim of addressing social challenges by efficiently managing resources and jointly providing economic, social and environmental benefits. Green walls for grey water treatment (GW-GW) are engineered green walls that use greywater as an irrigation source and also allow the treatment of excess irrigation water for further reuse. As conventional green walls, GW-GW provide multiple benefits such as the improvement of the thermal efficiency of buildings and contribute to reduce the heat island effect, mitigate noise pollution, contribute to biodiversity and improve population's well-being. The present work presents the results from a GW-GW installed on the external facade of an educational building at the Instituto Superior Técnico (Lisbon, Portugal) both in terms of water quality improvement and suitability for reuse as well as the water balance of the installation.

Keywords: green walls, grey water, water quality, water reuse

Towards Climate-Ready Cities: Nature-Based Solutions in Peruvian Urban Drainage Reconstruction

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Nature-based Solutions (NbS) offer vital benefits and services amidst escalating biodiversity loss, closely tied to worsening climate emergency and extreme weather events. Emerging evidence underscores NbS as potent tools in addressing the global climate crisis and providing environmental, social and financial benefits.

Globally, countries grapple with escalating environmental threats affecting economies and livelihoods, and Peru is no exception. Despite being one of the world's most biodiverse countries, Peru faces heightened vulnerability to climate change impacts, including natural disasters like earthquakes, floods, landslides, and droughts. The El Niño Phenomenon exacerbates these events, with climate change intensifying their frequency and severity. Compounded by existing challenges such as deforestation, water pollution, and poor land use management, these climate risks imperil Peru's future development.

Following the devastating 2017 El Niño climate cycle, the UK Department for International Trade collaborated with the Government of Peru in June 2020 to reconstruct urban drainage systems, schools, health facilities, and flood protection. In partnership with Mace and Gleeds, Arup worked with the client, local designers, and contractors to reconstruct resilient and climate-ready sustainable urban drainage systems.

Arup facilitated technical assurance through design workshops, engagement with local experts, site visits, and the formulation of design guidelines. A comprehensive document outlining design guidelines was created to offer practical technical guidance, emphasizing design principles, benefits, and crucial coordination for the effective implementation of NbS in an arid urban drainage design.

The twofold purpose of the guidelines is :

1. To deliver comprehensive, valuable, and practical guidance for the client to support the design process and technical delivery of the NbS projects within the Urban Drainage Reconstruction programme.
2. To provide the client and local designers with tools and processes to increase strategic delivery of NbS, their benefits and opportunities, and to make steady progress in turning Peru’s climate change goals into reality.

Keywords: Nature-based Solutions; Climate; Resilience; Reconstruction.

ÍA.Porto: an environmental qualification instrument for urban operation

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The *Porto's Índice Ambiental* (*ÍA.Porto*) was fostered, designed, and made to ensure Porto Municipality compliance of the Article 145 of Porto City Master Plan (2021). It is the first national initiative committed to create an unbiased and objective framework to assess the urban environmental performance of buildings and give incentives and other financial mechanisms according to the scores obtained in several environmental dimensions (energy, vegetation, water, materials, etc.) and fully set to be included in municipal land use planning process and regulations to promote climate change adaptation strategy. Like a growing number of cities, Porto intends to have a new policy instrument to promote, through the granting of incentives of different types, an environmental qualification of its urban operations. This is a *bottom-up* user-friendly tool, well connected to the pre-existing planning rules, set to disseminate environmental qualification practices at the scale of the urban planning operations with a positive cascade effect on smaller scales by promoting biodiversity, decarbonization or adaptation to climate risks. In operational terms, *ÍA.Porto* is supported by easy-to-apply tailored tool, consisting of a wide range of qualification solutions (e.g. vegetation cover, water mosaics, green roofs, storage solutions, treatment and reuse of rainwater, reuse of construction materials, etc.), which are scored differently according to the importance of the benefits they can bring to the balance of Porto's particular ecosystems. To this end, we did an accurate local climatological analysis, a review of ongoing experiences in several cities that have already implemented this type of instrument and maintained a constant dialogue with all internal and external stakeholders who are/will be end users of this tool. The outcomes obtained allow us to consider that it will be an eye-catching, well accepted, recognized and great step forward to achieve the municipality's goals in terms of adapting to climate change, both through the effects of concrete actions on the climate system and by increasing the climatological literacy of decision-makers, city builders and population.

Keywords: green factor; environmental qualification; urban operations; sustainability; climate adaptation

SINGAPORE'S JUNGLE OF GLASS: IN THE SEARCH FOR A CERTAIN TOPIA

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Singapore is a city-state whose cosmopolitan reality boasts an extensive array of contemporary buildings and public spaces, aimed at positioning Singapore on the global stage. Rapid economic and demographic growth was spurred in 1965 with independence from Malaysia, transforming the island from a place of decay into a metropolis with 5.45 million inhabitants. In just over fifty-eight years, Singapore has flourished into a global focal point, with one of its major attractions being the seamless integration of nature into the urban landscape, emphasizing the harmony between architecture, urban planning, and the natural environment.

Furthermore, it is worth mentioning that this article originates from a master's dissertation completed at the University of Minho in December 2023, titled *Architectural Simulacrum of Hypertopia: The Singapore Mode*l. Although it does not cover all aspects of the original work, it does touch upon significant points addressed within the dissertation, specifically in the sustainable milestones of Singapore. The research that culminated in the dissertation was conducted in two phases: a theoretical phase from 2022 to 2023, and a practical one in March 2023. The practical phase, which lasted over one month in Singapore, included conducting interviews, visiting and mapping local sites, documenting and archiving culture, and photographing daily life.

Singapore, frequently seen as a green sanctuary amidst Asia's glass jungle, stands as a global model in urban sustainability. Despite its small size and high population density, the city has introduced numerous innovative initiatives to secure a green future. This article intends to share the insights, experiences, and knowledge gathered by the authors during their research about Singapore, focusing on sustainability. These experiences have led to a certain apprehension regarding the idealized image promoted by Singapore concerning the magnificence of sustainability, the incorporation of green spaces into everyday life, and particularly, the aesthetic crafted around a nature-inspired lifestyle that demands continuous upkeep.

Keywords: Singapore. Sustainability. Hypertopia. Architecture. Urbanism.

Land Cover Classification and Change in Porto, Portugal: Spatial Analysis for Urban Vegetation and Green Roof Adoption

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As urban environments develop, there are increasing pressures on creating multifunctional areas, which provide space for people as well as ecosystem services. Geographic information Systems (GIS) and Remote Sensing (RS) are technologies available for visualizing, monitoring, analyzing and applying spatial data to urban planning issues. Our area of interest was Porto, Portugal, and our questions were: 1) which supervised classification technique is most accurate for this study area, 2) how has landcover changed between 2017 to 2022, 3) how much area may be available for conversion to green roofs, 4) how does Normalized Difference Vegetative Index compare to supervised classification? Landcover was classified into seven categories for five Concelhos of Porto District Portugal using PlanetLabs PlanetScope satellite imagery. Images were selected for low cloud cover and similar time of year, and obtained for 4 July, 2017 and 1 July, 2022. Political boundaries were obtained from the National Institute of Statistics. Of the four methods tested, k-nearest neighbor was the most accurate supervised classification method with 2017 Kappa = .87 and 2022 Kappa = .98. Shadow, Other Roofing Material, and Bare Ground increased, and Water, Tiled Roof, Pavement, and Vegetation decreased from 2017 to 2022. NDVI shows little change in vegetation overall, mean .02 slight increase. NDVI maps identified areas of substantial vegetation increase and decrease for further analysis. There were 142,505,000 square meters classified as impervious surface in 2022, of which 32,675,000 square meters were “other roofs”, commercial or industrial white surfaced roofs, which may be the most likely targets for vegetative interventions. Zonal statistics will reveal trends between freguesias or neighborhoods, and if combined with socioeconomic data could inform decisions addressing climate justice. LiDAR data would increase the accuracy further and allow for clearer selection of elevated flat surfaces.

Keywords: GIS, remote sensing, landcover change

Nature-based solutions for sustainable marine antifouling applications

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The search for new antifouling (AF) agents among marine natural products is a promising approach to the replacement of biocides currently in use in AF protective coatings worldwide. Natural cyclic dodecapeptides (NCPs) isolated from the cyanobacterium *Phormidium sp.* LEGE 05292 showed high effectiveness in the prevention of mussel larvae settlement (EC50 = 3.16 µM), and also bioactivity towards the growth of marine biofouling bacterial strains, while showing low toxicity towards both target and non-target marine species. Considering the potential of NCPs in *in vivo* AF and ecotoxicity bioassays, their incorporation in commercial polyurethane and silicone (PDMS)-based marine coatings were carried out to demonstrate their industrial applicability. NCPs-based AF coating formulations were tested *in situ* in a real marine environment scenario for proof of concept. Results showed improvements in the ability to prevent the colonization of fouling organisms on substrates coated with marine formulations containing NCPs (~0.7wt.%), being a step forward in the consideration of natural products as active ingredients in new sustainable antifouling technologies. This research was supported by national funds through FCT (Foundation for Science and Technology) within the scope of Base Funding UIDB/04423/2020 and UIDP/04423/2020 (CIIMAR); UIDB/04046/2020 and UIDP/04046/2020 (BioISI).This research was supported by the Innovation Pact, Project No. C644915664-00000026 (WP2 Vertical Bivalves), under the “Blue Bioeconomy Pact”, resulting from the submission of the application to Notice No. 02/C05-i01/2022, within the scope of the Recovery and Resilience Plan (PRR), co-funded by the Portuguese Republic and the European Union. J.R. Almeida and E.R. Silva acknowledge for the work contracts through the Scientific Employment Stimulus Individual Call (https://doi.org/10.54499/2022.03876.CEECIND/CP1728/CT0005 and https://doi.org/10.54499/CEECIND/03530/2018/CP1553/CT0011, respectively).

Keywords: natural products; cyanobacteria; antifouling; sustainable technologies

Nature-based Solutions in urban areas: how to fit into the New European Bauhaus framework

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Three-fourths of Europe's population resides in urban areas, with cities facing a greater susceptibility to climate change impacts compared to rural regions. Initiating novel research and strategies to mitigate the repercussions of climate change should commence at the urban level. Despite climate change being a global phenomenon, tackling its effects necessitates localized actions and initiatives due to the heightened visibility of impacts at the local level. Nature-based Solutions (NBS) emerge as crucial tools in counteracting the heat island phenomenon, fostering biodiversity, managing runoff, and enhancing air and water quality – benefits extensively studied in recent years. Beyond environmental sustainability, NBS also yield various social advantages, encouraging participatory and co-management approaches to heighten public awareness and involvement. The New European Bauhaus (NEB) contemplates the potential for sustainable, inclusive, and adopting a holistic approach to regeneration initiatives that not only considers environmental aspects but also encompasses socio-cultural dimensions. This article endeavors to explore the foundational principles of Nature-Based Solutions (NBS) and the New European Bauhaus (NEB), seeking to identify shared elements and examine them within a broader perspective. After examining the two topics, the study aims to compile a set of shared values to establish the parameters under which NBS can serve as a crucial tool in promoting the New European Bauhaus initiative. Through an analysis of relevant literature, the objective is to construct a comprehensive framework where these two themes coexist and collaborate towards a common objective. Following the definition of common elements, the article will also delve into topics that may initially appear unrelated to the two themes but could offer intriguing insights and perspectives.

Keywords: NBS; NEB; sustainability; urban areas; climate change adaptation.

Benefits from Nature Based Solutions in Industrial Parks, evidences from the INDNATUR Project

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Nature Based Solutions (NBS) are essential a key element in industrial areas, as they promote environmental sustainability, climate resilience, economic prosperity, and human well-being. Integrating NBS into industrial park development is paramount for creating more sustainable and balanced environments where industry and nature can coexist. INDNATUR, a transnational cooperation project, joined efforts from different Institutions to provide valuable contributions to the incorporation of NBS in Industrial Parks. It focused primarily in two Industrial Parks: Argales, Valladolid, Spain, and Cantaria, Bragança, Portugal. Among the main outcomes of this project, several interventions were designed to incorporate NBS in these Industrial parks. Other contributions included practical guides for interventions and support for the development of regulations. Aiming at providing a comprehensive interpretation of local environmental conditions and an evaluation of the benefits of NBS projects, a set of assessment and monitoring practices were applied in both industrial Parks. Among the assessed parameters were vegetation, air quality, microclimate, permeability, and biodiversity. This presentation will focus on the components of Microclimate, air quality and water permeability. From the microclimate perspective, monitoring shows that industrial areas' low vegetation cover and few trees, make such areas more prone to higher temperatures, mainly during the summer daytime. Simulations done using ENVI-Met to a specific intervention in the Argales Park, allowed to project a substantial amelioration of local thermal comfort conditions, namely by the projecting the increase of the planted trees, with a reduction of air temperature during the summer of up to 4 ºC. From an air quality perspective, both industrial parks show no evidence of exceeding the legal limits. As they mostly covered by commercial facilities, air quality is mostly influenced by automobile sources. The plantation of trees while not expected to substantially change the existent air quality, will certainly contribute to the maintenance of low air pollution levels. Water permeability was also addressed in this project, combining both onsite unaltered soil samples collection and analysis, with experimental assessment of existent sidewalks pavements. In site soil collection and permeability assessment demonstrated that there was a substantial increase in the permeability of soils in the aftermath of intervention in the Argales Industrial Park. The experimental assessment of different sidewalks materials allowed to demonstrate that the use of large cement blocs substantially reduce the infiltration of water in the soil and a subsequently increase superficial drainage. The use of smaller blocs introducing additional infiltration gaps, can help increase the infiltration in sidewalks. Overall, the INDNATUR project allowed for the demonstration of multiple benefits of the introduction of NBS in Industrial Parks, as a key element in local sustainability.

Keywords: Nature Based Solutions, Thermal Comfort, Air Quality, Soil Permeability, Industrial Parks.

Building-Integrated Greenery. Collaborative xeriscaping-based maintenance and monitoring in Mediterranean cities (BIG4LIFE)

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The BIG4LIFE project aims achieving the co-design of framework plans for collaborative maintenance, monitoring, and evaluation of impacts, of Building-Integrated Greenery (BIG) systems, i.e. green roofs, walls, and facades, under the demanding conditions of the Mediterranean climate. The BIG4LIFE project will demonstrate that by applying xeriscaping and networking approaches, supported by suitable smart solutions, a positive service life of BIG systems can be achieved in terms of both, their long-term sustainability, and the provided ecosystem services. Co-designed with key stakeholders, and following a "by building typology approach", the elaborated plans will be tested and validated in real BIG projects under operational phase, both failed and successful ones. The aim is to demonstrate that by means of establishing "networking approaches" through involving owners, users, maintenance companies, among other, as well as also taking advantage of the Community Service-Learning methodologies, it is possible to achieve long-term sustainability for BIG systems. Moreover, by assessing and enhancing their positive service life, it is possible to calculate their cost-effectiveness and feasibility to be subsequently incorporated in the local and national policies and standards.
By promoting the re-naturalization of the built environment through sustainable construction systems, the BIG4LIFE project aims to promote the building sector's transition towards a more sustainable, circular, toxic-free, energy-efficient and climate-resilient model, in addition considering the restoration and improvement of life quality. As a result, the BIG4LIFE project will contribute to the New European Bauhaus initiative through the reduction of environmental impacts of new and refurbished buildings, the creation of circular value chains to boost urban economies whilst producing urban and territorial regeneration, as well as enhancing citizen's well-being and supporting biodiversity in the urban environment.

Keywords: Nature-based solutions, building-integrated greenery, green roofs, green walls, green facades, ecosystem services

Mangroves as a nature-based solution for a sustainable city: Macao SAR as a Case Study

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Nature-based solutions (NBS) have emerged as promising approaches for addressing sustainability challenges in urban environments. Among these solutions, wetlands like mangroves play a crucial role in promoting ecological resilience and mitigating environmental issues. This presentation explores the significance of mangroves as NBS for fostering sustainability in cities, focusing on Macao SAR. Like many coastal cities globally, Macao faces significant environmental challenges, including climate change impacts and coastal water pollution. Our research in Macao SAR investigates the potential of mangroves for climate change adaptation and mitigation, phytoremediation of coastal water pollution, and plastic pollution entrapment. We also discuss how scientific research translates into action through community outreach initiatives. Drawing on these studies, we demonstrate the practical applications and benefits of mangrove restoration and conservation for sustainable urban development. By analyzing the ecological and social dimensions of mangrove-based interventions, this presentation highlights their potential to address pressing urban challenges, including climate change adaptation, water quality management, and biodiversity conservation. Ultimately, we aim to inform policy-makers, urban planners, and stakeholders about the value of mangroves in building sustainable and resilient cities.

Keywords: mangroves; nature-based solution; climate change; pollution; phytoremediation

STREAMBANK STABILIZATION IN RIVER PÓVOA, LOURES, PORTUGAL

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This project is part of a wider EU-funded investment totaling 5,8 M€ to the city of Loures (Portugal), and generally aimed for the sustainable flood control using bioengineering solutions in a total of 32 km. For this case, the objectives were to stabilize both river margins of a 250 m stretch of river Póvoa in Loures city and to restore the native vegetation, promoting biodiversity. The site is located in a highly populated area near Lisbon and is prone to recurring (and severe) floods. This is due to several reasons: it falls within the floodplain of river Trancão; part of its basin drains water from steep hills located at less than 1 km; it suffers the influence of the Atlantic Sea tides via river Tagus. The problems observed were both geotechnical and ecological. In the first case, several mass movements and cracks with more than 20 cm depth and 30 m long where present. The ecological problems were mainly related to the dominance of the giant reed (Arundo donax), an invasive species which the superficial roots do not contribute to in-depth slope stabilization. The major aim of the latter was to develop a global solution for sustainable water management in the event of floods. During this process, the hydrology and hydraulics of river Loures basin was studied. The interventions included not only several works of civil engineering – culvert widening, installing passive tide gates, etc. – but also soil and water-bioengineering techniques (SWBT). These would promote erosion control, slope stabilization and consolidation as well as the ecological recovery of the site. The hydrological and hydraulic model concluded that a maximum velocity of 1.8 m/s and a maximum shear stress of 17.068 N/m2 was expected for the 100-year flood, this including a high-tide scenario. Taking this into consideration along with the site characteristics and a thorough review of SWBT literature, the solution adopted to stabilize the streambanks was a vegetated crib wall. This structure is able to withstand water velocities between 3 and 6 m/s and 200-300 N/m2 of shear stress, thus suitable for the existing conditions. The design included a retaining structure in two terraces in both riverbanks and a total height of 2.6 m. The bottom crib wall was to be filled with drain rock and the upper structure with soil and live willow stakes. In the winter period, the site was subject to heavy rainfall that caused 3 major floods, including the nearby area. Although the vegetated cribwall was not finished, the structure remained intact. This Project and specifically the constructed vegetated crib wall showed that a careful conception and design of SWBT allied with a solid construction is vital for a successful outcome.

Keywords: Environmental benefits; urban green spaces; sustainability; urban planning.

The estimation of the ecosystem services in the urban forest of Vila Real - a tool to evaluate and monitor nature-based solutions in the city

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Urban nature-based solutions (NbS) address multiple challenges, including climate change adaptation and biodiversity loss, disaster risk, water and food security, human health and socio-economic development. It is estimated that more than half the population currently lives in cities and the forecast is that by 2050 the total urban population will be 70%. These figures reinforce this 21st century challenge of quantifying and evaluating ecosystem services, namely biodiversity, tackling climate change, always with the aim of making cities more sustainable, resilient and also promoting urban comfort.

Urban trees contribute to the quality of urban life by improving human health and well-being with positive impacts on air quality, reducing temperature, increasing humidity, promoting biodiversity, mitigating heat wave, valuing heritage and landscape. Despite that, planning and managing of public street trees according to social, economic and impactful climate scenarios is challenging. Particularly in Portugal, legislation published in 2021 (Republic Diary No. 59/2021) imposes that all the municipalities shall prepare a complete inventory of the urban tree heritage in order to foster a city's sustainability.

The city of Vila Real has several different types of urban areas: historic areas, contemporary areas built up until the early 80s of the 20th century and major urban expansion after the 80s. A sample of 2500 trees representing the different typologies of street trees in the city was assessed to quantify its efficiency in terms of ecosystem benefits based on 2021 field work. i-Tree software (www.itreetools.org), is been used to provide a means for the analysis and evaluation of urban forest and its ecological and economic benefits.

The results are important to support the municipality in sustainable urban planning and the implementing of NbS, as well in the review of regulations applicable to the management of green spaces and in the creation of new decision criteria.

Keywords: Environmental benefits; urban green spaces; sustainability; urban planning.

Bio Ilhas Project: Blending Research with scientific and educational dissemination

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Freshwater ecosystems provide humanity with a wide range of services, particularly water supply and purification. However, many of these ecosystems and their associated biodiversity are threatened significantly. Therefore, the introduction of nature-based solutions, such as floating wetland islands, in these ecosystems can contribute to the improvement of water quality and habitat provision and, when integrated with an environmental education context, can be used as powerful tools to engage students, tourists, and the general public in interactive experiences, allowing them to become more familiar with the function of freshwater ecosystems and biodiversity. Both the Fervença and Côa rivers are located in the Douro basin. The Fervença is an urban river, about 25 km long, which flows through Bragança. Along its course, it encounters non-point and point sources of pollution. In the urban core, the riverbed has been regulated, an artificial riverbank has been created, and the riparian forest has been partially removed. In this area, algal blooms occur, especially in summer, which negatively affect the water and visual quality of the area. The Côa is about 140 km long and flows through an agricultural and natural landscape. Nevertheless, the longitudinal connectivity of the river is reduced by several weirs, and the coffer dam has never been removed, even after a dam construction project was abandoned due to the discovery of important archaeological heritage. The Bio ilhas project, led by the Bragança Ciência Viva Science Center, aims to place floating islands in the urban core of Fervença and the lentic area influenced by the Côa coffer dam, the river areas affected by human activity at different levels. Therefore, the present communication aims to present the Bio ilhas project and the related activities conciliating research with scientific and educational dissemination to ultimately contribute to freshwater ecosystem conservation.

Keywords: Bio Ilhas Project; floating islands; Scientific and Educational dissemination; Freshwater ecosystems conservation.

Blended Intensive Programme (BIP) in Nature-based Solutions for resilient, sustainable and equitable cities

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The new Erasmus+ Program 2021-2027, promotes the Blended Intensive Program (BIP), allowing new and more flexible mobility formats in order to reach students from different areas, regardless of their origin or country. These short-term intensive programs feature innovative ways of teaching and learning, including online cooperation resources, where transnational and transdisciplinary groups work together to address challenges, linked to the UN SDG or other societal challenges identified by regions, cities or companies.

A participatory placemaking approach to equitable co-design, co-creation and co-management of Nature-based Solutions (NbS) that include multiple stakeholders and beneficiaries has the potential to address societal issues such as climate change and other socio environmental inequalities across both spatial and temporal scales.

NbS implementation in cities is inherently complex due to their multidisciplinary nature and at odds with many siloed governance structures, largely due to knowledge and skills gaps and the lack of coordination across sectors or departments, particularly at local authority level. In this context, the main objective of the BIP "Nature-based Solutions for resilient, sustainable and equitable cities" is to provide knowledge on how to implement NbS for creating resilient, sustainable and more equitable cities. As this is a highly interdisciplinary task, the course aims to provide a learning experience that overcomes disciplinary gaps and leads participants to a new level of understanding cost-effective provision of multiple co-benefits for residents in cities with NbS. This BIP is promoted by the School of Agriculture of the Polytechnic Institute of Viana do Castelo (Portugal) in partnership with the Higher Technical School of Agricultural Engineering of the University of Seville (Spain), the Agro-Environmental and Water Economics Research Institute of the University of the Balearic Islands (Spain), the Faculty of Biology of the University of Vigo (Spain) and the Faculty of Art & Design of the University of Lapland (Finland).

Keywords: Blended Intensive Programme, Nature-based solutions, resilience, sustainability, equity

Assessment of green roofs ecosystem services: the Falcão School case study

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The urban population is growing, and it is estimated that by 2050, two thirds of the world's population will live in urban areas. Climate change will require cities to adapt rapidly, especially to extreme weather events. Nature-based solutions (NBS) will play a key role in the resilience of cities. NBS are solutions inspired and supported by nature, simultaneously providing environmental, social and economic benefits. Some examples of NBS are green roofs, green walls, SuDS (sustainable urban drainage systems), constructed wetlands and rain gardens.

Green roofs provide a variety of ecosystem services, contributing to the well-being of territories, especially in urban environment. Some of the key ecosystem services provided by green roofs include: i) stormwater management; ii) biodiversity promotion; iii) air quality improvement; iv) temperature regulation; v) noise reduction; vi) aesthetic and recreational; vii) thermal insulation and energy savings; vii) extended roof's membrane lifespan; vii) increase in solar energy production and viii) higher property value.

This study aims to qualify and quantify the ecosystem services provided by the various types of green roofs installed at the EB1/JI do Falcão school in Porto. Several NBS were installed in the school 2023 rehabilitation: extensive green roof with *Sedum*, a bio solar roof, a semi-intensive green roof with expanded cork agglomerate as insulation and drainage layers and a rain garden. The aim is to understand the benefits on produced energy through photovoltaic panels by analyzing data from areas with and without vegetation. Indoor energy efficiency in classrooms will also be assessed by comparing classrooms with and without green roofs. Furthermore, other benefits, like stormwater runoff will be considered.

Keywords: ecosystem services; green roofs; educational buildings; economic value;

GREENFUTURE Platform: A Portuguese website gathering technical and scientific knowledge on green roofs and façades

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Green roofs and facades are becoming increasingly important in today's reality. In fact, these solutions can bring various benefits to the urban environment, helping to mitigate the effects of climate change and to the buildings themselves by improving their performance. However, the dissemination in Portugal is still scarce, namely, due to the lack of knowledge about these solutions, the difficulty in understanding the phenomena involved and in quantifying the real benefits provided by these solutions. The GREENFUTURE platform was developed with the aim of gathering and disseminating relevant information on green roof and façade systems. It is intended to help in the adoption of the best practices in the processes of development, CE marking, project preparation and installation of this type of systems. It also aims to act as a vehicle to encourage the more widespread adoption of these systems, promoting sustainability and resilience to the effects of climate change in urban spaces. The platform is divided into three main sections corresponding to support materials, tools and case studies, which are available to all interested users. This platform is one of the main results of the GREENFUTURE project (POCI-01-0246- FEDER-181322), which aimed to promote the transfer and dissemination of scientific and technological knowledge on green roofs and façades, especially for small and medium-sized Portuguese companies.

Keywords: Green roofs; Green walls; Nature Based Solutions; Online platform.

Rainwater harvesting with conventional or green roofs?

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The present approach aims to evaluate the technical and financial feasibility of a rainwater harvesting system for an industrial building in Northeast Portugal, considering the existing conventional roof (scenario 1) and the adaptation of a green roof to the existing roof (scenario 2). In this evaluation, the impact of the two scenarios on the water savings of the building was considered. The expected water savings were 64.47% and 59.43% for scenarios 1 and 2, respectively. Therefore, the expected reduction in the annual water bill was €3867.07 + VAT (scenario 1) and €3564.63 + VAT (scenario 2). For scenario 1, considering a reservoir of 70 m^3 for non-potable purposes, such as washing the floor of the building and use in industrial machinery, and an initial investment of 41,109.13 € + VAT, the single payback is 11.29 years. The single payback for Scenario 2 largely exceeded the lifetime of the green roof. However, financial incentives could be proposed to implement green roofs in this building typology, as they are considered interesting solutions to reduce the negative externalities of industrial settlements.

Keywords: rainwater harvesting, conventional roofs, green roofs, technical and financial feasibility, industrial building

Electricity production in plant-microbial fuel cells – A new green infrastructure ecosystem service

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The urgent need to overcome fossil fuel dependency and adopt carbon-neutral technologies alongside with the increasing demand for food, particularly in space-constrained urban areas were the main motivation for project SEIVA - Energy Systems and Green Infrastructures for food production. The project addresses the specific issues of vertical farming and environmental parameters monitoring using nature-based solutions and is in line with the ambition of the EU research and innovation policy in positioning the EU as leader in innovating with nature to achieve more sustainable and resilient societies. In fact, green walls are emerging as a resilient solution for food production in cities, but also to strengthen local economies and bringing together communities, two fundamental aspects for the recovery and resilience of communities and territories. At the same time, plant microbial fuel cell (P-MFC) is emerging as a promising technology that can meet the increasing energy demands globally. P-MFC can continuously generate electricity without interfering with plant growth and food production, producing stable power for biosensing in self-powered IoT applications, thus addressing the needs of future smart agriculture applications, by providing an energy neutral monitoring system to achieve consistent autonomous vertical farming. In this context, the main goal of the present study was to assess the potential of P-MFC with *Mentha piperita* or *Mentha pulegium* to produce bioelectricity capable of powering environmental sensors in green walls. Both plant-microbial fuel cells with *M. pulegium* and *M. piperita*, were able to produce bioelectricity. The highest and more stable values were obtained in the P-MFC systems with *M. piperita*. The P-MFC with *M.pulegium* had an average voltage of 376 mV and the P-MFC with *M. piperita* 201 mV. Regarding the maximum power obtained, this was 4.92 mW/m^2 and 5.24 mW/m^2 for *M. pulegium* and *M. piperita*, respectively.

Keywords: Plant-Microbial Fuel Cells, food production, bioelectricity, green walls, ecosystem services

Assessing Sustainable Urban Stormwater Management: A Comparative Study of Green Roofs and Detention Basins Strategies in Three U.S. Cities

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In 2022, floods caused nearly 2.8 billion U.S. dollars of property and crop damage in the U.S.A. Impervious surfaces do not allow precipitation to infiltrate onsite, directing runoff to storm conduits. Therefore, it is necessary to implement intentional infrastructures that allow interception and treatment of water in urban areas. We evaluated three cities in three of the mid-content EPA ecoregions: Denver, Colorado, High Plains; Omaha, Nebraska, Temperate Prairies; and Dallas, Texas, Semi-Arid. Each has a different ecoregion classification but share similar stormwater management challenges. Spatial data were collected from city open GIS data servers, the Multi-Resolution Land Characteristic Consortium (MRLC) and the U.S. Geologic Survey (USGS). We completed 288 predictive modeling scenarios to compare proposed area of green roofs (GR) and detention basins (DB) with climate change predictions using CLASIC – a tool utilizing a lifecycle cost framework to inform decisions about stormwater infrastructure. We found that the costs of implementing GR are always higher than DB because GR is still an emerging technology in the U.S., with developing incentives and demand. As GR does not capture runoff from adjacent, impervious surfaces, the area needed to capture the same volume of water is larger than for DB. GR reduced more runoff than DB in Denver, while Dallas and Omaha had opposite results. All three cities presented increased evapotranspiration when GR were implemented and increased infiltration with DB. In Denver, GR had a greater contaminant load reduction than DB. In Dallas and Omaha, GR had a greater reduction of total suspended solids and smaller total phosphorus reduction than DB, while total nitrogen reduction is close to both technologies. Finally, GR presented a more significant indicator for social, economic, and environmental benefits. By integrating nature-based solutions we can prevent flooding, provide ecosystem services, and improve social and climate justice for urban residents.

Keywords: Green-infrastructure, stormwater management, lifecycle-costs and benefits

Integrating Green and Purple Roofs into Smart Cities for Sustainable Urban Development

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As cities around the world grapple with the challenges of rapid urbanization, the concept of smart green cities emerges as a beacon of hope, offering a promising framework to address urban complexities through technological advancement and innovative solutions. Central to the vision of smart cities is the seamless integration of nature-based solutions, such as green and purple roofs, which stand as veritable pillars of urban sustainability, resilience, and enhanced quality of life. Green roofs, characterized by lush, vegetated surfaces, offer a myriad of potential environmental benefits to urban landscapes. From potentially mitigating the urban heat island effect and managing stormwater runoff to potentially fostering biodiversity conservation, these eco-friendly rooftops hold promise as green oases amidst concrete jungles. Meanwhile, their counterpart, purple roofs, equipped with rainwater harvesting and reuse systems, could provide an additional layer of sustainability by conserving precious water resources and promoting sustainable resource management practices. The potential synergies between green and purple roofs and smart city initiatives appear vast and promising. These solutions could be seamlessly integrated into the urban fabric, potentially contributing to various aspects of urban infrastructure, including smart irrigation systems, heat island mitigation strategies, stormwater management practices, and biodiversity conservation efforts. Moreover, they could play a pivotal role in public education and engagement programs, potentially raising awareness about sustainable urban living and fostering a culture of environmental stewardship. Beyond green and purple roofs, a plethora of nature-based solutions exist to tackle urban challenges. From permeable pavements and green walls to urban forests and blue-green corridors, cities worldwide are exploring innovative ways to harness the power of nature in creating healthier, more resilient urban environments. Examples from major cities like New York, London, Tokyo, and Sydney suggest possible approaches and transformative potential of nature-based solutions on urban sustainability and resilience. Through discussions of best practices and policy recommendations, this session aims to shed light on the potential role of green and purple roofs as integral components of smart cities. By championing these nature-based solutions, cities worldwide could potentially chart a course towards sustainable urban development, resilience to climate change, and the creation of healthier, more livable urban environments for present and future generations.

Keywords: Smart cities, Green roofs, Purple roofs, Urban sustainability, Nature-based solutions

City Nature-based Solutions Integration to Local Urban Infrastructure Protection for a Climate Resilient Society - NBSINFRA

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NBSINFRA is a pioneering European initiative funded by the EU, focused on advancing Nature-Based solutions to protect critical urban infrastructure against natural and human-induced hazards. Climate change is one of the most significant challenges to be faced (https://www.unenvironment.org/news-and-stories/story/how-climate-change-making-record-breaking-floods-new-normal). It is not possible to escape from climate change implications,which include tremendous protection and restoration costs, extreme threats to communities' prosperity and growth, and rigid policies to apply with a significant impact on international relations. In a moment when cities become gravitational centers, this effect is even higher in urban areas due to the dense spatial concentration of infrastructures and people (https://doi.org/10.2760/007069). An additional challenge is that current adverse events occur in places and regions where such phenomena have not been noticed before and are beyond the limits of the scientifically and statistically predicted disaster impact areas. These are reasons for a fundamental shift in the conceptualization of hazards from natural phenomena dealing with engineering solutions to natural and sociotechnical phenomena, which are produced from andresolved by the synergy of the local societal context and nature.

The NBSINFRA mission extends to creating resilient urban environments capable of withstanding the challenges aforementioned. Thus, five "City Labs" established in representative European regions assess the cost-effectiveness of NBS in the protection of local infrastructure with the creation of citizen-owned solutions and co- created by end-users, managers and civil society. NBSINFRA's methodology passes to develop a toolkit by using the lessons learned and observing the generated tools. By combining insights from a broad perspective, together with information at local level, it will be possible to share friendly recommendations and educational materialfor stakeholders.

Keywords: nature-based solutions; city; resilience; civil society; climate change.

Treatment of organic compounds in floating plant root mat

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Floating plant root mat (FPRM) is hybrid of soil matrix-free pond systems and conventional soil matrix based constructed wetlands (CWs) containing macrophytes, growing as a floating mat on the water surface or touching to the bottom of the water body where it function as a plant root mat filter (PRMF) for the contaminated water. Recently, floating treatment wetland were used for different types of wastewaters. However, investigation on FPRM for the treatment of wastewater contaminated by organic compounds such as volatile organic compounds (VOCs) and herbicides are missing. In this study, a FPRM and PRMF (pilot scale) were investigated for the treatment of water contaminated by benzene and methyl *tert*-butyl ether (MTBE), and a FPRM and four conventional CWs were investigated for the treatment of water contaminated by herbicides. Results show that both systems have the similar removal behavior for benzene and MTBE removal during the two years of operation. However, better removal for both pollutants during the summer was found in the first year. The emission rates of benzene and MTBE were less than 16 and 12 mg/m/d, respectively. This means less than 7% benzene was removed through volatilization. But the volatilization of MTBE reached up to 60% of the total removal. The metabolites (OA and ESA) of herbicides peaked at 9 days in the FPRM, while the detected metabolites account for 20% ~ 25% of the mother compounds. In conclusion, FPRM is the most cost-efficient alternatives for VOCs and herbicides removal due to the absent of substrate.

Keywords: Benzene; Floating plant root mat; MTBE; Volatile organic compounds

Exploring Challenges and Opportunities of Nature-Based Solutions for Urban Agriculture within Buildings

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Urban centers, teeming with increase population density, rely on their rural and peri-urban counterparts for food provision. However, this conventional linear food system gives rise to environmental challenges, such as an elevated carbon footprint due to extensive transportation networks and the accumulation of waste from excessive packaging materials. Promoting Urban Agriculture (UA) within buildings, coupled with Nature-Based Solutions (NbS), holds significant promise for revolutionizing urban food systems and fostering the development of more resilient and sustainable cities, particularly in densely populated urban areas such as Macao. Indeed, Macao relies on mainland China for its fresh fruits and vegetable supply which results in shortages of fresh food when cross-border activities are restricted. This study conducted a comprehensive literature review to identify the technologies, environmental and social impacts, as well as the main challenges and barriers for the public acceptance of UA in buildings.

The primary findings from the literature review reveal that the most prevalent NbS for UA within buildings include indoor hydroponics, rooftop farming, and greenhouses. These solutions contribute to significantly decrease the carbon footprint, while promoting food security, healthier dietary choices and reducing reliance on imported or processed foods. Moreover, UA helps mitigating the urban heat island effect by providing shade and cooling the surrounding environment and improving air quality, creating more comfortable and sustainable urban living environments. However, UA in buildings encounters several challenges, including high energy consumption, generation of consumable waste from building farming facilities, restrictions on crop selection, and limitations imposed by building orientation for facade farming. Recognizing and addressing these challenges is paramount to develop tailored sustainable agricultural systems in buildings. Such initiatives have the potential to significantly benefit communities in densely populated cities. To grasp the full potential of UA in buildings, policymakers and stakeholders need to collaborate closely in tackling the accompanying challenges.

Keywords: Building-integrated agriculture; food production; urban agriculture; nature-based solutions

Nature-Based Urban Planning: up-scaling NBS for sustainable urban transitions

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NBS is high on the policy agenda. Although the concept of NBS is relatively well-defined, there exists a policy gap in integrating it at the planning level beyond its association solely with green infrastructures and isolated space projects, which are sometimes regarded as mere "fixes" for poor urban planning. Furthermore, urban planning policies currently lack the capacity to mainstream NBS, necessitating a paradigm shift to effectively tackle the challenges of sustainability transition. Additionally, the practice of green infrastructure design, in general, has not sufficiently incorporated NBS. It is therefore understandable that the practice of urban planning has not yet fully embraced the idea of planning with and for nature in a systemic manner. To scale up NBS practices, we propose the concept of Nature-Based Urban Planning (NBUP), which provides a comprehensive framework for a more environmentally conscious urban vision and its accompanying policies. NBUP also aims to establish legal foundations for defining binding norms and metrics to guide local authorities, landowners, and developers in the urban development process. These norms must be applied in the development of territorial planning models, land use zoning, regulation, and monitoring processes, integrating green infrastructure in a connected, multifunctional, systemic, and inclusive manner, harmoniously aligned with grey infrastructure. There already exists a substantial body of knowledge on how natural processes, particularly biodiversity, provide ecosystem services. This knowledge serves as the basis for reshaping legal regimes and norms to mainstream biodiversity in urban planning, thereby enhancing control and mitigation of urban biodiversity loss, alongside facilitating participatory processes to ensure stakeholder adherence to policies. This paper aims to present insights from the BIOValue Project (https://biovalue-horizon.eu) and advocate for collaboration in the Plann@t project, which endeavours to further enhance science-policy communication toward Nature-Based Urban Planning.

Keywords: Planning system; Regulations; Metrics; Green/grey integration; Governance.

A wildlife refuge and educational field laboratory in the city: a case study of the Granja stream in Porto

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The Ribeira da Granja is a small watercourse that follows an entirely urban route until it flows into the Douro River. Much of its course has been culverted, but an 800-meter section was restored to an open-air condition in the 2010s. Still surrounded by vegetable gardens and uncultivated land, it has become a wildlife hub with diverse habitats. Its destiny is determined by municipal planning and urban licensing, and it will likely be confined in a near future to a narrow linear park along the watercourse.

Considering this space, which still retains a wild character, we aimed to explore its overall and educational significance. We intended to showcase the multiple forms of biodiversity found within the remaining area of the Granja stream and present to the public the fundamental aspects of its ecological importance. Additionally, we wanted to emphasize the educational value of this urban wild space.

A summary survey has been conducted to identify habitats and forms of biodiversity. Two outdoor posters were conceived and placed at the entry points drawing attention to biological points of interest along the route. The river stretch has been utilized for study visits, mainly through self-initiative of nearby schools and by the city council's environment division.

The stream and its surroundings function as a field laboratory where schools can observe ecosystems *in situ* and students may encounter small animals they would not typically encounter in their daily lives. A conventional park, featuring a row of trees along a watercourse, surrounded by lawns and wooden benches, might suffice for some visitors. However, it lacks educational appeal and fails to evoke the untamed essence of the natural environment. A new type of park that seamlessly integrates habitats and diverse species, serving as wild refuge, is needed.

Keywords: wildlife refuge; urban wild space.

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