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EU Research and Innovation policy agenda for

# Nature-Based Solutions & Re-Naturing Cities

*Final Report of the Horizon 2020 Expert Group on 'Nature-Based Solutions and Re-Naturing Cities'*

**EUROPEAN COMMISSION**

Directorate-General for Research and Innovation
Directorate I — Climate Action and Resource Efficiency
Unit I.3 — Sustainable Management of Natural Resources

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Directorate-General for Research and Innovation
2015 Climate Action, Environment, Resource Efficiency and Raw Materials EN

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## Contents

# EXECUTIVE SUMMARY

1. Nature-based solutions harness the power and sophistication of nature to turn environmental, social and economic challenges into innovation opportunities. They can address a variety of societal challenges in sustainable ways, with the potential to contribute to green growth, 'future-proofing' society, fostering citizen well-being, providing business opportunities and positioning Europe as a leader in world markets.
2. Nature-based solutions are actions which are inspired by, supported by or copied from nature. They have tremendous potential to be energy and resource-efficient and resilient to change, but to be successful they must be adapted to local conditions.
3. Many nature-based solutions result in multiple co-benefits for health, the economy, society and the environment, and thus they can represent more efficient and cost-effective solutions than more traditional approaches.
4. An EU Research & Innovation (R&I) agenda on nature-based solutions will enable Europe to become a world leader both in R&I and in the growing market for nature-based solutions. For this, the evidence base for the effectiveness of nature-based solutions needs to be developed and then used to implement solutions. Both need to be done in conjunction with stakeholders. The potential for transferability and upscaling of solutions also requires further investigation. There is also a need to develop a systemic approach that combines technical, business, finance, governance, regulatory and social innovation.
5. Four principal goals have been identified that can be addressed by nature-based solutions:
   - **Enhancing sustainable urbanisation** through nature-based solutions can stimulate economic growth as well as improving the environment, making cities more attractive, and enhancing human well-being.
   - **Restoring degraded ecosystems** using nature-based solutions can improve the resilience of ecosystems, enabling them to deliver vital ecosystem services and also to meet other societal challenges.
   - **Developing climate change adaptation and mitigation** using nature-based solutions can provide more resilient responses and enhance the storage of carbon.
   - **Improving risk management and resilience** using nature-based solutions can lead to greater benefits than conventional methods and offer synergies in reducing multiple risks.
6. Based on the four goals, seven nature-based solutions for R&I actions are recommended to be taken forward by the European Commission and Member States:
   - Urban regeneration through nature-based solutions
   - Nature-based solutions for improving well-being in urban areas
   - Establishing nature-based solutions for coastal resilience
   - Multi-functional nature-based watershed management and ecosystem restoration
   - Nature-based solutions for increasing the sustainability of the use of matter and energy
   - Nature-based solutions for enhancing the insurance value of ecosystems
   - Increasing carbon sequestration through nature-based solutions

This report was produced by the Horizon 2020 Expert Group on 'Nature-Based Solutions and Re-Naturing Cities', informed by the findings of an e-consultation and a stakeholder workshop.

# INTRODUCTION

An EU R&I agenda on nature-based solutions is an essential component to greening the economy and achieving sustainable development. To contribute to the development of this R&I agenda, the Expert Group on 'Nature-Based Solutions and Re-Naturing Cities' was commissioned. Since the nature-based solutions concept is relatively new, the Expert Group developed an appropriate definition, before considering the opportunities for nature-based solutions.

## Nature-based solutions – what are they?[1]

Nature-based solutions aim to help societies address a variety of environmental, social and economic challenges in sustainable ways. They are 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. Nature-based solutions 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.

## Nature-based solutions – why now?

**Seizing the momentum for change**: We are living in a time of great opportunities for addressing societal challenges, such as increased urbanisation, economic inequalities and climate change, and for ensuring our society is protected from foreseeable future changes. After much investment in studies of how nature works and how it benefits all people, we can now use this knowledge to turn these challenges into actions for sustainable and green growth. Nature-based solutions involve innovative governance, institutional, business, and finance models and frameworks, leveraging both public and private funding. They also involve working beyond 'silos' and engaging with others across disciplines and sectors, as well as systemically involving all stakeholders, including citizens. All of these ideas are largely becoming recognised.

**A growing awareness of the value of nature:** There is a growing interest and awareness within the business community[2] of the value of managing and maintaining biodiversity and ecosystem services, as a business opportunity and as an essential means to reduce economic risks by ensuring the continued supply of vital resources. The burgeoning number of international[3], national[4], regional and local[5] policy initiatives for the conservation and sustainable use of the natural environment are evidence of the realisation by policy makers of the importance of nature to society. Civil society also is increasingly recognising the benefits derived from nature for enhancing well-being, as seen in the numerous bottom-up initiatives, particularly in community efforts to bring nature back into urban areas. Finally, the science and research community is currently focusing on 'people and nature', generating knowledge for resilient and adaptable socio-ecological systems.

**Business has an opportunity:** Infrastructure spending amounts to about 3.8% of global GDP, equivalent to US$2.6 trillion in 2013, and could grow to US$3.4 trillion per year through 2030[6]. In a time of fiscal austerity, cost-effectiveness has become critical. As a result governments are interested in identifying cost-effective alternatives to grey or technology-based infrastructure to tackle challenges arising from biodiversity loss, climate change, more frequent natural disasters and rapid urbanisation. Nature-based solutions have demonstrated financial advantages due to a

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1 See Annex 1 for a more elaborated definition
2 e.g. World Business Council for Sustainable Development, The Natural Capital Coalition
3 e.g. Sustainable Development Goals, United Nations Office for Disaster Risk Reduction
4 e.g. UK Natural Environment White Paper (2010) Government's aim to be the "first generation to leave the natural environment in a better state than it inherited"
5 e.g. Freiburg Green City
6 WBCSD (2015) http://action2020.org/business-solutions/investing-in-natural-infrastructure

reduction in initial capital expenses and on-going operational expenses and they have been used strategically to recapitalise ageing resources. For example, the City of Philadelphia found that the net present value of green infrastructure for storm-water control ranged from $1.94 to $4.45 billion, while grey infrastructure benefits ranged from only $0.06 to $0.14 billion over a 40-year period[7]. Nature-based solutions also offer more opportunities than 'grey' infrastructure, as they not only increase the resilience of society to external economic and environmental stresses, but contribute positively to human health and well-being. These components are essential for sustainable competitiveness.

**Europe as an inspiration and world leader in markets:** Although significant questions and knowledge gaps remain, Europe has extensive pools of knowledge, scientific expertise, skills and technological capability relevant to nature-based solutions. Local examples abound. What is needed is to enhance the evidence-base and rationale and to implement nature-based solutions at a greater speed and a wider scale. The aim of the EU R&I policy on nature-based solutions is to position Europe as the world leader, both in R&I on nature-based solutions and in the global market for nature-based solutions. This will be done by developing, demonstrating and replicating innovative nature-based solutions and establishing a European evidence base (see Annex 3 in the full report available online) to support their market deployment, as well as exploring new governance, institutional, business and finance models which leverage both public and private funding. It also seeks to set the scene for their application in other EU policy areas, but also by Member States, business and civil society.

The EU R&I agenda on “Nature-Based Solutions and Re-Naturing Cities” is focused on new and innovative nature-based solutions to societal challenges, but also builds on and supports other closely related concepts and policies, such as the ecosystem approach, ecosystem services, ecosystem-based adaptation and mitigation, and natural, green and blue infrastructure.

[7] Stratus Consulting (2009) A Triple Bottom Line Assessment of Traditional and Green Infrastructure Options for Controlling CSO Events in Philadelphia’s Watersheds (Stratus Consulting, Boulder).

# Research & Innovation Agenda on Nature-Based Solutions and Re-Naturing Cities

| Goals | Research & Innovation Actions | |
|---|---|---|
| Enhancing sustainable urbanisation |  | Urban regeneration through nature-based solutions |
| |  | Nature-based solutions for improving well-being in urban areas |
| Restoring degraded ecosystems |  | Establishing nature-based solutions for coastal resilience |
| |  | Multi-functional nature-based watershed management and ecosystem restoration |
| Developing climate change adaptation and mitigation |  | Nature-based solutions for increasing the sustainable use of matter and energy |
| |  | Nature-based solutions for enhancing the insurance value of ecosystems |
| Improving risk management and resilience |  | Increasing carbon sequestration through nature-based solutions |

# KEY OPPORTUNITY AREAS FOR RESEARCH AND INNOVATION POLICY ON NATURE-BASED SOLUTIONS

The expert group identified four goals that offer exciting opportunities for promoting systemic and sustainable nature-based solutions, which will help Europe to achieve its aim of being a world leader in responsible innovation, while meeting the needs of society. The four goals are: enhancing sustainable urbanisation, restoring degraded ecosystems, developing climate change adaptation and mitigation and improving risk management and resilience[8]. The recommendations are not just for the EU, but also for application at the national and sub-national levels.

## Goal 1: Enhancing Sustainable Urbanisation (Annex 2a)

Currently, 73% of Europe's population live in cities and this is projected to increase to 82% by 2050, resulting in over 36 million new urban citizens[9]. This will pose a range of challenges for cities, including resource availability and equitable economic growth. The quality of urban environments is also at risk, necessitating their sustainable development and regeneration in order to provide citizens with healthy and liveable conditions. This also represents a business opportunity, for all actors that will need to be engaged with, in meeting the extensive demands for new construction and renovation of housing, infrastructure, and other facilities.

Nature-based solutions for sustainable urbanisation rely in large part on natural areas and features in and around cities to perform essential ecosystem services. They provide multiple strategic opportunity areas, which can be categorised under three main interconnected challenges and trends. Firstly, nature-based solutions support economic development in urban areas, which is highly dependent on the amount and quality of natural resources available, such as water for sanitation, drinking and manufacturing. The sustainability concerns in cities could drive the emergence of new business models, which decouple economic growth from resource depletion and the uneven distribution of resources. This would build on the circular economy and increased reliance on local resources, leading to greater efficiency in the use of energy and materials. In addition, the regeneration of neglected urban spaces can improve business and residential areas, as multifunctional design with nature can create new dynamic spaces that increase land and neighbouring property values, thus attracting investors, whilst improving citizens' well-being.

Secondly, sustainable urban planning with nature-based solutions has a positive environmental impact. It provides opportunities for adaptation to climate change, thus increasing urban resilience to risks, such as droughts, floods and heatwaves, as well as opportunities for small-scale climate mitigation through increased carbon storage. It can also reduce pressure on peripheral natural areas, for example, waste water can be treated closer to residential sources and provide satisfactory near-home recreation opportunities that diminish the need to travel for contact with nature.

Thirdly, nature-based solutions contribute to the social dimension of sustainable urbanisation. For example, green space availability can be related to people's perceived happiness and general health, while having green space nearby appears to reduce the incidence of costly forms of illness, such as heart disease, obesity and depression. In England, the benefits of urban greenspaces for physical and mental health have been estimated to reduce treatment costs by £2.1 billion[4]. Such benefits appear to be stronger for vulnerable groups: children, elderly, and people of low socio-economic status. Parks, urban farms and community gardens provide places for people to be physically active and to meet others. Moving nature-based solutions higher up the urban design and planning agenda is a major opportunity to prepare our cities for the future, providing an innovative ecosystems approach that can contribute to the resilience and economic growth of a city and to human well-being.

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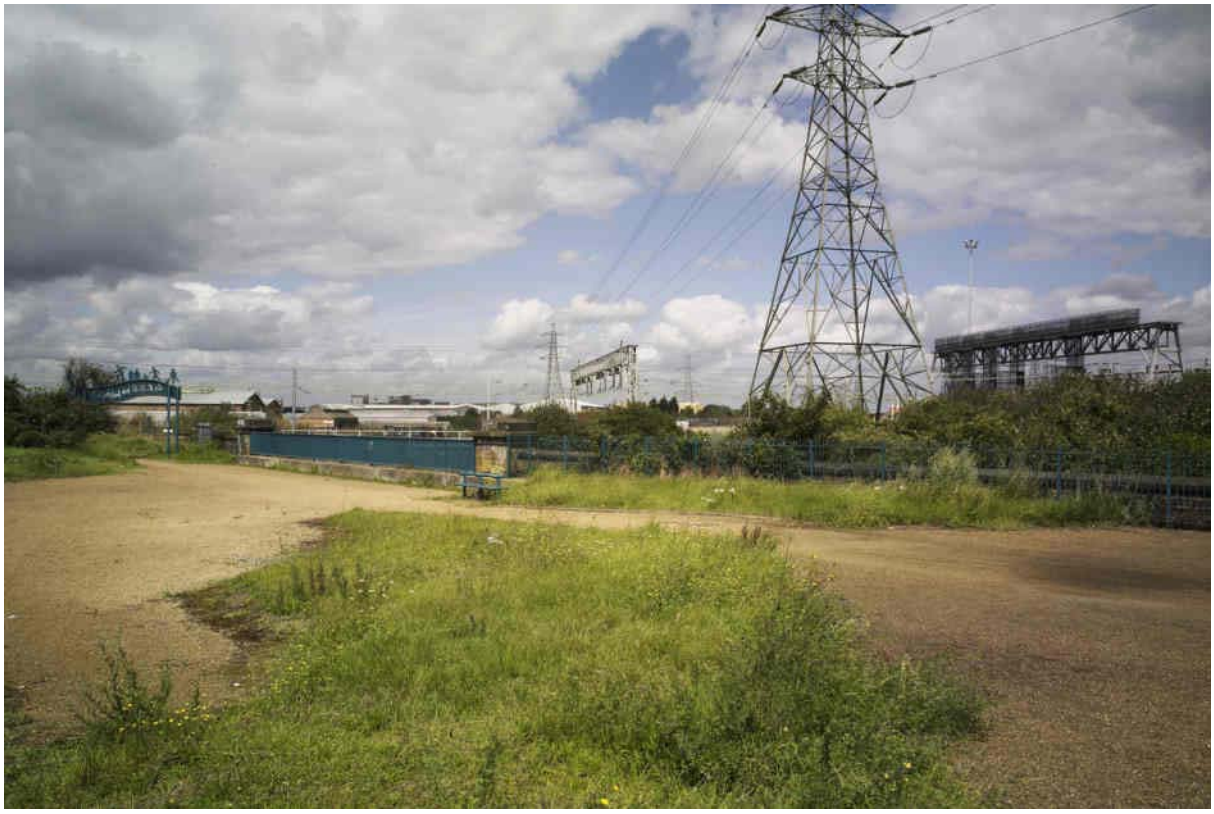
[8] Resilience addresses the capacity of a system to absorb shocks and disturbances and undergo change in order to maintain approximately the same identity (see Annex 2d for further details)

[9] UN (2014) http://esa.un.org/unpd/wup/Highlights/WUP2014-Highlights.pdf



*The Queen Elizabeth Olympic Park, located in East London and a formerly deprived area, has been at the heart of a major urban regeneration plan, in view of the 2012 Olympic Games. Photos show parts of the area before and after the regeneration.*

## Goal 2: Improving the Restoration of Degraded Ecosystems (Annex 2b)

In Europe, significant areas of ecosystems are being lost or degraded as a result of human activities. For example, between 60% and 70% of European wetlands have been completely destroyed[10].The drivers of loss and degradation vary according to the ecosystem and location, but the key pressures include agricultural intensification, grey infrastructure expansion, pollution of brownfield sites, hydrological modifications to water bodies, the intensification of forestry practices and, generally speaking, climate change. These affect the ecosystems' ability to function, deliver ecosystem services and meet other challenges, such as water purification, soil erosion protection, flood damage control, carbon sequestration and the provision of liveable places and recreational opportunities that contribute to human well-being, economic stability and physical security. According to economists, each year we lose 3% of GDP due to the loss of biodiversity and nature, which costs the EU €450 billion[11]. Whilst the first priority is to prevent further degradation of ecosystems and avoid unsustainable use of natural resources, the restoration of at least 15% of degraded ecosystems is now a global and European goal.

A strategic opportunity is the growing interest and awareness of the need to maintain, and also to restore, the functionality of degraded ecosystems and their services. It is seen as an essential ingredient within future business investments for generating revenue and by society wishing to improve the attractiveness of landscapes and cities, which would generate investment and other economic benefits, as well as contributing to human health and well-being.

There is growing evidence that ecosystem restoration can also play a key role in increasing resilience to impending risks and threats. For example, coastal restoration makes coastal communities more resilient to sea level rise and storms by re-initiating natural sedimentation processes, and forest restoration protects against floods and mitigates runoff and landslides, for example, by stabilising slopes. Restoring forest ecosystems through afforestation or change in management can, amongst other things, significantly contribute to $CO_2$ sequestration, achieving an additional sink of 90 to 180 $MtCO_2/yr$[12] and reduce the risk of landslides and avalanches in mountainous areas resulting in high cost savings (e.g. between €1.5 to 2.5 billion per year in Switzerland[13]). Such actions not only contribute to the stabilisation of ecosystems, but also can generate benefits exceeding investment costs in the long term. In Cambridgeshire, U.K., the conversion of drained, intensively farmed arable land to a wetland habitat resulted in a net gain to society of €160/ha/yr for a one-off investment in restoration of €1.900/ha[14]. Restoring and enhancing such habitats can also provide wider benefits, for example, boosting local tourism including related economic activities), providing employment and education opportunities and augmenting biodiversity conservation.

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[10] Revenga, C. et al. (2000) Pilot Analysis of Global Ecosystems, Freshwater Systems. World Resources Institute, Washington, DC

[11] EC, DG Environment (2015) http://ec.europa.eu/environment/nature/biodiversity/comm2006/2020.htm

[12] IPPC (2007). Forestry. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment report of the IPCC

[13] UNFCCC (2011) https://unfccc.int/files/adaptation/application/pdf/3eba.pdf

[14] Peh et al. (2014) Benefits and costs of ecological restoration: Rapid assessment of changing ecosystem service values at a U.K. wetland. *Ecol Evol*. 4(20): 3875–3886.

*The restoration of the natural dynamics of a Danube floodplain to the east of Vienna was aimed at protecting riverine habitats and species but also at moderating floods and droughts. Photos show the floodplain before and after the hydrological restoration, which included the removal of all artificial elements to generate a natural river bank structure*

## Goal 3: Developing Climate Change Adaptation and Mitigation (CCAM) (Annex 2c)

Addressing climate change is a challenge as its impacts on Europe are likely to increase and it affects all aspects of the environment, economy and society. For example, the annual damage of climate change to the EU economy, measured as GDP loss from today's conditions, could be between €20 billion for a 2.5°C scenario and €65 billion for a 5.4°C scenario with high sea level rise[15]. There are two responses to climate change: adaptation that seeks to reduce the impacts and mitigation to decrease $CO_2$ emissions or energy demand or increase carbon storage. Climate change is also one of the main drivers of ecosystem degradation and loss, often affecting the ability of nature to provide solutions to the challenges our society faces. Since climate change is an over-arching and cross-cutting challenge, there is a need to develop integrated nature-based solutions that address both adaptation and mitigation and can be applied across different sectors and/or goals and challenges.

One important strategic opportunity area is integrating grey with green and blue infrastructure, so that more traditional methods of management, for example water management in urban areas, are complemented or enhanced by using nature to increase their contribution to CCAM, as well as their social and economic benefits. Improved natural resource management by "zero waste" production is another critical area relevant to CCAM. Here, waste is seen as a resource and nature-inspired and nature-supported solutions can be applied, so that the use of resources is circular, with closed nutrient, gas, water and energy cycles, whenever possible. This could include re-designing human-made infrastructure and production systems as natural ecosystems or developing nature-based "frugal technologies" for lowering energy use.

The investment in CCAM nature-based solutions, such as developing low cost, low maintenance and low carbon emissions solutions to climate change mitigation will enhance the cost-effectiveness of responses to societal, environmental, and possibly economic challenges. This can also be achieved, for example, by investing in new approaches such as bio-inspiration and biomimicry, to enhance carbon sequestration through techniques, such as carbon biomineralisation, as well as learning from how nature adapts to extreme events.

A good example of a CCAM nature-based solution that meets several objectives and challenges is floodplain restoration. For example, the floodplain of the Noordwaard polder, Netherlands is being restored as part of the "Room for the river" programme[16]. The programme will provide climate change related flood protection for four million people, most of them in cities, improve the environmental quality for people and nature, and to increase recreational facilities and boost the economy.

[15] Ciscar, J. et al. (2011) Proceedings of the National Academy of Sciences, 108, 2678-2683.
[16] Ruimte voor de rivier (2015) http://www.ruimtevoorderivier.nl/english/room-for-the-river-programme/

*The restoration of the floodplain of the Noordwaard polder, the Netherlands, will provide climate change-related flood protection, improve the environmental quality for people and nature, increase recreational facilities and boost the economy.*
*Both photos show the situation after depoldering, which has left more room for the river.*

## Goal 4: Improving Risk Management & Resilience (Annex 2d)

Europe is exposed to a range of natural and technological hazards, including drought, extreme temperatures, floods, industrial and transport accidents, landslides and avalanches, storms, volcanoes and wildfires. In the EU, between 2002 and 2012, numerous such events generated 80,000 fatalities and €95 billion in economic losses[17]. Whilst fatalities are predominantly due to extreme temperatures, 40% of the damages and 50% of the total population affected are due to floods. As human populations and activities are concentrated in exposed areas, such as cities, with climate change, the damages could reach unbearable levels. Estimations of the expected annual damages in Europe by the 2080s from coastal flooding are €17.4 to 25.4 billion (currently €1.9 billion) and from fluvial flooding €97.9 billion (currently €5.5 billion)[18], unless strong prevention and adaptation policies are implemented.

The implementation of nature-based solutions offers major opportunities to reduce the frequency and/or intensity of different types of hazards. Therefore, they should form part of a range of measures and actions in integrated risk management, as they can provide more advantages than conventional methods. They combine multiple functions and benefits, for example, pollution reduction, carbon storage, biodiversity conservation and the provision of recreational activities and economic opportunities. In the short term, these more continuous benefits are important and need to be demonstrated to ensure a widespread involvement of politicians and private companies in the implementation and funding of such solutions.

Nature-based solutions also offer synergies in reducing multiple risks (for example drought and floods) and meet the objectives of different European regulations, for instance the Flood Directive and the Water Framework Directive, as well as contributing to climate change adaptation and mitigation. A further strategic opportunity is the development of the methodology and empirical studies of the insurance value of ecosystems, i.e. the value of the sustained capacity of ecosystems to maintain their functioning and production of benefits despite any disturbance.

Cities are particularly concerned with improving their risk management and nature-based solutions are attractive, as in the long run they can be more cost-effective. There are a number of new approaches for the implementation of nature-based solutions including integrating living systems with built systems through innovative combinations of soft and hard engineering. Heat stress in cities can be addressed by increasing green spaces and using green walls and green roofs. These measures could reduce temperature by up to 10$^{o}$C in Mediterranean areas. All of these approaches can also contribute to reducing flood risk and air pollution hazards, reducing energy demand in buildings (by 10-15%) and improving quality of life.

[17] Centre for Research on the Epidemiology of Disasters (CRED)

[18] European Commission, DG Environment (2014) Study on Economic and Social Benefits of Environmental Protection and Resource Efficiency Related to the European Semester.

*Improved protection against natural hazards, including avalanches, through intentional afforestation, adapted forest management (densification) and additional technical measures in Parsenn (Switzerland) between 1945 and 2007*

## RECOMMENDED RESEARCH & INNOVATION ACTIONS

Seven (7) priority nature-based research and innovation actions to meet societal challenges in the above four goals have been identified.

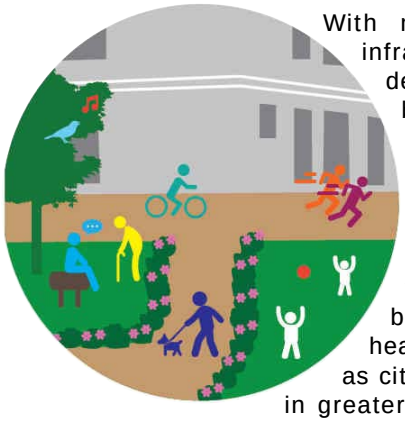
### Urban regeneration through nature-based solutions


Changes in land use, neglected land and abandoned areas are challenges for many cities. Urban regeneration through nature-based solutions offers a context for innovative interventions for green growth.

Nature-based solutions have an important role to play, for instance, through supporting the implementation and optimisation of green, blue and grey infrastructure. Green infrastructure can contribute to cutting energy and resource demands and costs, as trees provide cooling and insulation and reduce the urban heat island effect, and green roofs and green walls can decrease the need for heating and air conditioning. Co-benefits include reduced air pollution, flood control, and recreation. Planners are now seeking to exploit space more effectively through finding new uses for underused and unused land and grey infrastructure, often using nature-based solutions. The Promenade Plantée in Paris, where an elevated freight rail line was transformed into a park and plans for the use of underground space for underground parks in New York (Low Line)[19] are good examples. Possibilities for sustainable urban growth also can be found in the conversion of abandoned land into urban farms and community gardens and the regeneration of former factory sites through the bioremediation of toxic soils and subsequent transformation into green space. Parco Nord in Milan is just one of many examples.

Efforts to identify and implement nature-based solutions may also drive the re-examination of the economic basis of the cities and provide openings for businesses to innovate in the revitalisation of derelict urban and fringe areas. This may in turn drive innovation in business models which are driven by sustainability concerns in cities and which decouple economic growth from resource depletion and uneven resource distribution. Cities can serve as laboratories for innovation, experimentation and testing the effectiveness of nature-based solutions, with a view to maximising a range of environmental, social and economic co-benefits for all. Existing city networks can facilitate the replication of demonstration projects and up-scaling capacity of interventions.

### Nature-based solutions for improving well-being in urban areas



With millions more people needing housing, services, workplaces, infrastructure and institutions by 2050[20], the potential impacts of development decisions are unparalleled. By integrating nature-based solutions into urban design and planning, increasingly large and dense cities can improve human health and well-being, while offering ecological and economic co-benefits.

An increasingly strong evidence base shows the positive effects of access to green spaces and good-quality landscape on health, well-being, social cohesion and community support. Using nature-based solutions to enhance neighbourhood spaces can stimulate healthy physical activity and promote the development of social ties, as citizens are attracted outdoors to utilise public spaces together and in greater numbers feel safer to move around freely[21]. Even a permanent 1% reduction in the sedentary population of the UK could deliver up to £ 1.44bn a year in

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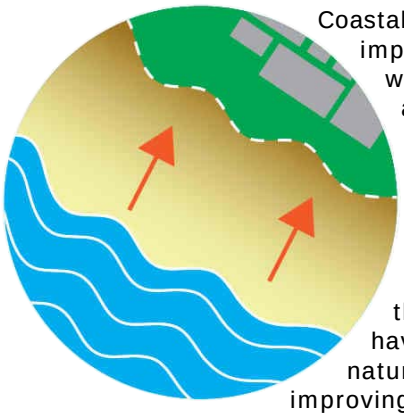
[19] The LowLine (2015) http://www.thelowline.org/about/project
[20] UN (2014) http://esa.un.org/unpd/wup/Highlights/WUP2014-Highlights.pdf
[21] Coley, R.L., Kuo, F.E., and Sullivan, W.C. (1997) Environment and Behavior, 29, 468-494, and Wacquant, Loïc (2010) 'Urban Outcasts', Polity Press.

economic benefits, equivalent to £800 per person, through social benefits and reduced health risks[22]. In the future, the challenge for urban planning will not just be in squeezing the most out of the space, but in squeezing the most out of the experience of urban life and green spaces that can bring important benefits in delivering a more livable urban environment[23]. Therefore, there is a need for demonstration projects which show how the multiple social benefits, and other co-benefits, of nature-based solutions can be most effectively realised through the systemic integration of nature-based solutions into urban planning.

Urban planners need to promote the flexibility of spaces and services, but also to stimulate change through adaptability and innovation. This means reconsidering the natural and built environment and the attitudes of officials and citizens. Those engaged in creating healthy places, such as public health professionals and landscape architects already widely recognise urban greening as an asset that has enormous potential to improve health and well-being[24]. The search for locally suitable nature-based solutions will provide a context in which these professionals also can explore the flexibility of spaces and services, and in turn stimulate change through adaptability and innovation. Nature-based solutions also appear to resonate with the urban publics, and citizen empowerment and citizen-driven innovation are crucial to capitalising on the potential benefits of nature-based solutions for urban social regeneration. New forms of stakeholder engagement and citizen participation in urban design and planning must be explored in order to harvest these innovative capabilities, resources and cooperation.

## Establishing nature-based solutions for coastal resilience



Coastal habitats are iconic and of considerable economic and social importance across the EU, protecting against floods and erosion, while providing livelihoods for many individuals through tourism and fishing. With sea level rise, isostatic change (the tendency for some areas to sink) and increasing flood risks there is growing awareness that the cost-effectiveness of hard engineering (e.g. the provision of built coastal defences) has to be discussed. Alternatives, including soft engineering options such as restoring salt marshes, have been shown in many cases to be highly relevant in reducing flood risk, while other options may reduce the risk of coastal erosion. These more nature-based options can have multiple benefits, for example, in attracting tourists, increasing natural productivity and thus fish stocks, benefiting wildlife and improving water quality.

New evidence shows that substantial changes have been and are being experienced by many intertidal and subtidal habitats[25]. For example, oyster reefs were once ubiquitous in estuaries but many of these have now disappeared and the extensive sea grass beds are also largely gone. Studies have shown that that these had substantial roles in settling sediment by providing physical structures and improving water quality through the filtration by oysters, mussels or clams[26] and oxygenating it through photosynthesis.

Restoration of coastal habitats has tended to be neglected compared to other habitats and there is considerably greater uncertainty regarding the most suitable methods for these habitats compared to well-established approaches, such as tree planting or creating wetlands, for purely terrestrial habitats. There is a considerable need for scientific research and the development of innovative methods to identify the cost-effective means of restoring coastal habitats and assessing the associated co-benefits.

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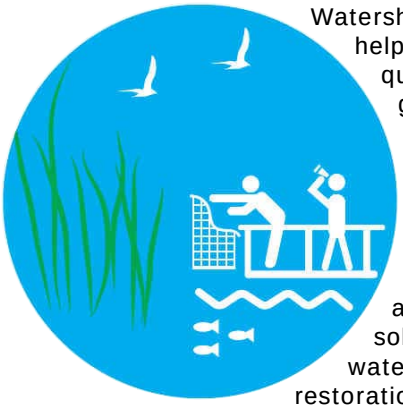
[22] CJC Consulting (2005) Green Spaces for Physical and Mental Health: Scoping Study. Forestry Commission report.
[23] Hartig, T. et al. (2014). Annual Review of Public Health, 35, 207-228.
[24] Landscape Institute (2013) Public Health and Landscape: Creating Healthy Places, Landscape Institute, UK
[25] Airoldi, L. and Beck, M. W. (2007) Loss, status and trends for coastal marine habitats of Europe: Oceanography and Marine Biology Annual Review, 45, 345-405.
[26] Zu Ermgassen, et al. (2013) Quantifying the loss of a marine ecosystem service: filtration by the Eastern Oyster in US estuaries: Estuaries and Coasts, 36, 36-43.

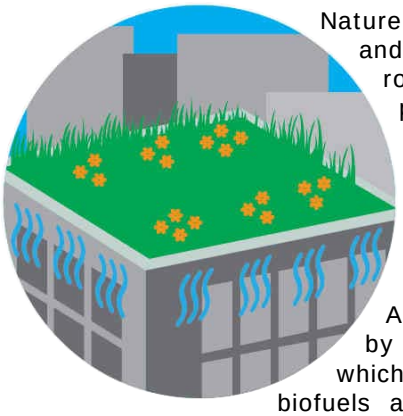
## Multi-functional nature-based watershed management and ecosystem restoration



Watershed management and restoration using nature-based solutions can help to reduce the risk of floods and droughts, while improving water quality and quantity. Floodplain restoration, for example, can generate multiple benefits. In the case of the River Elbe and its tributaries, it had a total economic benefit of €1.2 billion and a cost-benefit ratio of 1:3[27]. The benefits included protection from flood damage, improved living conditions for wild species, re-flooding of carbon-rich soils, reduction of nutrient loads and landscape improvements. Restoring degraded terrestrial ecosystems, such as grasslands, arable land and forests, as well as former industrial and brownfield sites by using nature-based solutions also can deliver a variety of benefits, including improved water quality, carbon sequestration, and attractive landscapes. The restoration of peatlands, for example, can reduce current emissions of 10-20 t $CO_2$/hectare[28] and for England this has been estimated at being worth £570 million over 40 years. It would also improve water supply, as well as species and habitat conservation. Restoration actions can create recreational areas and jobs too, which serve to sustain human well-being. It has been estimated that upstream of cities and on suitable lower grade agricultural land, wetland creation could give a benefit:cost ratio of 3:1 and possibly up to 9:1[29].

In addition to ensuring adequate institutional frameworks and greater connectivity between legal frameworks, banks and (health and risk) insurance companies should be approached as key potential investors given the (insurance) value of ecosystems in relation to other investments and their function, for example, in mitigating risks to human health and real estate. Particular attention must be paid to the involvement of society and individuals in restoration actions, with the aim of re-connecting people with nature, raising awareness of societal benefits and creating a public demand for restoration actions. In this context, living labs that allow for the development and testing of new forms of social engagement and financing can be a potential instrument.

## Nature-based solutions for increasing the sustainable use of matter and energy



Nature-based solutions can decrease resource demand through energy and matter-efficient processes. In cities, green spaces and green roofs provide natural cooling or insulation. Nature-based chemical processes, either bio-inspired or bio-supported are already contributing to a greener chemistry using fewer natural resources and preventing pollution[30]. Regarding manufacturing, room temperature "growing materials" using mycelium and organic waste have been recently commercialised[31], as well as nature-based 3D printing techniques[32].

Also, solutions inspired by nature can improve resource efficiency by providing a range of alternative sources of energy and matter, which are based on potentially renewable, organic sources, including biofuels and biomaterials, artificial photosynthesis or growing algae to produce hydrogen[33]. Several studies currently address the possibilities of copying atmospheric

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[27] Grossmann, M., Hartje, V. & Meyerhoff, J. (2010): Ökonomische Bewertung naturverträglicher Hochwasservorsorge an der Elbe und ihren Nebenflüssen. Bundesamt für Naturschutz, Bonn.

[28] Schäfer, A. (2009). Moore und Euros – die vergessenen Millionen. Archiv für Forstwesen und Landschaftsökologie 43, 156–160.

[29] Natural Capital Committee (2015) The State of Natural Capital. Third report to the Economic Affairs Committee.

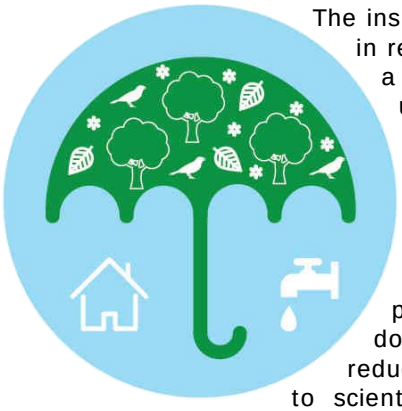
[30] Swiegers, G. (2012) Bioinspiration and Biomimicry in Chemistry,

[31] Ecovative (2015) http://www.ecovativedesign.com/

[32] Can 3D Printing Unlock Bioinspiration's Full Potential? Fermanian Business & Economic Institute, 2014.

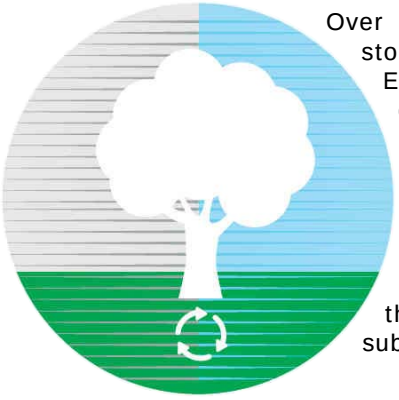
carbon photosynthetic sequestration for fuel production (methanol and methane)[34]. Also, bacteria can be used in the breakdown of organic matter to produce biomethane and cars fuelled on biomethane are more efficient than those run on petrol or diesel.

## Nature-based solutions and the insurance value of ecosystems



The insurance value of ecosystems[35] has to date been largely overlooked in research and practice and mostly discussed in relation to its role as a metaphor for the value of resilience. In a world facing greater uncertainties and in the light of projected climate change impacts, there is an increasing interest in nature-based solutions, such as investments in green infrastructure and the restoration of ecosystems to reduce risks (e.g. of flooding, heat waves). The insurance value of an ecosystem results from the system itself having the capacity to cope with external disturbances and includes both an estimate of the risk reduction due to the physical presence of an ecosystem (e.g. area of upstream land/number of downstream properties protected) and the capacity to sustain risk reduction (i.e. the resilience of the system). There is an urgent need to scientifically explore methodologies and conceptual frameworks for assessing the insurance value of nature and to integrate this into the disaster risk management agenda. This could be done, for example, by working with financial institutions and insurance companies to develop innovative ways for promoting nature-based solutions for risk management. One strategy could be to translate risk reduction capacity into value through calculating benefit/investment ratios in landscape management and restoration. Here, the benefits would represent the reduced risk and potential lower premiums of land and property insurance policies. A new legal framework that serves to create incentives for maintaining or enhancing the insurance capacity of ecosystems should be explored. It would be important to first develop a framework where the models and data (including downscaled climate change scenarios) capturing the capacity of ecosystems to reduce risks are made compatible and harmonised with the risk assessment models and data used by the private insurance sector. Secondly, to develop an economic approach to understanding ecosystems as representing the stock that generates the flow of services and explore how to capture the long-term benefits of maintaining and enhancing that stock. Thirdly, to explore the cultural dimension of the insurance value of ecosystems and people's perceptions of risks and insurance.

## Increasing carbon sequestration through nature-based solutions



Over the last 30 years, terrestrial and freshwater ecosystems have stored about a quarter of human generated $CO_2$ emissions[36]. Enhancing such carbon sequestration is one of the major issues for climate change mitigation. This challenge can be addressed by using methods that increase the biomass of living organisms, as well as by a range of new nature-based solutions, such as biosequestration, i.e. the use of living organisms as natural (longer-term) carbon stores. Some plants can store carbon in inorganic forms as phytoliths ("stones"). Wheat cultivars, for example, differ by a factor of 10 in their ability to store carbon in this way and phytolith carbon biosequestration rates indicate a substantial potential of about 50mt $CO_2$ equivalent $yr^{-1}$ [37]. Biobased

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[33] Nanowerk (2009) http://www.nanowerk.com/news/newsid=14019.php

[34] Olah, G.A., Goeppert, A., and Prakash, G. S. (2008) Chemical Recycling of Carbon Dioxide to Methanol and Dimethyl Ether. The Journal of Organic Chemistry, 74, 487–498.

[35] In this context the insurance value of ecosystems is taken as the value of the sustained capacity of ecosystems to reduce risks to human society caused by e.g. climate change related excess precipitation, temperature or by natural disasters.

[36] Settele, J. et al. (2014) Terrestrial and Inland Water Systems. In: Climate Change 2014: Impacts, Adaptation and Vulnerability. Cambridge University Press, Cambridge.

geological $CO_2$ storage techniques using or mimicking microorganisms' processes to combine calcium and $CO_2$ to produce minerals, are also under development or are being tested in some industrial processes[38,39].

[37] Parr, J.F. and Sullivan, L.A. (2011) Phytolith occluded carbon and silica variability in wheat cultivars. Plant Soil, 342, 165–171.
[38] CO2SolStock - Biobased geological CO2 storage (2013) http://co2solstock.org/
[39] The biomimicry institute (2015) http://www.asknature.org/product/9242c6b587aba1877c788cd8409d60ac

# CONCLUSIONS

Within the overall aim of contributing to greening the economy and making development sustainable, the Expert Group recommends that the EU Research & Innovation agenda on Nature-Based Solutions and Re-Naturing Cities encompasses:

### The development and deployment of nature-based solutions that maximise cost-effectiveness and co-benefits

Nature-based solutions address specific demands or challenges, and at the same time they seek to maximise other environmental, social and economic co- benefits. They represent an effective, resource-efficient and flexible approach to sustainable and inclusive economic growth, while improving human health and well-being and the natural environment. They can improve resilience to natural disasters and offer cost-effective options for adapting to climate change and reducing pollution. Inspiration and support from nature can stimulate scientific innovation and strengthen the economy. The goals and research and innovation actions clearly demonstrate the opportunities to put nature-based solutions into practice. Examples of current nature-based solutions that could be applied or enhanced are provided in Annex 4 in the online version of this report. They also do not have clear boundaries and may intersect with other policy areas, such as eco-innovation and the bio-economy.

### The scaling-up of nature-based solutions across Europe, through a better evidence base

There is a clear need to compile a more comprehensive evidence base on the social, economic and environmental effectiveness of possible nature-based solutions, including a comparison with more traditional solutions. The evidence base should also address the limits to nature-based solutions: beyond certain boundaries of environmental change (e.g. in precipitation and temperature) where even large investments may result in small net effects in, for example, risk reduction. The importance of actions being based on sound evidence and how this can be achieved can be summarised in two main recommendations for evidence-based actions and policy-making (see Annex 3 in the online version of this report):

1. That the evidence on the social, economic and environmental effectiveness of key nature-based solutions under different conditions is assessed as soon as possible, as a coordination and support action, but building on existing initiatives. Ideally this should be prior to the main projects being implemented, to make the subsequent actions as effective as possible.
2. That the nature-based solutions are designed and implemented with the co-production of scientifically sound knowledge through multi-stakeholder engagement, so that the experience gained is shared with others.

The results of the research and innovation actions would form an important input to the evidence base. This would offer the opportunity to test the transferability of various solutions to different conditions in other regions of Europe, and devise models and large-scale demonstration projects for scaling up local solutions to tackle larger scale problems. It is important to synthesise and communicate the results effectively to maximise uptake of the most effective solutions.

### The development of new business and investment models and legal and institutional frameworks for nature-based solutions

Many of the research and innovation actions need further development and testing to establish how they can be turned into bankable opportunities, scaled up to leverage private capital flows, or transferred to other locations or actions. In order to be effective, they must also be successfully embedded into society, business and policy. This will require (i) adequate integrated institutional and legal frameworks and governance structures, so that the multiple benefits arising from nature-based solutions are captured, (ii) new business and cooperation models involving the private sector and enabling long-term financing, including public-private partnerships and market incentives. These all need to be developed, tested and employed.

### The empowerment, involvement and reconnection of citizens with nature to enhance their well-being

Nature-based solutions offer a tremendous opportunity to enhance well-being and strengthen community cohesion. Particular attention must be paid to the involvement of society and

individuals in restoration and other nature-based solutions, with the aim of re-connecting people with nature, raising awareness of societal benefits, and creating a public demand for healthy natural environments. In this context, living labs that allow for the development and testing of new forms of social engagement and financing can be a potential instrument.

**The Horizon 2020 Expert Group on 'Nature-Based Solutions and Re-Naturing Cities'**

The European Commission is developing a Research and Innovation agenda on Nature-Based Solutions to address some of the most pressing societal challenges of our time. The Horizon 2020 Expert Group on 'Nature-Based Solutions and Re-Naturing Cities' was established with the aim of engaging in forward looking reflection and contributing to establishing an EU reference policy framework for Research and Innovation on issues related to green economy and sustainable development, and more specifically on 'Nature-Based Solutions and Re-Naturing Cities'. This document has been prepared for the European Commission by the Expert Group. The Expert Group was established in accordance with the Horizon 2020 Work Programme 2014 for Societal Challenge "Climate action, environment, resource efficiency and raw materials".

The Expert Group was informed by the findings of an e-consultation and a stakeholder workshop[40]. It has provided these recommendations on the goals and Research and Innovation actions for nature-based solutions in the expectation that they will be taken up, not only by the European Commission, but also by Member States at the national and sub-national levels.

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[40] The reports from the e-consultation and the stakeholder workshop can be downloaded from: http://ec.europa.eu/research/environment/index_en.cfm

# ANNEX 1: DEFINITION OF NATURE-BASED SOLUTIONS

Nature-based solutions aim to help societies address a variety of environmental, social and economic challenges in sustainable ways. They are actions inspired by, supported by or copied from nature; both using and enhancing existing solutions to challenges, as well as exploring more novel solutions, for example, mimicking how non-human organisms and communities cope with environmental extremes. Nature-based solutions use the features and complex system processes of nature, such as its ability to store carbon and regulate water flows, in order to achieve desired outcomes, such as reduced disaster risk and an environment that improves human well-being and socially inclusive green growth. This implies that maintaining and enhancing natural capital is of crucial importance, as it forms the basis for solutions. These nature-based solutions ideally are resilient to change, as well as energy and resource efficient, but in order to achieve these criteria, they must be adapted to local conditions.

The “nature-based solution” concept builds on and supports other closely related concepts, such as the ecosystem approach, ecosystem services, ecosystem-based adaptation/mitigation, and green and blue infrastructure. They all recognise the importance of nature and require a systemic approach to environmental change based on an understanding of the structure and functioning of ecosystems, including human actions and their consequences. Nature-based solutions, however, have a distinctive set of premises: (i) some societal challenges stem from human activities that have failed to recognize ecological limitations; (ii) sustainable alternatives to those activities can be found by looking to nature for design and process knowledge. They therefore involve the innovative application of knowledge about nature, inspired and supported by nature, and they maintain and enhance natural capital. They are positive responses to societal challenges, and can have the potential to simultaneously meet environmental, social and economic objectives.

There has been much debate over the components of nature-based solutions and, within the current EU framework, nature-based solutions exclude methods that artificially alter nature, such as genetically modified organisms.

# ANNEX 2: THEMATIC GOALS

## Annex 2a: Enhancing Sustainable Urbanisation

### 1. Challenge, Trend

Currently, 73% of Europe's population live in cities and this is projected to increase to 82% by 2050, resulting in over 36 million new urban citizens[41]. Not only does the rapid urbanisation process affect the availability of resources in European cities, but it also poses challenges to equitable economic growth[42]. Due to the ongoing economic recession, European cities are struggling to integrate economic migrants, which puts further pressure on living conditions, health and quality of life in cities. We need to rethink our cities, if we are to achieve significant social, economic and environmental gains. They need to be developed and regenerated, so that they provide healthy and liveable environments. Thus, when addressing sustainable urbanisation, including health and well-being, we must consider the social, environmental and economic aspects of cities and the complex relationship between them.

### 2. Strategic Opportunity Areas

- Sustainable urbanisation requires increased attention on how human health and wellbeing in cities can be maintained and promoted. This challenge calls for improved residential design and transportation systems[43], new technologies[44], new business models[45] and a stronger focus on healthy urban environments through accessible green spaces and public sites.
- The enhancement of the quality of life is a crucial factor for the sustainability, vitality and competitiveness of a city. Nature-based solutions can play a pivotal role by in many areas - ensuring access to basic necessities, as well as supporting health-promoting individual activities and meaningful interactions among fellow citizens as well as improving the attractiveness of cities to residents and businesses, thus influencing property value and economic activity and providing climate change resilience. However, the precise ways in how urban greenspaces can achieve these outcomes needs further assessment[46].
- One of the socio-economic benefits of the greening of neighbourhood spaces is that social ties and support networks are strengthened, as citizens are encouraged to utilize these public spaces and be less fearful of moving around freely[47]. Therefore, there is a need for more awareness of the benefits of nature-based solutions in public spaces such as parks, squares, schools, and hospitals.
- Economic development in urban areas is highly dependent on the wealth and quality of natural resources. This means that we will have to find new ways of maintaining growth that do not extract and deplete our scarce natural resources, and it calls for business innovation modelling on how nature-based solutions have the potential to reduce energy and resource costs drastically and act as carbon sinks to mitigate risks of climate change.
- Nature-based solutions can also be used to tackle increased inequality and unemployment amongst youth. The economic recession has put an even greater strain on cities and forced

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[41] UN (2014) http://esa.un.org/unpd/wup/Highlights/WUP2014-Highlights.pdf
[42] UN population Division (2010) cited in European Environment Agency, 2010. The European Environment, State and Outlook 2010, Living in an urban world; European Commission, 2011. Global Europe 2050, Executive summary
[43] European Commission (7th of July 2014). The urban dimension of an EU policy- key features of an EU urban agenda
[44] McCormick, K., Anderberg, S., Coenen, L., & Neij, L. (2013). Advancing sustainable urban transformation. *Journal of Cleaner Production*, *50*, 1-11.
[45] Boons, F., Montalvo, C., Quist, J., & Wagner, M. (2013). Sustainable innovation, business models and economic performance: an overview. *Journal of Cleaner Production*, 45, 1-8.
[46] Hartig, T., Mitchell, R., de Vries, S., & Frumkin, H. (2014). Nature and health. Annual Review of Public Health, 35, 207-228.
[47] Coley, R.L., Kuo, F.E., and Sullivan, W.C. (1997). Where does community grow? The social context created by nature in urban public housing. Environment and Behavior, 29, 468-494.

politicians, administrations, researchers and citizens to think more innovatively in order to generate sustainable economic growth and inclusion. This presents the opportunity to think and act in new ways, by viewing cities as innovation hubs for nature-based solutions. Nature-based solutions in sustainable urban planning are most often linked to the regeneration of derelict areas, the improvement of recreation facilities and to the general well-being of citizens. However, they can also be used to stimulate growth and new jobs by encouraging nature-based solutions, actions and demonstration projects with a strong replication and up-scaling capacity, using existing city networks to identify frontrunners and followers. This approach can also be applied to historic districts in cities, as well as derelict industrial sites and run-down urban areas that can be transformed by enhancing their attractiveness and converting their use. Attention should also be paid to visionary approaches for innovation cities using nature, such as climate-adapted and resource-efficient nature-based solutions for improved transportation systems[48], new technologies[49] and new business models[50]. Policies should encourage developers and local authorities to consider nature-based solutions from the outset of any urban project or strategy.

## 3. Examples of Nature-Based Solutions

- Careful deployment of nature-based solutions in the city can cut energy and resource costs and act as carbon sinks to mitigate risks of climate change. For example, energy savings from green roofs have been estimated at around 10-15%[51], with a 12% reduction in energy demand reported for a green roof in the Mediterranean region[52], while in cities such as Athens, they have been shown to be able to reduce high cooling loads in buildings by 66%, with 4-hour reductions in cooling energy demand being reported[53]. They may also contribute to improving human health.
- Increasing the provision of greenspace can ameliorate the temperature of urban areas, thus reducing heat stress. Urban parks have been found to be able to reduce ambient daytime temperature by an average of 0.94°C; with an average night-time reduction of 1.15°C[54]. While modelling found that a 10% increase in the green area dense urban areas of Greater Manchester could retain maximum surface temperatures at, or below the 1961-1990 baseline until the 2080s for all emissions scenarios, thus mitigating the effects of climate change[55].
- Living close to green space has a positive influence on several general health indicators for (including perceived health, stress and disease morbidity)[56] and may also reduce crime rates. It has been estimated that the provision of equitable access to good quality green space for every household in England could lead to annual savings of £2.1bn in averted health costs[57].

[48] European Commission (7th of July 2014). The urban dimension of an EU policy- key features of an EU urban agenda
[49] McCormick, K., Anderberg, S., Coenen, L., & Neij, L. (2013). Advancing sustainable urban transformation.Journal of Cleaner Production, 50, 1-11.
[50] Boons, F., Montalvo, C., Quist, J., & Wagner, M. (2013). Sustainable innovation, business models and economic performance: an overview.Journal of Cleaner Production, 45, 1-8.
[51] Bigham, R. (2011). The Little Details. Pollution Engineering, 43(4): 7-7.
[52] Zinzi, M. & Agnoli, S. (2011) Cool and green roofs. An energy and comfort comparison between passive cooling and mitigation urban heat island techniques for residential buildings in the Mediterranean region. Energy & Buildings, 55:66-76.
[53] Alexandri, E., & Jones, P. (2008). Temperature decreases in an urban canyon due to green walls and green roofs in diverse climates. Building and Environment, 43(4): 480-493.
[54] Bowler, D.E. et al. (2010) Urban greening to cool towns and cities: A systematic review of the empirical evidence. Landscape and urban planning, 97(3): 147-155.
[55] Gill, S.E. et al. (2007) Adapting cities for climate change: the role of the green infrastructure. Built Environment, 33:115-133.
[56] Hartig, T. et al. (2014) Nature and health. Annual Review of Public Health. 35:21.1–21.22.
[57] Natural England (2009) Our Natural Health Service: The role of the natural environment in maintaining healthy lives. Natural England Report, Sheffield.

## 4. Research & Innovation Actions

- *Build the evidence base regarding the challenges and the potential socio-economic, public health and environmental benefits of nature-based solutions within sustainable urbanisation*

  The potential of nature-based solutions needs further investigation, particularly with regard to the generation of co-benefits. Measures such as green spaces, street greenery and green roofs are known to provide a variety of environmental benefits, as well as improve the liveability of cities, enhance their economic development and contribute positively to the health and social well-being of urban citizens. However, where knowledge of specific types of benefits is already available, it commonly requires integrating with knowledge regarding other types of benefits. Further attention also needs to be given to mapping the opportunities available for new nature-based solutions associated with buildings and infrastructure in cities, and for improving nature-based solutions currently in place.

- *Research on the effectiveness of nature-based interventions*

  In addition to organizing and integrating evidence regarding known benefits of nature-based solutions that have already been deployed, research and innovation efforts should address possible new nature-based solutions, considering questions about their effectiveness, such as:

  i. What combinations and configurations of vegetation in different sizes can maximize carbon capture and shading provision while also enhancing resident quality of life?
  ii. How can mobile green walls be designed and employed to provide opportunities to adapt and reshape spaces externally and internally, to help control temperature, improve air quality, reduce demand for building infrastructure, and offer aesthetic appeal?
  iii. How can existing grey infrastructure be greened and joined up with existing green spaces and urban greenery (e.g., street trees) so that cities enable a perception of a green living environment despite increasing residential densities?
  iv. How can interstitial spaces in cities (rooftops, public parks, road edges, and underused infrastructure) be more extensively used for urban food production?
  v. What is the feasibility of vertical farms in cities, and what business models can support their development?

- *Demonstrate the effectiveness of nature-based solutions*

  Some questions of effectiveness will be best addressed through demonstration projects. Cities can serve as laboratories for innovation, experimentation and testing of good practices, methods and tools for the identification of effective of nature-based solutions, which maximise a range of ecological, social and economic co-benefits. Existing city networks can facilitate the replication of demonstration projects and up-scaling capacity of interventions.

- *Research on how the uptake of nature-based solutions can be encouraged*

  Changes in policy, legislation and spatial planning are all possible ways of influencing the uptake of nature-based solutions and there are examples of each of these in practice. How each of these singly, or in combination, could be used to enhance the uptake and success of nature-based solutions needs further research. This research should build on the demonstrated effectiveness of different interventions.

- *Developing business models that enable economic growth through sustainable urbanisation, whilst providing health and social and economic progress for citizens and businesses*

  Research is needed on the economic gains achieved through nature-based solutions as components in sustainable urbanisation and how these gains translate into health and social benefits. Research and innovation efforts are also required to develop approaches (including financing mechanisms and capital market solutions) to cost-effectively scale up nature-based solutions, thereby leveraging increased capital flow and fostering partnerships. Attention also needs to be given to potential systemic changes toward a circular economy, including demonstration projects on eco-innovative business models and services, such as reuse, repair and recycling of resources across value chains and ecologically sensitive design of products.

- *Identify how nature-based solutions can be enhanced by connecting actors and activities*

  Nature-based solutions will require tools and methods for engaging with multiple stakeholders by facilitating communication and dissemination that will establish the ground for future

collaborations, innovations and recommendations. There is also a need to explore how to instill citizen-driven empowerment, involvement in and ownership of nature-based solutions in cities, given their general health and social implications.

## 5. Actors

Europe is faced with a series of global urban mega trends and challenges that require collaboration of actors, working across different professions and disciplines, sectors, institutions, governments and national borders. These diverse actors include practitioners, researchers, citizens, grass-root activists, policy-makers, think-tanks, companies involved in the design, creation and maintenance of nature etc. Numerous methods and approaches are available to facilitate multi-stakeholder involvement, including methods of co-creation, crowd-sourcing, taskforce groups, grassroots initiatives, citizen movements, social innovation community, amongst others. These offer viable ways of engaging complex multi-stakeholder collaboration in accelerating the identification, implementation and evaluation of nature-based solutions.

We need to draw on expertise from multiple stakeholders, including actors from the private and public sectors. To achieve more systemic urban governance, it is important to use a multi-stakeholder approach. This acknowledges how the individuals, organisations and governments, in interaction with others, play a pivotal role in identifying new ways, innovations and knowledge for better cities. There is a need for overarching coordination in order to map, analyse and assess existing successful business models, financing mechanisms and municipal initiatives to innovate cities with nature-based solutions, while adopting a systemic, multi-stakeholder and trans-disciplinary approach. The focus should be not only on capital cities but also on small-medium cities. Moreover, there is a need to propose and suggest tools and trainings for visionary architects, practitioners and policy makers.

## 6. Indicators

As an answer to the claim of sustainability, cities should be approached as labs and hubs for innovation and experimentation in the field of nature-based solutions. One way to maintain this development is by encouraging actions and demonstration projects with a strong replication and up-scaling capacity, relying on existing city networks to identify frontrunners and followers. Moreover, we need to pay attention to historic districts in cities, as well as derelict industrial sites and vast urban areas that are not functioning anymore, but can be transformed by enhancing their attractiveness and converting their use. Strong attention should be also paid to visionary approaches for innovating cities with nature, combining engineering and scientific approaches (i.e. eco-dynamic solutions). In addition, the demonstration projects should prove the added value of NBS for energy efficiency and climate change resilience in particular in contrasting urban heat island effect and investigating into blue and green solutions, creating recreational areas, improving air quality and reducing noise. Policies that encourage developers and local authorities to consider NBS from the outset of any urban project or strategy.

## Annex 2b: Restoring Degraded Ecosystems

### 1. Challenge, Trend

As a result of human activities significant areas of ecosystems are being lost or degraded especially by fragmentation, change in management, pollution and invasive species. The details of the drivers vary according to ecosystem type, but the key European pressures include agricultural intensification, grey infrastructure expansion, pollution of brownfield sites, hydrological modifications to water bodies, the intensification of forestry practices and, generally speaking, climate change. The resultant degradation threatens the health of ecosystems and their ability to function and deliver essential services, such as water purification, carbon storage, soil erosion protection, nutrient cycling, flood damage control, forest carbon storage, and the provisioning of liveable places and recreational opportunities. Consequently, degraded ecosystems also jeopardize human well-being, economic stability and physical security. While the first priority is to prevent further degradation of ecosystems and avoid unsustainable use of natural resources, the restoration of degraded ecosystems presents a current major key challenge.

### 2. Strategic opportunity areas

- With increasing population and expanding resource needs there are increasing competing demand for land within Europe, whether for agriculture, forestry, energy, transport, industry, human settlements or for provision of environmental benefits. Restoring degraded land can reduce this demand by increasing the social and economic benefits to society that such land provides.
- There is growing appreciation of the benefits of restoring ecosystems and establish a green infrastructure that delivers a wide range of services of benefits to society, such as reduced stormwater runoff or decreased costs of dealing with extreme temperatures.
- There is growing interest and awareness within the business community of the need to maintain, and also to restore, the functionality of degraded ecosystems and their services, as an essential ingredient within business investments for generating revenue.
- There is an increased awareness of and a rapidly growing interest across society in implementing solutions that increase the attractiveness of landscapes and cities so generating investment and economic benefits and contributing to human health and well-being.
- It is increasingly appreciated that environmental restoration can play a key role in increasing resilience to impending threats, such as climate change, by, for example, limiting extreme temperatures of urban environments and making coastal communities more capable of withstanding sea level rise.
- Restoration may lead to economic and social regeneration through increasing the environmental quality of life. Landscape improvements can lead to enhanced investment, greater job opportunities and reduced social tension.

### 3. Examples of Nature-Based Solutions

- Enhanced flood alleviation and improved water quality. Reducing the risk of flooding impacting upon society by the restoration of watersheds, wetlands, woodlands, riverbanks and floodplains, so delaying the downstream passage of flood flow, enhancing rainfall infiltration into the soil and increasing flood storage capacity so reducing extent and speed of water runoff. Restored areas are likely to have further benefits for society including through recreation, tourism, and increased investment linked to the enhanced human well-being.
- Coastal protection to deal with sea level rise and storm risk. Natural habitats, such as saltmarshes, dunes and reclaimed coastal areas, that allow natural processes, such as coastal sedimentation, have often been shown to provide cost effective solutions compared to hard engineering options. Restoring and enhancing such habitats can also provide wider benefits, for example to tourism and biodiversity conservation.
- Climate change mitigation. Afforestation and rewetting peatlands, financed through $CO_2$ certificates and public private partnerships (including foundations, schools, public authorities)

and involving a wide range of stakeholders, such as individuals, tourists, schools or business, can serve to enhance carbon storage and provide a range of simultaneous solutions to society.

## 4. Research & Innovation Actions

- *Synthesise and prepare relevant information for end-users*

  There is a considerable body of literature on the various means of restoring a range of habitats including grasslands, wetlands, woodlands, dune and marine habitats, but this information needs to be collated, synthesised and summarised to make it accessible to practitioners and decision-makers. Develop and establish platforms for exchange of experiences and knowledge across Member States.

- *Assess the effectiveness of possible restoration intervention options*

  Develop user-friendly tools to assess the cost-effectiveness of different options for ecosystem restoration as well as alternative (engineered) options incorporating a combination of ecosystem services and considering the full range of benefits, including the environmental, social and economic ones.

- *Develop business and investment models and corresponding platforms to create opportunities for public-private partnerships and (voluntary) market-based incentives for business and individuals*

  Identify mechanisms to encourage and/or support actors (companies and financial institutions – banks, pension funds) to invest in and restore/re-nature degraded ecosystems and also create supporting and adequate legislative and institutional structures to enable investments in ecosystem restoration.

- *Establish demonstration projects to reconnect people with nature and facilitate social learning*

  Design and initiate restoration projects at a local level that target/re-connect urban and peri-urban populations, together with children and young people, with nature and facilitate project ownership, build a sense of community and support shifts in mindsets and behaviours.

- *Develop business models to involve health insurance companies in restoration activities*

  Develop business models and means for collaboration to enhance physical and mental health e.g. by increasing opportunities for physical activity and facilitating behavioural change. Target the generation of funds and investments to invest in the restoration of degraded areas, which can serve as recreational and sport areas and increase mental health.

- *Develop business models for mainstreaming restoration into planning and economic decisions*

  Develop business models incorporating the value of ecosystems and ecosystem services, and then mainstreaming them into planning and economic decisions.

- *Develop innovative methods for delivering ecosystem services*

  Innovative methods are needed for ensuring the delivery of essential ecosystem services, such as reducing soil erosion, $CO_2$ sequestration and enhancing coastal protection using nature-based solutions.

- *Find means of leveraging funding*

  Given that capital flows are constrained by uncertainties around public policies and budgetary challenges, we need to find a way to leverage capital flows (maybe using EU funds as a catalyst).

- *Applying general methods to local conditions*

  The variation in soil, climate and hydrological conditions means that there is a need for determining and guidance on how different restoration methods, including different landscape patterns, planning procedures and vegetation types, are best fitted to local environments.

## Annex 2c: Developing Climate Change Adaptation and Mitigation

### 1. Challenge, Trend

Climate change is a challenge as its impacts on Europe are likely to increase and it affects all aspects of the environment, economy and society, therefore, it is relevant to all the objectives in this report. Also, it is one of the main drivers of biodiversity degradation and loss, often negatively affecting the ability of nature to provide solutions to the challenges our society faces. Climate change adaptation and mitigation (CCAM) are different, but complementary strategies for addressing their impacts forms an over-arching and cross-cutting priority given the widespread impacts of climate changes. A holistic approach, therefore, is needed in order to integrate solutions that meet both adaptation and mitigation objectives, harmonises regulations and mainstreams CCAM into sectoral policies. Nature-based approaches to CCAM present possible solutions, but less is known about the extent to which CCAM can address not only mean climate change and extreme weather events, but also other environmental, social and economic challenges. In this context, a theoretical and empirical exploration of the concept of insurance value of ecosystems is needed.

### 2. Strategic opportunity areas

A number of innovative nature-based opportunities for CCAM exist, both for further development of specific methods of CCAM, but also the realisation of the cross-sectoral synergies. These include:

- Developing holistic, integrated nature-based solutions for CCAM, that are applicable across different sectors and/or challenges, such as integrating grey, green and blue infrastructure and enhancing the natural components, as well as the social and economic benefits.
- Improved natural resource management by “zero waste” production, where waste is seen as a resource and the use of natural resources is circular, learning from and thus mimicking natural ecosystems, such that nutrient, gas, water and energy cycles are closed whenever possible. This could include re-designing human-made infrastructure as natural ecosystems, using both nature-inspired and nature-supported solutions or developing nature-based “frugal technologies” for lowering energy use.
- Enhancing the cost-effectiveness of responses to societal and environmental challenges through investing in NBS which can address multiple challenges, such as developing low cost, low maintenance and low carbon emissions solutions to climate change challenges.
- Responsible innovation through investing in new approaches, for example bio-inspiration and biomimicry, to enhance carbon sequestration through techniques, such as carbon biomineralisation, as well as learning from how nature adapts to extreme events.

### 3. Examples of Nature-Based Solutions

- Flood risk management– floodplain recreation can be the/part of the solution to flood risk through increasing water storage and slowing river response times. It can have multiple other benefits including: long-term improvement in water quality, increase in wetland habitats and species and carbon sequestration. The restoration of the flood plain of the Noordwaard polder, Netherlands is a good example. There is, however, a mitigation trade-off with increased $CH_4$ and $N_2O$ emissions.
- Heat stress in urban environments – green infrastructure can decrease temperatures and heat stress events. Trees are particularly effective, but green roofs and walls, gardens and parks all contribute, not only in addressing this issue, but also they are a good example of integrated NBS, as they can improve human health and well-being, biodiversity, reduce flood and drought risk and store carbon.
- Carbon sequestration for climate mitigation – planting sustainable woodlands can not only provide a long-term store for carbon, but also they can be beneficial for biodiversity, provide recreational opportunities and a source of natural products.

## 4. Research & Innovation Actions

- *Strengthen knowledge of the multiple benefits of nature-based CCAM and trade-offs*

  Knowledge on the trade-offs both between different nature-based CCAM actions and across other priorities is needed. This will require the assessment and/or improvement of (i) tools that can assess specific impacts in a particular context, (ii) indicators of impact. Green infrastructure could provide a good test case.

- *Demonstrate how CCAM nature-based solutions can be embedded in local level spatial planning and decision-making*

  This could include (i) the creation of living labs within cities, as a demonstration space, empty of rules where new forms of planning can be tested and demonstrated, and solutions can be translated to local situations. This would help to build up the evidence on the effectiveness of NBS in different contexts.

- *R&I projects on different forms of carbon biosequestration*

  These could include assessments of their potential for upscaling and how pilot schemes can be adapted to different industrial and agricultural settings, as well as to include communities and households. Also analyse their multiple benefits which could help speed up marketability and would be a way to ensure other revenue streams to help the translation of the activity into an income generating action.

- *Research on how energy and matter is produced and used by nature*

  There are many ways in which we could learn from how nature produces matter and uses energy (e.g. algal systems that capture CO2 or recycle organic waste as a carbon source to produce feed or new energy, where larger scale demonstration is needed), how nature uses them efficiently (e.g. buildings with microalgae on the façade which can treat wastewater and provide other ecosystem services) and how energy and matter flow.

- *Research on how to translate the adaptation strategies of ecosystems to climatic stresses into innovative solutions*

  Research is needed to identify key climate stresses and analyse and map examples of species' responses (e.g. how trees deal with drought).

- *Develop methods and models for analysing the socio-economic benefits of nature-based CCAM*

  Develop methods and models for analysing qualitatively and/or quantitatively the socio-economic benefits of nature-based CCAM, both in the short- and longer-term. This could include also (i) the investments needed to sustain the insurance capacity of ecosystems, (ii) an analysis of the effectiveness of performance-based contracts, (iii) a comparison of grey, green and blue infrastructure.

## Annex 2d: Improving Risk Management and Resilience

### 1. Challenge, Trend

Our world is exposed to a range of natural and technological hazard types: drought, earthquakes, epidemics, extreme temperatures, floods, industrial accidents, wet mass movements (landslides and avalanches), storms, transport accidents, volcanoes and wildfires. Between 2002 and 2013, within the European Union, numerous events generated more than 80,000 fatalities and several hundreds of billions euros of damages. Whilst fatalities are, for great part, due to extreme temperature, floods account for 40% of the amount of damages and 50% of the total population affected. Without strong prevention and adaptation policies, the damages could reach unbearable amounts by the end of 21st century, due to the evolution of human activities concentrated in exposed areas and to the effects of climate change (floods, heatwaves, droughts). Most Nature-Based Solutions (NBS) should aim to reduce the frequency or intensity of different types of hydro-meteorological hazards, such as floods, drought, heat waves, forest fires and reduce their impacts, thus making the system more resilient[58]. However, it is evident that they don't offer complete protection to vulnerable exposed territories/communities and there is always a residual risk of large-scale potential events. NBS are, therefore, not the only solution for risk management, but definitely a part of the solutions. They should be considered as a part of a range of measures and actions from an integrated risk management perspective. However, NBS aiming to improve risk management are still in an emerging phase.

### 2. Strategic opportunity areas

The implementation of NBS offers major opportunities. When NBS aim to prevent risk, they often combine multiple functions and benefits: reduction of pollution, carbon storage, preservation of biodiversity, recreational activities, and economic opportunities. Moreover, NBS may offer synergies in reducing multiple risks (drought and floods, for instance) and meet the objectives of different current regulations in Europe, for instance the Flood Directive and the Water Framework Directive. Also, they will contribute to climate change adaptation and mitigation. Risk prevention particularly needs multifunctional solutions. Why? Because investments in risk prevention generate long term benefits from a statistical perspective (every 10, 30 or 100 years). In the short term, other kinds of regular benefits are required to ensure a massive involvement of politicians and private companies in the implementation and funding of such solutions. This is why multifunctional measures, such as NBS, are great opportunities in the field of risk management. Cities are particularly concerned due to the high exposure of populations and activities to different kinds of risks. The implementation of NBS so far has been slow since the evidence base needs to be built, new approaches in integrating living systems with built systems (innovative combinations of soft and hard engineering) need to be developed and financial and institutional arrangements need to be developed to create opportunities, incentives and legal frameworks. Of special interest would be to develop the methodology and empirical studies of the insurance value of ecosystems, i.e. the value of the sustained capacity of ecosystems to reduce risks to human society caused by natural disasters. Promoting ecosystem-based solutions is in itself an innovative way to consider risk management as an integrated approach, combining different scales and planning perspectives.

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[58] The classic definition of sustainable development focuses on how to manage resources in a way that guarantees equity and welfare of current and future generations, while resilience addresses the capacity of a system to absorb shocks and disturbances and undergo change in order to maintain approximately the same identity. While sustainable development is inherently normative and positive, representing an overarching goal for society, resilience is non-normative since it denotes a property of a system. The desirability or non-desirability of resilience depends on careful analysis of resilience "of what, to what and for whom". Further, resilience is an attribute of a system not of a locality, for example the concept of a resilient city is problematic unless cities are viewed as open complex systems of systems extending over large spatial scales. To become meaningful, urban resilience has to address multiple scales, both below and above the city scale. A too narrow focus on a single city scale may be counterproductive and even destructive, since building resilience in one city often may erode it somewhere else with multiple negative effects across the globe (Elmqvist, T. 2014. Urban Resilience thinking. Solutions, 5, 26-30).

## 3. Examples of Nature-Based Solutions

Today, NBS aiming to prevent risks are implemented in different, often interconnected, areas, e.g. flooding along rivers (e.g. natural water retention measures, dyke relocation, re-naturing rivers, buffering areas, restoration of wetlands, woodlands, floodplain, re-meandering), sea level rise and erosion in coastal regions (e.g. de-poldering, set back of estuarine defences, maintaining dunes and beaches, salt marshes), heat island effects in cities (e.g. multifunctional green public spaces, sustainable urban drainage systems), droughts in rural areas (sustainable agricultural practices and irrigation systems), landslides, avalanches and rockfalls in mountainous zones (reforestation, rainfall water management, torrents and river management), forest fires (resistant and resilient species, firebreaks management, human settlements regulation in mountain regions).

## 4. Research & Innovation Actions

- *Developing a technical and scientific evidence base for NBS*
  - Develop models for (1) calculating different scenarios of risk reduction for different types of ecosystems (2) analyzing the effects of restoring degraded lands on risk reduction taking into account the ecosystem capacity (3) analyze the qualitative aspects of ecosystems needed to sustain the insurance capacity of ecosystems (long-term capacities of ecosystems to reduce risks in terms of stability and resilience against climate change impacts.
  - All models should include an explanation of uncertainties and integrate the distinction between fast and slow catastrophes.
  - Explore the capacity of NBS to simultaneously prevent different hazards.
  - Develop new innovative integration of living or bio-inspired systems with built designed systems and implement such NBS within land use planning, integrating several scales.
- *Developing decision support tools to foster the implementation of NBS*
  - Develop protocols, standards, performance tools to assess the relevance of NBS in economic, social, environmental and welfare terms.
  - Develop methodology to evaluate how multiple benefits are distributed between the stakeholders at different scales.
  - Develop methodology to assess the balance between short-terms and long-terms gains.
- *Developing financial instruments for NBS for risk management*
  - Work with insurance companies to develop innovative ways for promoting NBS for risk management e.g. pooling of insurance between towns/cities/regions, NBS linked to setting insurance premiums and pay-outs. Develop a methodology to operationalize the concept of the insurance value of ecosystems. Translate risk reduction capacity into value through, e.g. calculating benefit/investment ratios where benefits represent the reduced risk and potential lower premiums of property insurance policies.
  - Identify and adapt PES (payment for ecosystem services) schemes specifically designed for risk management that would link upstream and downstream stakeholders.
  - Creating financial incentives to support NBS for risk management e.g. tax breaks, etc.
- *Developing new institutional and governance arrangements to facilitate NBS acceptance*
  - Develop recommendations for governance and decision-making processes, including the issues of distributional effects and equity at different scales e.g. watershed scales and links between upstream and downstream, rural and urban areas. Indeed, often some NBS benefits are not generated on site, but spill over into many places inside and outside the area where the NBS is implemented, beyond the administrative limits.
  - Design new ways to bring together key parties: local governments, investors, engineers, companies, researchers.
  - Develop ways to involve local communities and stakeholders during decision-making processes.

- Assess the effectiveness of different current European regulations (for instance the Flood Directive or Water Framework Directive) to foster the implementation of NBS.
- Find ways to redirect and mobilize national defence resources to maintain and enhance the insurance value of ecosystem.
- Develop a new legal framework for insurance industry enabling the implementation of the concept of insurance value of ecosystem.

- *Enhancing the visibility of NBS at every stage*
  - In the field of research and education:
    - Build an accessible evidence base
    - Build networks among research groups in Europe
    - Explore the limits with new approaches of integrating living systems with built systems
    - Make available and accessible the literature review on NBS
    - Develop educational curricula on NBS
  - In the field of implementation: Develop demonstration sites and large-scale experiments to demonstrate the relevance of NBS and communicate practical examples.

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