Nature based solutions (NBS) as a new smart way to manage urbanism and civil engineering

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Nature based solutions is a real concept that should be part of smart cities. There are many examples around the world, working well. The new cities and towns have to be designed / developed according to these new concepts if we want to enjoy healthier places, with a less expensive maintenance and with a great landscape.

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Index

1. Introduction

Climate change presents one of the greatest challenges to society today. Effects on nature and people are first experienced in cities with extreme temperature gradients, and by now, about half of the human population globally lives in urban areas.

Climate change has significant impact on ecosystem functioning and well-being of people. Climatic stress leads to a decrease in the distribution of typical native species and influences society through health-related effects and socio-economic impacts by increased numbers of heat waves, droughts and flooding events. In addition to climate change, urbanization and the accompanying increases in the number and size of cities are impacting ecosystems with a number of interlinked pressures. These pressures include loss and degradation of natural areas, soil sealing, pollutants diffusion and the densification of built-up areas, which pose additional significant challenges to ecosystem functionality, the provision of ecosystem services and human well-being in cities around the world.

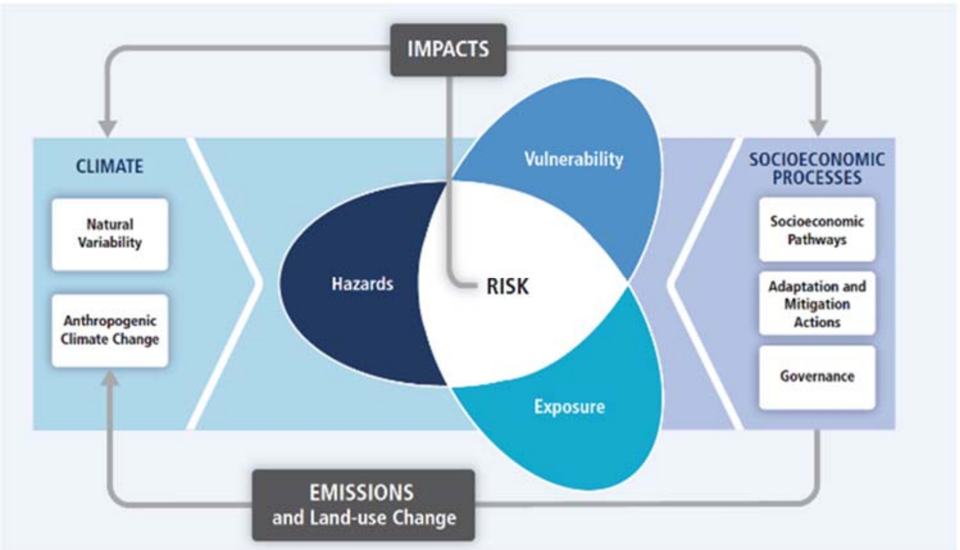

Fig 1: Illustration of the risk concept. Source: IPCC AR5 WGII (2014)

However, nature-based solutions have the potential to foster and simplify implementation actions by taking into account the services provided by nature. In many cases, they present more efficient and cost-effective solutions than more traditional technical approaches.

Nevertheless, we are just at the beginning of systematically analyzing their (long-term) effects, effectiveness for climate change adaptation and mitigation and provision of co-benefits.

To date, an increasing number of NBS projects have been implemented, but still knowledge is needed on measuring effectiveness and how the available evidence can be translated into management strategies and policy instruments.

2. Integrating the grey, green and blue in cities: Nature-based solutions for climate Change adaptation and risk

2.1 Grey infrastructures

Response to exposure of communities to natural hazards has traditionally relied on **Grey infrastructures**. These ones are built up, engineered and physical structure, often made of concrete or other long-lasting materials that mediate between the human built up system and the variability of the meteorological and climatic system.

These include dikes, floodgates, levees, embankments, sea walls and breakwaters for riverine and coastal flood protection, drainage systems for storm water management such as storm sewers, pipes, detention basins, and air conditioning or cooling centers to cope with extreme heat. Engineering approaches largely ignore or supplant the functions of biophysical systems.

Grey infrastructures provide an important means of adapting to biophysical challenges including hazards and climate driven extreme events, but are often costly to install and maintain. They have no long-term effects on ecosystems, tend to have low flexibility, and when they fail, can generate catastrophic impacts on social and ecological domains.

Grey infrastructures can fail, especially when confronted with climate driven extreme events and provide a wide array of drawbacks under most factors but are, on the other hand, easily adaptable to the urban context.

Fig 2: Examples of grey infrastructures (wastewater treatment plant and canals). Source: Recovered from http://www.butec.com.lb/activities/tripoli-wastewater-treatment-plant/ and http://www.watersafe.org/canals

2.2 Green and blue infrastructures

Green infrastructures are principally constituted by well-functioning biophysical systems to which some management and restoration may apply. They are represented, by healthy oyster reefs, coastal salt marshes, mangroves, coral reefs, sea grasses, sand beaches and dunes in the coast environment and mainly by wildlife native plants gardens, forests, parks, street trees, and grasslands inland.

They are flexible, no-regret measures and provide a wide range of benefits and co-benefits, which go beyond the mere protective or buffering functions.

Blue infrastructures include all bodies of waters, including ponds, wetlands, rivers, lakes and streams, as well as estuaries, seas and oceans. Since water and land come together in multiple ways, including riparian areas, beaches, wetlands, and more, combining green and blue infrastructure is gaining attention in both research and practice for CCA (Clima Change Adaptation) and DRR (Disaster Reduction Risk).

Green and blue infrastructures, rely primarily on healthy, functioning ecosystems and allow for little or no technological/infrastructure intervention.

Initial research and practice has shown that well managed ecosystems and their regulating services can contribute to the reduction of risk and are very often cost-effective, multifunctional and win-win solutions.

Fig 3: Examples of green and blue infrastructures (Wetland restoration and Riparian buffers) Source: Old gravel mine was restored to marsh, pond and willow habitat at John D. Rockefeller, Jr. Memorial Parkway, Wyoming (2012) and recovered photo from https://landstudies.com/help-fund-riparian-buffer-project/

Currently, there is a lot of research done on the role of ecosystems in mitigating hazards. The results are accurate enough to demonstrate the benefits of NbS implementation. In Montornès del Vallès, there is an open air laboratory which works in that line, URL (Urban River Lab) where we are working to know better the ecosystem services related to improve the quality of the water.

These infrastructures can be used in cities or in natural areas as independent infrastructures or as we can see below, mixing approaches that make use of engineering and ecosystem functions together.

3. Types of Nature-based solutions (NBS)

Nature-based solutions are a form of 'eco-innovations' that specifically 'promote nature as a means for providing solutions to climate change (mitigation and adaptation) diffuse pollutants, bad air quality, loss of biodiversity, etc.

NBS can provide several types of ecosystem services. The first is provisioning services, such as food, raw materials (i.e. tree biomass), fresh water and medicinal resources. Second, NBS can provide regulating services such as local climate regulation (i.e. combating heat island effect), air quality regulation, coastal protection, noise reduction, carbon storage, flood regulation, water purification and pollination. Third, NBS provide habitat for species, thus supporting biodiversity. Finally, cultural services are provided through recreation space, support of mental and physical health, tourism, aesthetic appreciation and inspiration for arts, culture and design.

The different NBS to mitigate and reduce the hydro-meteorological hazards can be classified in:

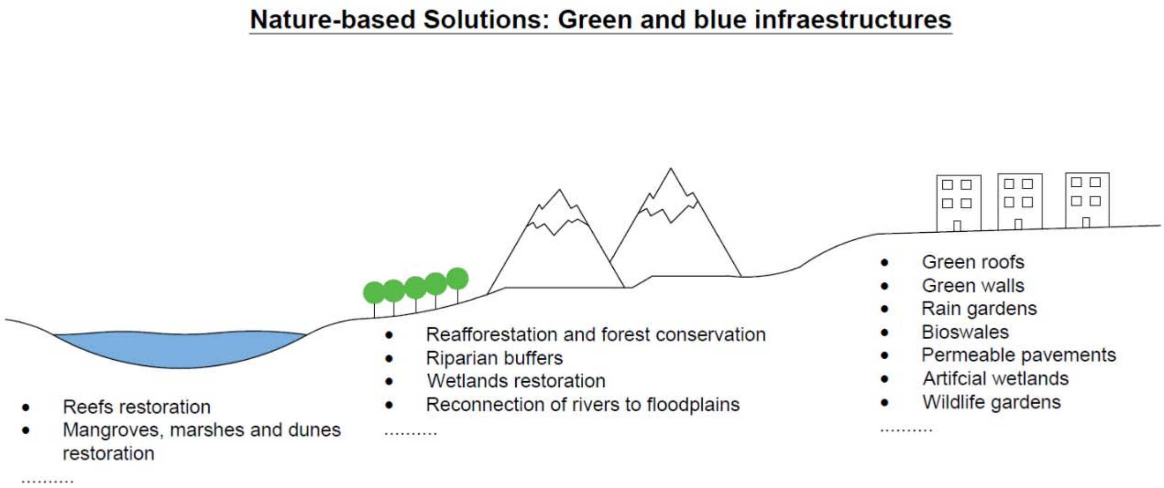

Fig 4: Scheme of different NBS to mitigate the disaster risks. Source: Own source

3.1 Reafforestation, afforestation and forest conservation.

Reafforestation and afforestation refer to activities where trees are established on lands with no forest cover. The concept of reafforestation is usually used in reference to areas where there was recent forest cover. For areas without an historical record of forest cover, the planting of trees is referred to afforestation. The activities could also include making a conscious decision to maintain forests on lands that would otherwise be handed over for other types of land development, as part of targeted water management interventions.

Fig 5: Example of a reafforestation activity Source: Recovered from http://www.mitsubishielevator.co.th/2018/en/news/155/CSR--Reafforestation-activity

3.2 Riparian buffers

Riparian buffers are vegetated, often forested, areas adjacent to streams, rivers, lakes and other waterways protecting aquatic environments from the impacts of surrounding land use. Use of riparian buffers to maintain water quality in streams and rivers is considered to be one of the best forest and conservation management practice in many countries and is mandatory in some areas.

Fig 6: Example of a riparian buffer executed Source: Naturalea

3.3 Restoration wetlands

Wetlands restoration is the renewal of wetlands that have been drained or lost as a result of human activities. Wetlands that have been drained and converted to other uses often retain the characteristics of soil and hydraulics and therefore can be restored. In general, the best way to prevent further loss of ecological and economic value due to degradation of wetlands is by eliminating the pressures driving the loss and degradation of wetlands.

Fig 7: Example of a restored wetland Source: Recovered from http://www.apacheco.com/wetlands.html

3.4 Reconnecting rivers to floodplains

Along many major rivers, levees have been constructed close to the edge of the river channel, which maximizes the amount of land protected by a levee. By placing levees close to the channel, rivers become more effective conduits for drainage. It can also maximize the use of surrounding lands, even in times of high water levels. However, levees close to the channel can create a set of problems and challenges. Because they greatly narrow the area available to transport floods, they do work to rapidly flush floodwaters and sediments through the system, but this means that the levees are exposed to high-velocity water along their “wet” side. This can result in erosion and high maintenance costs.

Because of the vulnerability to erosion, these levees often require armouring to prevent erosion and meandering, further diminishing the natural habitat values of the river’s edge, which is generally the most biologically valuable habitat. Also, while levees may prevent flooding at one location, they may increase the risk of flooding upstream and/or downstream of the levees. Moving levees back away from the channel, often called “setback levees”, can alleviate these problems.

Fig 8: River restoration in Sant Hilari Sacalm Source: Naturalea

3.5 Protecting/restoring reefs (coral/oyster).

Coral and oyster reefs are considered to be types of coastal wetlands. Coral reefs are shallow-water marine ecosystems characterized by massive calcium carbonate formations secreted by colonies of coral polyps and algae living in their tissues. Reefs build up as each coral species secretes uniquely shaped carbonate skeletons over older skeletal remains. Coral reefs are home to high fish and invertebrate biodiversity, all uniquely adapted to reef life, yet fundamentally dependent on coral survival

For a long time, grey solutions have been dominant in coping with coastal hazards. Approaches include artificially hardening the shoreline or creating artificial barriers by dumping gabions made of cement and rock into the water. This is not only damaging to marine ecosystems, but can also shift the impacts of storms to communities down shore, increasing the need for additional defense structures.

Coral reefs provide natural breakwaters that can mitigate flooding and the erosive effects of storms along low-lying shores, by forming a natural barrier. The reefs are the first line of coastal defense from the damaging impacts of waves, erosion and flooding.

Fig 9: Example of an oyster reef Source: Recovered from http://www.reefball.org/

3.6 Protecting/restoring mangroves, marshes and dunes

Coastal wetlands such as marshes, dunes and mangroves are instrumental in reducing vulnerability to hazards of often densely populated coastal areas and are also source of income and support to livelihoods of millions of people.

Coastal sand dunes are naturally occurring wind formed sand deposits representing a store of sediment in the zone just landward of normal high tides, functioning as a natural defense barrier between the sea and the land.

Planting nurse species, such as native cord grasses, for example, may be an effective way to help stabilize bare sediment and mitigate erosion in preparation for either natural or planted colonization by mangroves. Mangrove colonization success and survival are sensitive to tidal flooding depth, frequency and duration (Lewis 2005), which need to be restored to conditions meeting species requirements for successful recovery and survival of mangrove communities. Restored sites can then be planted with native species where no natural seed source exists and no other impediments stand in the way of success.

3.7 Green Roofs

A green roof is a roof of a building that is partially or fully covered with a layered vegetation system comprising of plants, growing medium, waterproof membrane, additional layers such as root barriers, and drainage and irrigation systems (where the climate necessitates). Green roofs serve several purposes for a building, such as absorbing rainwater, providing insulation, creating a habitat for wildlife and helping to lower urban air temperatures and mitigate the heat island effect.

Fig 10: Examples of green roofs in cities. Source: Recovered from https://zincogreenroof.com/systems/irrigated-extensive-green-roof

3.8 Green façades and green vertical walls

Green walls can be divided into three main types: traditional green façade, where climber plants use the façade material as a support; double-skin green façade or a green curtain, with the aim of creating a double-skin or green curtain separated from the wall; and perimeter flowerpots, where, as a part of the composition of the façade, hanging pots or shrubs are planted around the building to create a green curtain. Green walls can also be used for low level landscaping of car parks, services and for providing shade.

Fig 10: Green wall in Paseo del Prado (Madrid) Source: Recovered from https://www.miradormadrid.com/paseo-del-prado/paseo-del-prado-24/

3.9 Rain gardens and bioswales

Rain gardens have a slight depression to help collect water and are vegetated with plants that can withstand moisture regimes ranging from flooded to dry. The existing soil is often used in rain gardens if it provides adequate water infiltration rates, although native soils can also be amended with some sand or compost if needed. They are designed specifically to withstand high amounts of rainfall, stormwater runoff, as well as high concentrations of nutrients typically found in stormwater runoff – particularly nitrogen and phosphorus, minimizing the amount of rainwater that enters storm drains

Bioswales achieve the same goals as rain gardens by slowing and filtering storm water, but are designed to manage a specified amount of runoff from a large impervious area, such as a parking lot or roadway. Because they need to accommodate greater quantities of storm water, they often require use of engineered soils and are deeper than rain gardens. They are also linear systems that are greater in length than width. Like rain gardens, they are vegetated with plants that can withstand both heavy watering and drought.

Fig 12: Scheme and example of a Rain Garden Source: Recovered from https://vaswcd.org/rain-garden

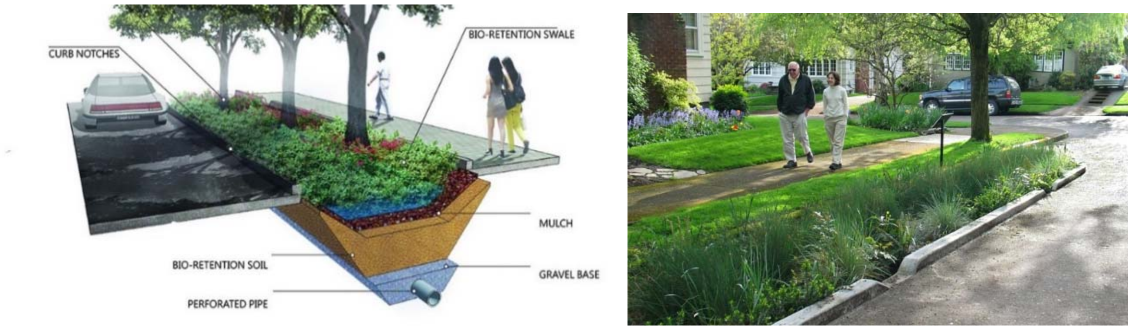

Fig 13: Scheme and example of a bioswales Source: 2007 Professional Residential Design Honor Award. NE Siskiyou Green Street, Portland, Oregon / Kevin Robert Perry, ASLA

3.10 Wildlife native plants gardens

The urban vegetated zones can be with natural species with minimal or no maintenance, always without cleanings, and with structures simulating mature ecosystems; It is what is called Wildlife Gardens. These areas, once consolidated, have no maintenance cost for the city, allow the natural breeding of many useful species for the regulation of urban ecosystems. It is in the line of permeaculture. Residential landscapes can be home to humans and wildlife. We can share our landscapes with the plants and animals with which we have evolved. The first step when landscaped for wildlife is to determine the priority species. Next, identify the food, water, shelter and other resources that each animal needs. The following are the essential elements:

Provide food / Provide water / Create spaces to hide, rest and nest

Fig 14: A native bunchgrass meadow in the Berkeley hills, with California poppy *(Eschscholzia californica),* Chinese houses *(Collinsia heterophylla),* and buttercups *(Ranunculus californicus).* Photo by Saxon Holt.

3.11 Permeable pavements

Conventional pavement alternatives such as asphalt and concrete are impervious surfaces, preventing any runoff infiltration. Permeable pavement is made of materials that allow for the water to infiltrate, be filtered and recharge groundwater.

Permeable pavements usually have two underlying layers: one of finer sediment that work as a filter, and one of gravel that conveys and stores water and gives structural support. They are usually advised for areas with low traffic volumes and low exposure to potential contaminants, such as residential roads, parking lots, walkways, driveways, court yard, etc.

Fig 14: Permeable pavements Source: Recovered from https://texashomeandgarden.com/idea-center/landscaping/permeable-paving/attachment/grass-growing-thru-pavers/

3.12 Artificial wetlands

Artificial wetlands are a system of natural purification based on the creation of optimal conditions for bacteria associated with the transformation of organic matter or the metabolism of nutrients. Actually, it is the imitation of the processes that take place in humid zones where the plants have a fundamental role as a physical and biogeochemical support of the biofilm, which allows it to be a very resilient ecosystem.

There are different typologies of artificial wetlands, but all try to reduce contaminating parameters by recreating humid habitats through the construction of lagoons and bed of gravel with vegetation. The plants used are from riparian vegetation, in particular helophytes.

In this way the best possible conditions are created for the bacteria responsible for the decomposition of the organic matter used in the biological systems of traditional purification, associated with the humid natural ecosystems.

If an adequate sizing of these systems has been carried out, the water leaving the process can be poured into the river or reused as water for irrigation or cleaning.

Fig 15: Artificial wetland Source: Naturalea

4. Soil & Water Bioengineering, a key tool for the application of NBS

The soil and water bioengineering is a set of techniques that facilitate the consolidation of a set of autochthonous plants that at the same time, have structural, biochemical properties ... that provide solutions to the problems associated with urban systems. Over time, the structure of the technique disappears, and a natural landscape is created with ecosystemic and structural service with the use of native plants. Other techniques aim to make it possible for nature to enter difficult spaces to reconnect with the landscape.

The soil and water bioengineering is based on the selection of native species with properties of interest and with the establishment of an introduction system over the ordinary and extraordinary impacts to ensure the success of the implantation. These systems of implantation work especially with nearby materials, wood, stone, remnants of pruning...

So when planting or sowing are also done for a functional purpose (stabilize a slope, improve a soil ...) is considered a bioengineering technique. These techniques become more complex as the starting challenges that must be faced are more difficult. From the plantation of a simple stake, we can move to a reinforced structure of trunks simulating an armed soil wall where the stakes themselves will have the stability conditions they need to grow. They will guarantee regrowth or development independently of droughts or floods.

5. Discussion and Conclusions

Nature-based solutions are a real alternative to mitigate the hydro-meteorological hazards in front of the classical grey solutions. Due to the loss and limited availability of green spaces in metropolitan areas, because of the rapid urbanization over recent decades, there is a necessity to promote sustainability cities for the future.

However, nature-based solutions are often overlooked in building design and planning due to the complexity in their design and evaluation and because there is a lack of research in identifying pathways to put into place the green actions for the necessary building planning and design.

Each of the systems described have a specific function in the urban and natural area and their implementation will improve the well-being and the ecosystem services.

The Nature Based Solutions are something real that should be part of the concept of smart cities. There are plenty of samples around the world, working well. The new cities and towns should be design/urbanize according these new concepts if we want to leave in a most healthy places, less costly maintenance and with great landscape.

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KEY CONCEPTS: NBS, DRR, CCA, Hydro-meteorological hazards.