

Nature based solution, green infrastructure and ecosystem services: a framework for understanding and creating resilient urban ecosystems

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Synoptic:

Climate-proof cities rely on Nature-based solutions, green infrastructures, ecosystem-based adaptation and ecosystem services to create resilient urban ecosystems. Nevertheless, the relation among these concepts is still not completely clear. This paper aims at providing a better understanding of these concepts and of their integration into urban planning, to support cities embedding those within their plans.

1. Introduction

‘Everything you can imagine, nature has already created’ (Einstein).

It is now widely recognized that human activities have reached a level that could result in abrupt and, in some cases, irreversible environmental changes detrimental to human development (Eggermont, H. et al., 2015). Societies face increasing challenges such as climate change, jeopardized food security and water resource provision, and enhanced climate related risks, such as floods, drought, cloudburst, heat waves, etc. In this regard urban areas, with around 60% of world population living in cities, will face even greater constraints due to overpopulation, social inequities, environmental challenges, and limited available resources. In this context, Nature Based Solutions (NBSs) can provide a valuable answer to environmental and societal challenges, and can contribute to increase urban resilience.

In the last years, NBSs have entered in the scientific and research vocabulary as an appealing term to define solutions that are inspired by nature and that are able to provide multiple benefit in a range of impact categories (water management, climate adaptation, food provision, urban regeneration, social inclusion, etc.). Although the concept of Nature Based Solutions strongly relies on green infrastructures, ecosystem-based solutions and ecosystem services, the relation among these notions is still under debate in current scientific literature. Moreover, the integration and implementation of those concepts within urban areas poses a great challenge to urban planning and policies, even if, at the same time, it provides decision and policy makers with a unique opportunity to shape future resilient urban ecosystems. The transition from traditional urban planning to an ecosystem approach planning process, sometimes called ecological planning, has been recognized in literature (Ygitcanlar, 2015 and Vasishth, 2008) but is still far from being systematically integrated into cities' plans and strategies. The shift from a mere preservation and conservation of urban ecosystems towards an integrated planning and management of nature based services and solutions is slow, but it will be crucial to develop liveable, health and resilient cities.

The aim of this paper is to present an overview of the different concepts (NBSs, green infrastructure and ecosystem services). First, starting from existing literature, the paper will provide a comparative analysis of the different definitions of the analysed concepts. Secondly, it will investigate an example of integration of such concepts within strategic planning (Greenspace quality, Scotland).

2. Definitions

The idea of finding solutions to the increasing societal challenges that are nature-based is gradually spreading into EU cities and regions. Nevertheless, different terminologies and concepts have been used in the last decades to define instruments, tools and solutions that refer to the use of ecosystems and nature to tackle a broad range of challenges and to improve humans' wellbeing and health. Within the scope of this paper, the focus will lie on the definition and integration of such solutions in urban and peri-urban areas.

2.1 Green Infrastructures (GIs)

Green and blue infrastructures have been identified in the last decades as one of the most interesting and promising strategy for achieving sustainability. One of the first definition of GI has been given by the Conservation Fund (2004) delineating them as 'the interconnected network of natural and semi-natural areas, features and green spaces that support native species, maintain natural ecological processes in rural and urban areas, and contribute to the health and quality of life for human beings' (The Conservation Fund, 2004).

The idea of planning those infrastructures in an integrated and interconnected way always support the concept of GI and the same conservation fund in 2006 renamed them as 'a strategically planned and managed network of natural lands, working landscapes, and other open spaces that conserve ecosystem values and functions and provides associated benefits to human populations, in order to link GI concept closely to its implementation'.

With the same vision and objectives in mind, the EU Commission proposes in 2013 the strategy on green infrastructure to enhance Europe natural capital. Within this strategy, GI are defined as 'a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services such as water purification, air quality, space for recreation and climate mitigation and adaptation. This network of green (land) and blue (water) spaces can improve environmental conditions and therefore citizens' health and quality of life. It also supports a green economy, creates job opportunities and enhances biodiversity. The Natura 2000 network constitutes the backbone of the EU green infrastructure'.

Compared with the previous ones, this definition strongly connects GI with the ecosystem services they can provide and it includes at the same level green and blue spaces; moreover, by mentioning Natura 2000 network as the main backbone of EU green infrastructure, the urban dimension of GI appears to be less evident than in the Conservation Fund definition, that was focusing on citizens' health and quality of life as the main impacts to be considered. Nevertheless, as also mentioned by Wang et Banzhaf (2018), the scale, the range, the extent and the implementation of such solutions can strongly vary from case to case as well as the benefits and the impacts they can produce on human wellbeing and health and on the environment. Thus, a strategic planning of such solutions is absolutely needed to maximize those benefits.

In the same line, the definition from the German Federal Agency for Nature Conservation in 2017 considers GI as a 'strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings'. In this case, the concept of green and blue infrastructures is highlighted and their integration into planning strategies is strongly supported.

GI concept are also often mentioned in Chinese (Wang et Banzhaf, 2018) and US (EPA, 2008, Fletcher et. Al, 2014, Coutts et Hahn, 2015) literature, being the concept operationalized at worldwide level.

2.2 Ecosystem services

The definition of ecosystem services (ES) and the huge work that has been done so far to evaluate and assess their values already give a clear idea of the power of this concept and definition. ES have reached a worldwide recognition and found their basis in 2005 with the Millennium Ecosystem Assessment (MEA), an impressive work that involved more than 1300 scientists worldwide. The definition that came out from that momentum summarizes the 'anthropocentric' conception of the term, stating that ES 'are the ecological characteristics, functions, or processes that directly or indirectly contribute to human wellbeing: that is, the benefits that people derive from functioning ecosystems (Costanza et al., 1997; Millennium Ecosystem Assessment (MEA), 2005).

ES have been categorized in 4 different types of services such as provisioning, regulating, cultural and supporting services, each of those providing a different kind of benefits to people. To support the relevance of this concept and reach decision and policy making, different approaches in the last decades have focused their attention mostly on the mapping, evaluation and economic assessment of such services. In particular, at EU level, the Biodiversity strategy requests Member States to map and assess the state of ecosystems and their services in their national territory with the assistance of the European Commission. They must also assess the economic value of such services, and promote the integration of these values into accounting and reporting systems at EU and national level by 2020 (Target 2, Action 5, Biodiversity Strategy). Although most of the attention is focused on evaluating and assessing ecosystem services, it is important to mention also the possible trade off generate by ecosystem to human being, called ecosystem disservices. Indeed allergenic pollen, spread of diseases, etc. should be considered whenever an ecosystem is evaluated.

2.3 Nature Based Solutions (NBS)

'Nature based solutions' is the youngest term introduced in this context and, most likely for this reason, currently the one on which there is less consensus. The first reference to the term nature-based solution can be found in the late 2000s in a report of the World Bank focusing on solutions to mitigate and adapt to climate change (MacKinnon et al. 2008). In this report, attention is mostly focus on nature, while biodiversity preservation and urban environment are hardly mentioned, and the proposed concept doesn't differentiate much from the previous definitions of GI.

In 2015, the EU Commission set up an expert group on Nature Based Solutions and re-naturing cities, which set the way towards a dedicated funding stream within the Horizon 2020 funding programme. In that context, NBSs have been analyzed with a strong focus on urban environment and have been defined as 'actions which are inspired by, supported by or copied from nature. Some involve using and enhancing existing natural solutions to challenges, while others are exploring more novel solutions, for example mimicking how non-human organisms and communities cope with environmental extremes. NBSs use the features and complex system processes of nature, such as its ability to store carbon and regulate water flow, in order to achieve desired outcomes, such as reduced disaster risk, improved human well-being and socially inclusive green growth. Maintaining and enhancing natural capital, therefore, is of crucial importance, as it forms the basis for implementing solutions. These nature-based solutions ideally are energy and resource-efficient, and resilient to change, but to be successful they must be adapted to local conditions'. Building on this report, the EU Commission in 2016 adopted the following definition: 'NBSs are solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions'. Within this definition, the role of NBSs as actual solutions to pre-identified societal challenges within cities assumes a strong relevance, while at the same time, the

focus on mimicking, which was clearly mentioned in the expert group report, appear to loose relevance.

The IUCN definition, 2016, built on the idea of nature-based solutions as one of the possible strategies to tackle societal challenges defining them as 'actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits'. Anyway, also in this case the focus looks broader than the urban scale stating that NBSs are applied at a landscape scale, thus not including punctual solutions implemented at a building level (i.e green roof), for instance. Again, this concept is quite similar to the GI definitions mentioned in the previous paragraph.

This EU Commission definition appears broader than the IUCN one, and could be further developed using a categorization made by DELTARES. In particular, they divided NBSs into two categories:

- The use of existing natural areas as NBS, where we can use one or more ecosystem services in addition to the conservation or promotion of biodiversity, mostly focusing on ecosystem preservation (i.e national and regional parks, earth biosphere, Natura 2000 sites)
- New NBS designed and installed to support one or more ecosystem services and to make a given contribution to biodiversity

The second category has been further subdivided into two groups. This differentiation assumes a great importance when referring to urban environments, since they requires different implementation strategies at the operational level:

- Hybrid NBS: combinations of hard infrastructure with soft or green elements, examples being green walls, green roofs, mobile plant containers, and so on. They often focus on one or two benefits in addition to the contribution they make to biodiversity. Effectively, they cannot exist without the hard structure. They are not connected to the subsurface and therefore not dependent on the nutrient fluxes or hydrological flows in the local system. As a result, their potential for replication is really high.
- Ecosystem-based NBS: re-installations of ecosystems or parts of ecosystems, examples being urban parks, natural embankments, urban wetlands, and so on. They are connected to the subsurface and are therefore highly dependent on local hydrological flows and nutrient fluxes. This consideration, and the fact that we expect them to deliver numerous ecosystem services, thus creating multiple impacts, makes the implementation of these solutions complex.

For the first time, in these definitions it is possible to find the reference to small scale projects, i.e green roofs, vertical walls, etc., which are increasingly spreading around cities. Those solutions provide ecosystem services and can be considered as a component of a broader green infrastructure vision, but that are not included, as such, in none of the other definitions.

3. Relation among the different concepts

Although the definitions of the three considered concepts in some cases appear to overlap and to be separated by vague borders, there is a need for a clearer differentiation.

Assuming that NBS are predominately an EU-based terms, not really spread in extra EU literature and practices, here below some relations among them are delineated.

3.1 Nature based solutions and Green Infrastructures

NBS and GI both represent solutions based on natural (green and blue) features and processes used to tackle clearly identified societal challenges. Both need to be carefully planned and strategically integrated with reference to urban, peri-urban and rural areas, being GI in EU mostly mentioned with reference to peri-urban and rural areas and NBSs for predominantly urban areas. Nevertheless, the main difference between the two, according to the authors' view, stands in the scale and the range of the project themselves. Indeed hybrid NBSs can be implemented in single, punctual and small scale projects (i.e green roofs and walls developed by private households), while ecosystem-based NBSs (i.e urban parks, lakes, floodplain) need much stronger financial, planning and administrative support and should be embedded in a broader vision of green infrastructures connection and network. Moreover, since ecosystem based NBSs are predominately embedded within urban projects and solutions, the social impacts they can create assume, sometimes, stronger relevance in comparison with other generated impacts.

3.2 Nature based solutions, Green Infrastructures and Ecosystem Services

ESs have sometimes been considered as a concept comparable to NBS and GI (Demuzere et. al, 2014, Maes and Jacob, 2015, Eggermont et. al. 2015), not clearly defining the different application of those concepts. In accordance with Pauleit et al, 2017, while NBSs and GI can be considered as more practical and solution oriented approaches, the concept of ESs is more abstract with a very strong focus on evaluation and assessment. Indeed ESs can be used in the evaluation of implemented NBS and GI infrastructure projects, providing decision makers with useful evidences regarding the environmental, social and economic benefit of such solutions. This approach could push forward the implementation and the integration of NBSs and GI within spatial and urban planning, assuming that those kinds of solutions create multiple impacts that traditional grey solutions don't.

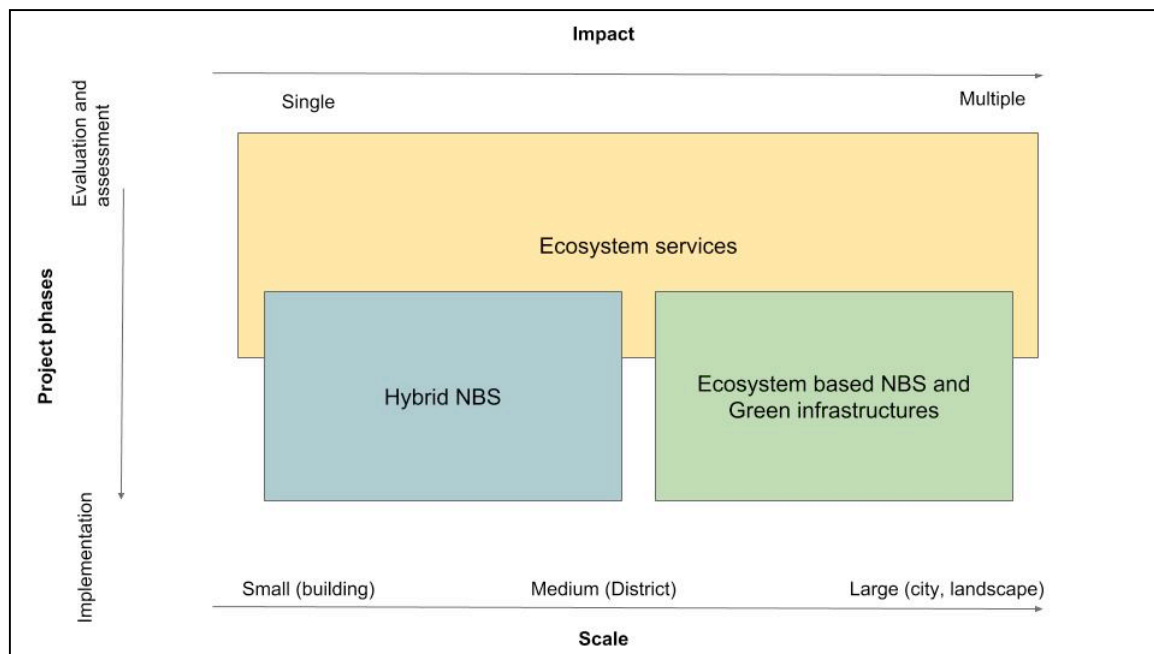


Figure 1 Relation among NBS, GI and ESs (Authors' elaboration)

Building on the conclusion of Pauleit et. al., 2017, Fig.1 summarizes the relations among the three described concepts. ESs can be considered as an assessment methodology while NBSs and GIs works at the implementation level. Hybrid NBS (i.e. green roof, vertical walls) are implemented at a smaller scale (building) and usually produce smaller impacts, if not

integrated in a wider plan. On the other side ecosystem-based NBS and GI are implemented at wider scale (district, urban, regional) and produce a wider categories of benefits and impacts.

4. From theoretical definition to practice: challenges and good practices

As illustrated in the previous section, the concept of green infrastructures and NBSs has emerged as a way to secure the provisioning of ecosystem services in human-dominated landscape (Ahern, et al. 2014).

Beside the fact that ecosystems provide benefits to people also very far from the ecosystems themselves (i.e food provision, drinking water), a wide range of benefits (i.e. air quality, climate regulation services, soil permeability, recreation and cultural services) directly affect people living within or very close to a particular ecosystem. By 2050, the world's urban population is expected to nearly double, making urbanization one of the twenty-first century's most transformative trends (UN, 2017); for this reason, urban ecosystems, already established or newly created through NBSs, assume a crucial and fundamental role in improving people health and quality of life. In this sense, the interest of including NBS and GIs into strategic urban planning and ecosystem services as an assessment methodology of urban plans and projects is rapidly growing. Although the definition and the understanding of these concepts and their evaluation in terms of effectiveness and impact assessment is constantly growing in research and practices, their integration into 'business as usual' urban planning process still has to come. This issue is also at the centre of the Urban Agenda for the EU debate, as it is one of the issues tackled by the Sustainable Land Use and NBS partnership. The scope of this paper will be limited to present a good practice implemented in Scotland for the integration of functional and qualitative approach into planning strategies and assessment, even though a wider and deeper discussion on the opportunities and challenges presented by the topic is needed.

4.1 Greenspace quality guide: the case of Scotland

In 2008, Greenspace Scotland published a report "Greenspace quality- a guide to assessment, planning and strategic development", that detailed the steps to be followed to deliver a comprehensive greenspace strategy. In this context, greenspaces correspond to the above-mentioned ecosystem-based NBS and GIs referring mostly to urban parks, green corridors and urban farming.

The key measures of such spaces have been defined through the analysis of 3 different values:

- *Quantity*: "quantity in terms of the overall quantity of greenspace, its distribution spatially and in terms of differing types of greenspace (parks, green corridor, etc.)". The quantity criteria is currently the most used in urban planning standards and minimum requirements, probably due to its easy applicability and monitoring.
- *Accessibility*: "accessibility in terms of how well connected, accessible and inclusive greenspace is to the communities". Accessibility, as well a quantity, is a common indicator used in urban planning and it is easy to monitor and evaluate.
- *Quality*: "quality in terms of how well a greenspace or a wider network of greenspace assets addresses the varied functions need and aspirations of its users and other stakeholders".

This definition of quality recalled the idea of functions and services that a particular ecosystem – greenspace in this report- can provide to the community. The core role of the community in the greenspace planning appears even more relevant in the quality definition; indeed "quality of greenspace is a relative term and is best understood in terms of fitness to purpose". The idea of fitness to purpose implicitly includes the identification of targets to be reached and/ or final consumers to satisfy. The process of quality definition suggested in this

guide is indeed built on the customers/users' and the stakeholders/local authorities quality definition. Even though the responsible local authorities should delineate the general plan towards the final targets and requirements, also in line with regional, and national objectives to be reached, quality needs also to be discussed and agreed by local actors. Indeed quality parameters and perceptions are embedded in and dependent on the local and climatic conditions and circumstances, different cultural background and local needs.

5. Conclusion

Social inequalities are likely to increase in our cities in the following years, due to overpopulation, migrations and increasing disparities. At the same time climate change effects will make our settlements more and more prone to extreme events such as drought, floods, fire, etc. Re-naturing cities is one of the most promising solutions to tackle social and environmental challenges and to make urban ecosystem more livable and resilient.

NBSs and Green Infrastructures, through the ecosystem services they provide, will strongly support the creation of climate proof cities, improving, at the same time, wellbeing and quality of life of citizens. In this context, this paper reviewed 3 concepts -Nature Based Solutions, Green Infrastructures and Ecosystems Services - to compare and relate those with current planning approaches. In this sense, ESs can be considered an assessment methodology while NBSs and GIs are operational solutions at strategic and implementation level. A further differentiation of NBS has been discussed: hybrid NBS (i.e. green roof, vertical walls) as solutions implemented at small scale (building) provide narrow impacts, if not integrated in a wider plan. On the other side ecosystem-based NBS and GI are implemented at wider scale (district, urban, regional) and can generate a wider categories of benefits and impacts. In both cases, that to be as effective as possible both NBSs and GI should be carefully and strategically integrated into urban regional and national plans and strategies.

To generate multiple impacts and benefits NBSs and GI have to be carefully planned and designed. Indeed the services that a particular solution can provide strongly depend on how this solution has been planned and designed (i.e type of vegetation used, interconnection with other NBSs, etc.), and are not directly related with the extension of the implemented solution. In this sense the quality of those solutions assume a great value, criteria which is not included in minimum planning requirement so far.

This concept of quality and performance indicators can push forward the integration of NBS and GI into urban environment. In this sense this paper mentioned an interesting case in Scotland where a shift towards a more qualitative approach in planning is being performed. Through this case the authors wanted to focus the attention of one of the possible approaches to relate NBSs and ESs with urban strategic planning, but further research on the topic is needed.

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