European Commission

Towards an
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

EN

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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 (Annex 3) 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" 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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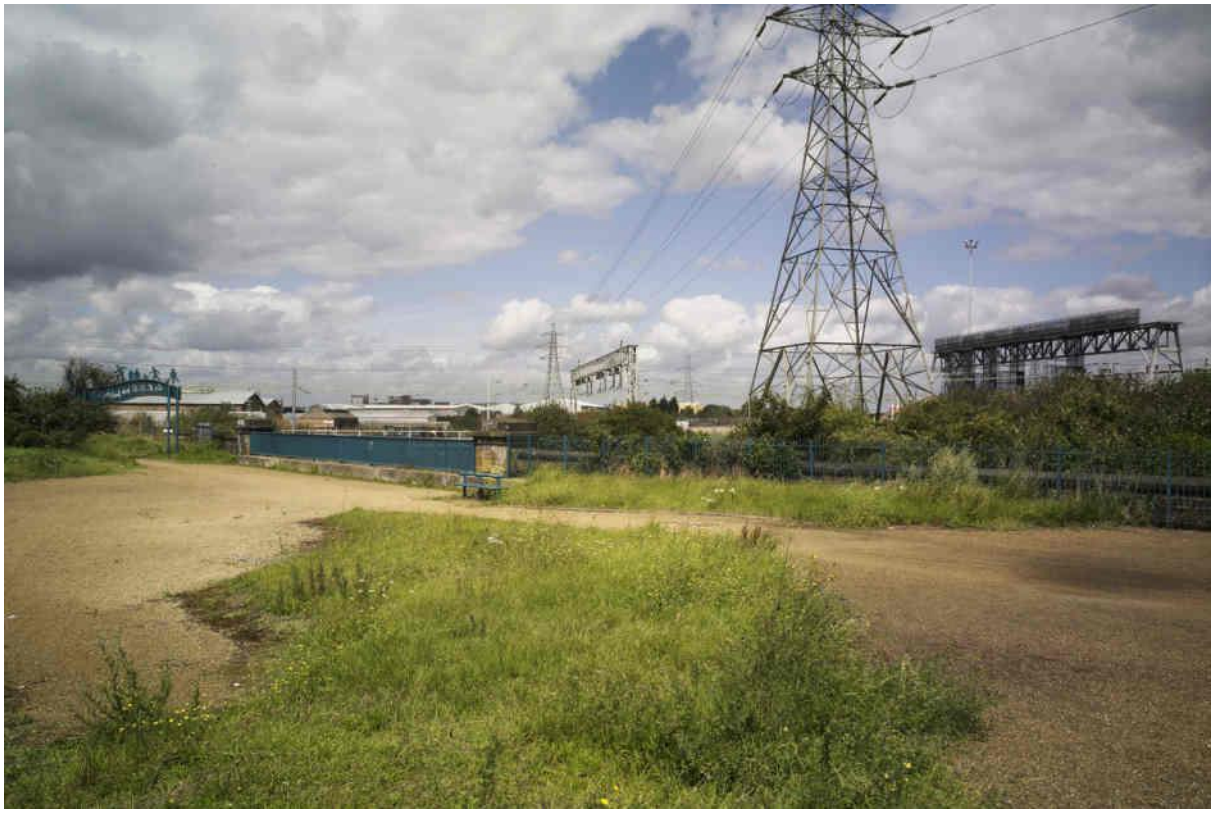
[8] Resilience addresses the capacity of a system to absorb shocks and disturbances and undergo change in order to maintain approximately the same identity (see Annex 2d for further details)

[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[17]

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[18]. 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)[19], 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.

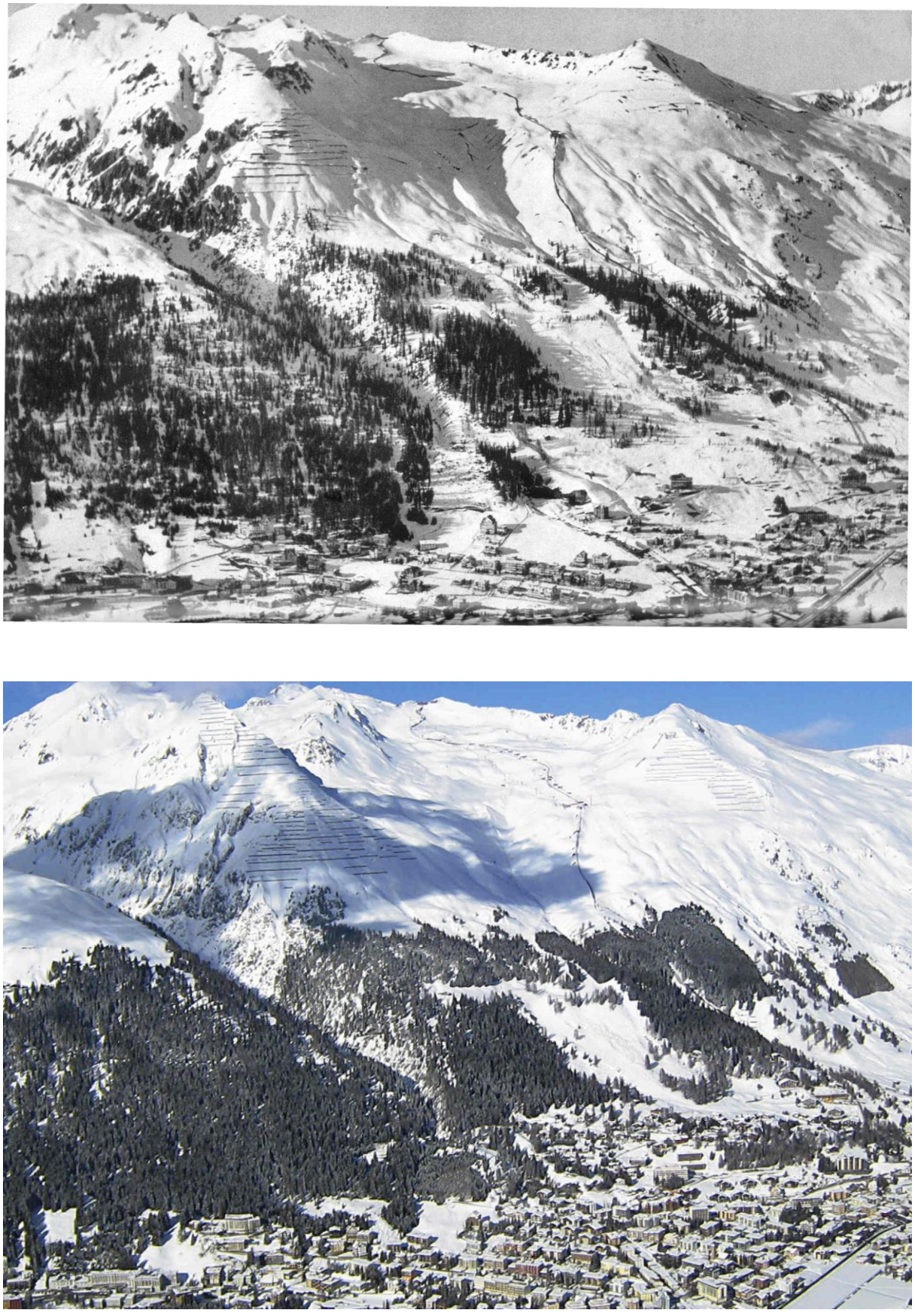
Nature-based solutions also offer synergies in reducing multiple risks (for example drought and floods) and meet the objectives of different European regulations, for instance the Flood Directive and the Water Framework Directive, as well as contributing to climate change adaptation and mitigation. A 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°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] See Annex 2d for further information

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

[19] 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.

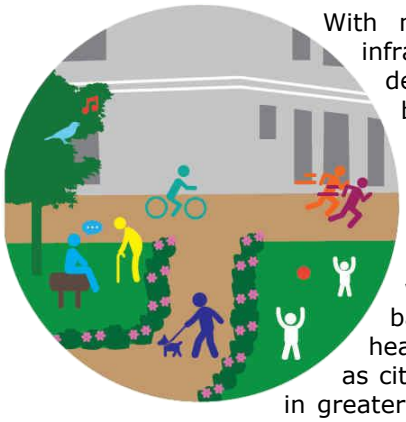
Urban regeneration through nature-based solutions

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)[20] 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[21], 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[22]. 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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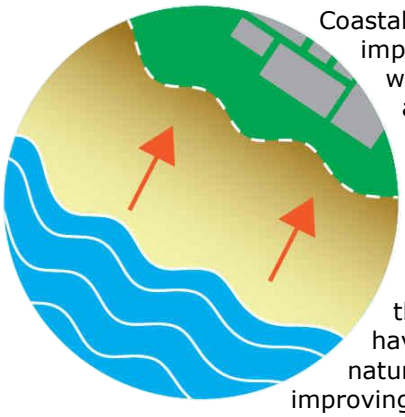
[20] The LowLine (2015) http://www.thelowline.org/about/project
[21] UN (2014) http://esa.un.org/unpd/wup/Highlights/WUP2014-Highlights.pdf
[22] Coley, R.L., Kuo, F.E., and Sullivan, W.C. (1997) Environment and Behavior, 29, 468-494, and Wacquant, Loïc (2010) 'Urban Outcasts', Polity Press.

economic benefits, equivalent to £800 per person, through social benefits and reduced health risks[23]. 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[24]. 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[25]. 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[26]. 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[27] 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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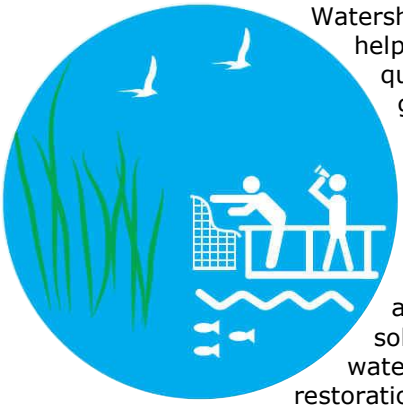
[23] CJC Consulting (2005) Green Spaces for Physical and Mental Health: Scoping Study. Forestry Commission report.
[24] Hartig, T. et al. (2014). Annual Review of Public Health, 35, 207-228.
[25] Landscape Institute (2013) Public Health and Landscape: Creating Healthy Places, Landscape Institute, UK
[26] 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.
[27] 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.

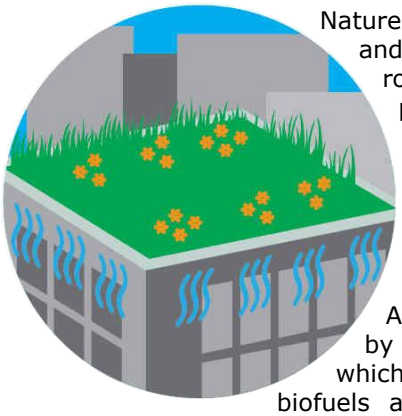
Multi-functional nature-based watershed management and ecosystem restoration



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[28]. 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[29] 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[30].

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[31]. Regarding manufacturing, room temperature "growing materials" using mycelium and organic waste have been recently commercialised[32], as well as nature-based 3D printing techniques[33].

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[34]. Several studies currently address the possibilities of copying atmospheric

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

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

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

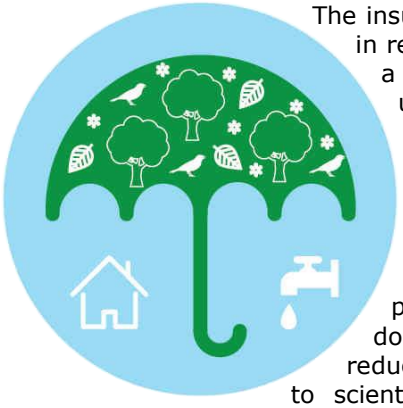
[31] Swiegers, G. (2012) Bioinspiration and Biomimicry in Chemistry,

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

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

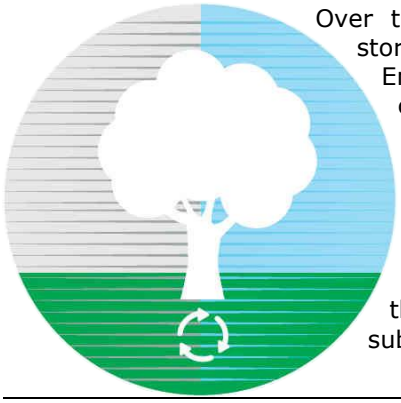
carbon photosynthetic sequestration for fuel production (methanol and methane)[35]. Also, bacteria can be used in the breakdown of organic matter to produce biomethane and cars fuelled on biomethane are more efficient than those run on petrol or diesel.

Nature-based solutions and the insurance value of ecosystems



The insurance value of ecosystems[36] 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[37]. 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} [38]. Biobased

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

[35] 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.

[36] 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.

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

[38] Parr, J.F. and Sullivan, L.A. (2011) Phytolith occluded carbon and silica variability in wheat cultivars. Plant Soil, 342, 165–171.

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[39,40].

[39] CO2SolStock - Biobased geological CO2 storage (2013) http://co2solstock.org/
[40] 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 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. 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):

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[41]. 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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[41] 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[42]. Not only does the rapid urbanisation process affect the availability of resources in European cities, but it also poses challenges to equitable economic growth[43]. 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[44], new technologies[45], new business models[46] 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[47].
- 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[48]. 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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[42] UN (2014) http://esa.un.org/unpd/wup/Highlights/WUP2014-Highlights.pdf
[43] 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
[44] European Commission (7th of July 2014). The urban dimension of an EU policy- key features of an EU urban agenda
[45] McCormick, K., Anderberg, S., Coenen, L., & Neij, L. (2013). Advancing sustainable urban transformation. *Journal of Cleaner Production*, *50*, 1-11.
[46] 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.
[47] Hartig, T., Mitchell, R., de Vries, S., & Frumkin, H. (2014). Nature and health. Annual Review of Public Health, 35, 207-228.
[48] 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[49], new technologies[50] and new business models[51]. 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%[52], with a 12% reduction in energy demand reported for a green roof in the Mediterranean region[53], 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[54]. 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[55]. 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[56].
- Living close to green space has a positive influence on several general health indicators for (including perceived health, stress and disease morbidity)[57] 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[58].

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*

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[49] European Commission (7th of July 2014). The urban dimension of an EU policy- key features of an EU urban agenda
[50] McCormick, K., Anderberg, S., Coenen, L., & Neij, L. (2013). Advancing sustainable urban transformation.Journal of Cleaner Production, 50, 1-11.
[51] 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.
[52] Bigham, R. (2011). The Little Details. Pollution Engineering, 43(4): 7-7.
[53] 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.
[54] 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.
[55] 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.
[56] Gill, S.E. et al. (2007) Adapting cities for climate change: the role of the green infrastructure. Built Environment, 33:115-133.
[57] Hartig, T. et al. (2014) Nature and health. Annual Review of Public Health. 35:21.1–21.22.
[58] Natural England (2009) Our Natural Health Service: The role of the natural environment in maintaining healthy lives. Natural England Report, Sheffield.

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[59]. 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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[59] 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.

ANNEX 3: EVIDENCE BASE AND POSSIBLE INTERVENTIONS IN NATURE-BASED SOLUTIONS

A suggested methodology for evidence-based policy making

The aim of nature-based solutions is to help societies address a variety of environmental, social and economic challenges. In this annex we examine how this can be done most cost effectively by efficient use of research and innovation. This process entails co-designing knowledge and the co-implementation of results as an iterative process involving researchers, practitioners and other stakeholders.

Research shows that conservation practitioners often make little use of the published evidence (just for 2.1% of decisions[60]) for a range of reasons, including most being behind paywalls, shortage of time and the challenges of extracting practical advice from academic papers. When the results of research are presented in a palatable manner then it often results in changes in the decisions they make[61].

A serious challenge is the mismatch between the policies and the evidence. The solution is to separate the general objectives into specific interventions[62]. For example, the broad objectives of greening cities to reduce pollution, noise and improve health and investment will actually be implemented through a wide range of interventions, such as planting trees to reduce air pollution, encouraging green roofs and walls, creating attractive green spaces for exercise and restoring derelict land. Each of these can then be further separated. For example, there are a wide range of means for creating green roofs. It is then possible to use the evidence to assess the most cost-effective means of delivering these.

Delivering evidence-based nature-based solutions requires using the evidence to answer three key issues:

i. Is the proposed measure effective in addressing the problem? For example, how effective is tree planting in reducing air pollution? How does this differ between different tree species? How does this differ between different spacing patterns?
ii. What are the most effective means of establishing and maintaining the green solution? For example, what is the success of the various means of establishing green roofs?
iii. How does the effectiveness change with local conditions? Many will vary according to the climate, local ecology or societal variation.

The challenge is then to systematically review the evidence, assess its relevance and quality, and then make this available to practitioners.

Without this accessible evidence base there is a serious risk that considerable funds will be spent on activities that are not effective. This is well known in medicine, but there are also examples related to the natural environment. Similarly, for agri-environment schemes, for which €24 billion had been spent between 1994 and 2002, the effectiveness was mixed, with 6% showing decreases, 23% showing no change and 17% a mixed response[63]. Other examples include ineffective interventions for the conservation of bats[64],[65];[66], counter-effective habitat management

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[60] Sutherland, W.J. et al (2004) The need for evidence-based conservation. Trends in Ecology and Evolution, 19, 305-308

[61] Walsh, J.C. et al (2014) Conservation practitioners make more effective management decisions after reading scientific evidence. Conservation Biology online early

[62] Pullin, A.S., Knight, T.M. and Watkinson, A.R. (2009) Linking reductionist science and holistic policy using systematic reviews: unpacking environmental policy questions to construct an evidence-based framework. Journal of Applied Ecology, 46, 970-975.

[63] Kleijn, D. & Sutherland, W.J (2003) How effective are European agri-environment schemes in conserving and promoting biodiversity? Journal of Applied Ecology, 40, 947-969

[64] Abbott, I.M., F. & Harrison, S. (2012) When flyways meet highways – The relative permeability of different motorway crossing sites to functionally diverse bat species. Landscape and Urban Planning. 106, 4293–302

[65] Berthinussen A. & Altringham J. (2012) Do bat gantries and underpasses help bats cross roads safely? PLoS ONE, 7, e38775

[66] Berthinussen, A., Richardson, O.C. & Altringham, J.D. (2014). Bat Conservation. Global evidence for the effects of interventions. Pelagic Publishing

for amphibians in the USA[67] [68],[69]and ineffective government timber harvesting guidelines for protecting the Siberian flying squirrel[70].

The current best practice in assessing evidence is a four stage process.

1. The first stage should be a collation of the possible interventions, with the objective of being as comprehensive as possible (e.g. Sutherland et al. 2014[71]). These should be detailed, for example, listing all the possible means of reducing flood risk through changes in land management. A reasonably comprehensive list has already been made by the expert panel (see end of this Annex), but this needs some more work.
2. The interventions need to be prioritised according to the likelihood of being implemented, for example, those that relate to urban environments are likely to be considered a priority.
3. The published literature needs to be reviewed in a systematic and unbiased manner with the relevance and quality of the evidence assessed. The extent to which local environmental or social conditions modifies effectiveness needs to be determined, so it is possible to produce local solutions to local conditions.
4. The results should be synthesised and presented to practitioners in a manner that can be used readily by a wide range of individuals, for example through existing web sites. In effect, this will result in an online resource provided recommended evidence-based practice for different interventions under different conditions.

The results of this assessment can then be used to direct research and innovation. Practitioners, policy makers and researchers can then be brought together to identify the gaps in knowledge where the requirement of practitioners is poorly met by the scientific literature[72],[73]. Innovation plays a critical role where satisfactory solutions are lacking or where existing methods can be improved. The knowledge gaps can be targets for future research funding.

We suggest that the proposals should be designed so that they test those promising interventions and innovations for which evidence is insufficient. The design should be scientifically rigorous with appropriate use of controls and sufficient replication. Randomised, replicated, controlled trials are the strongest study designs for evaluating the effectiveness of interventions[74],[75]. Sites treated with the intervention must be compared with controls, which are either sites not treated with the intervention, or the same sites before the intervention is implemented compared with afterwards. Sample sizes must be large enough to determine whether there is a significant difference between treatment groups. Achieving large sample sizes is often impossible if the interventions need to be carried out at separate sites, on threatened individuals or in protected areas. Therefore, the best strategy is to replicate the experiment as many times as is feasible, given time and cost constraints. Results from such studies can be fed back into the evidence base so improving further practice and ensuring that these experiences are shared widely within Europe, but also even more widely through, for example, the growing global research community within Future Earth who are applying this approach[76].

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[67] Bailey, M.A. et al. (2006) Habitat Management Guidelines for Amphibians and Reptiles of the Southeastern United States, Technical Publication HMG-2, Partners in Amphibian and Reptile Conservation (PARC)

[68] Dicks L.V. et al (2014) Organising evidence for environmental management decisions: a '4S' hierarchy. Trends in Ecology and Evolution, 29, 607-613

[69] Smith, R.K. and Sutherland, W.J. (2014) Amphibian Conservation: Global Evidence for the Effects of Interventions, Pelagic Publishing

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[71] Sutherland, W. J. et al (2014) Solution Scanning as a Key Policy Tool: Identifying Management Interventions to Help Maintain and Enhance Regulating Ecosystem Services. Ecology and Society, 19 (2), 3

[72] Dicks, L.V., et al (2013a) Identifying key knowledge needs for evidence-based conservation of wild insect pollinators: a collaborative cross-sectoral exercise. Insect Conservation and Diversity, 6, 435-446

[73] Dicks, L.V. et al (2013b) What do we need to know to enhance the environmental sustainability of agriculture? A prioritisation of knowledge needs for the UK food system. Sustainability, 5, 3095-3115.

[74] Eccles, M., Grimshaw, J., Campbell, M. and Ramsay, C. (2003) Research designs for studies evaluating the effectiveness of change and improvement strategies. Quality and Safety in Health Care, 12, 47-52.

[75] Coalition for Evidence-Based Policy (2007) Hierarchy of Study Designs for Evaluating the Effectiveness of a STEM Education Project or Practice. Coalition for Evidence-Based Policy, Washington, USA.

[76] See http://www.futureearth.org/impact

We make two recommendations:

1. That, as a coordination and support action, the evidence on the effectiveness of key nature-based solutions is systematically assessed as soon as possible, building on existing initiatives. This should ideally be prior to the main projects being implemented to make the subsequence action 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.

Nature-based solutions – a preliminary list of possible interventions

The aim of this list (developed and extended from Sutherland et al., 2014[77]) is to provide an initial classification of the possible interventions that could be applied when constructing nature-based solutions. This is simply those interventions that are used or have been suggested. Inclusion here does not mean they have been tested or shown to be effective.

AIR QUALITY REGULATION

This section considers interventions to maintain non-climate related services concerned with air quality, including the extraction of chemicals such as particulates and direct air contaminants, and the emission of chemicals.

Forests

1. Protect and expand forested area to absorb gaseous pollutants and trap particulates.

Coastal areas

2. Maintain vegetation in coastal wetlands, especially mangrove systems, to absorb gaseous pollutants and trap particulates.

Agricultural land

3. Plant shelter belts to absorb gaseous pollutants, intercept aerosols from pesticides and trap particulates.
4. Use soil conservation measures (such as cover crops, wind breaks and minimum or conservation tillage) to reduce wind erosion and hence airborne particulates.

Urban settings

5. Protect urban green spaces, to absorb gaseous pollutants and trap particulates.
6. Plant trees alongside roads to trap particulates.

CLIMATE REGULATION

This section covers interventions relating to the control of greenhouse gases (particularly carbon dioxide, methane and nitrous oxide), through reducing emissions and/or enhancing removal of such gases from the atmosphere. It incorporates more local climatic controls, such as ecosystem controls over temperature or precipitation. Ecosystem services relating to impacts of climate change such as storm surges and sea level rise are considered under natural hazard regulation.

[77] Sutherland, W. J. et al (2014) Solution Scanning as a Key Policy Tool: Identifying Management Interventions to Help Maintain and Enhance Regulating Ecosystem Services. Ecology and Society, 19 (2), 3.

Forests

7. Protect the area and condition of existing forest areas from clearing and degradation from logging, fire and unsustainable levels of non-timber resource extraction.
8. Adopt reduced impact logging techniques (including logging inventories, directional felling, liana clearance, low-impact extraction techniques, retention of roots, off-cuts and dead wood) in forestry operations to reduce collateral damage from timber extraction.
9. Reforest degraded land and encourage benign abandonment of low productivity or disused land.
10. Encourage enrichment planting in degraded and regenerating forests.

Terrestrial wetlands

11. Maintain and enhance natural wetlands.
12. Install dams in drains to restore degraded peatlands and avoid further drainage of undisturbed areas.
13. Re-vegetate bare peat to prevent oxidation.
14. Use geo-textiles to arrest peat erosion.
15. Practise controlled removal of peatland vegetation or use appropriate grazing to reduce the risk of wild-fire.
16. Avoid planting forests on peat.
17. Limit use of fire in agriculture on or near peat soils.
18. Avoid over-grazing of vegetation.

Coastal areas

19. Protect remaining intertidal muds, saltmarshes and mangrove communities, seagrass beds and vegetated dunes from further degradation, fragmentation and loss.
20. Re-establish and restore previous intertidal habitat by de-poldering or coastal realignment.
21. Prohibit new aquaculture developments in intertidal areas.
22. Restore micro-topography, creek networks, sediment inputs and nutrient exchange in abandoned aquaculture ponds.
23. Create new intertidal habitat through planting of mangroves, saltmarsh or seagrass at appropriate elevations in the tidal frame.
24. Enhance or facilitate habitat expansion, including the facilitated range expansion of mangroves, as warming conditions and changes in storm occurrence permit.
25. Establish appropriate levels of saltmarsh grazing pressure to stimulate below-ground biomass production and carbon uptake.
26. Encourage development of early successional sand dune habitats (dry dunes and wet slacks) where carbon sequestration rates are high.
27. Restore or enhance sediment supplies from river or coastal sources to encourage carbon sequestration by coastal wetlands.

Marine environment

28. Fertilise oceans to increase carbon removal and deep ocean storage through enhanced phytoplankton productivity.

Agricultural land

29. Use soil conservation measures (such as cover crops, wind breaks, deep-rooted plants and minimum or conservation tillage) to enhance storage of soil carbon.
30. Produce and integrate biochar into agricultural soils.
31. Reduce management intensity on permanent grassland (in particular reduce fertilizer inputs) to promote botanically-diverse swards and enhance carbon sequestration to soil.
32. Promote inter-cultivation in perennial and agroforestry cropping systems with deeper rooting systems that create carbon stocks.
33. Provide herbicide-free strips in orchards and vineyards to increase carbon sequestration.
34. Reintroduce or enhance populations of deep-burrowing (anecic) worms to help sequester carbon.
35. Increase soil organic matter by incorporating green manure, slurry or incorporating crop residues to enhance carbon storage.
36. Reduce stocking rates of livestock.
37. Grow crops with a lower harvest index so more biogenic carbon is returned to the soil
38. In seasonal environments, use supplementary animal feed from on-farm crops, such as maize and sugar cane, to reduce soil erosion.
39. Use sub-soil drainage to reduce emissions of nitrous oxide from wet soils.
40. Adjust soil pH and add lime to enhance organic storage.
41. Reduce use of chemical pesticides that have adverse effects on soil microflora.
42. Avoid conversion of permanent grassland to arable.
43. Change sowing date.

Urban settings

44. Protect urban green spaces to store carbon.

WATER FLOW REGULATION

Interventions that support the role of ecosystems in altering the magnitude and timing of water runoff and flooding as well as the recharge of aquifers (see also natural hazard regulation for regulator services linked to coastal defence and flooding).

Forests

45. Limit use of heavy machinery in forestry operations to avoid soil compaction.
46. Retain forest cover on steep slopes.
47. Avoid felling operations during rainy seasons
48. Switch plantation forests from coniferous to deciduous to reduce acidification.
49. Plant forests at lower densities.
50. Practise alternatives to clearfell, such as continuous cover forestry.

Terrestrial Wetlands

51. Maintain and enhance natural wetlands.
52. Restore wetlands in areas of groundwater recharge.
53. Re-vegetate bare peat to increase surface roughness.
54. Use geo-textiles to arrest peat erosion.

55. Reconnect rivers with floodplains to enhance natural water storage.

Freshwater

56. Encourage re-vegetation of riverbanks (such as through livestock exclusion, and/or direct planting).
57. Increase up-stream structural diversity (such as through the re-introduction of beavers).
58. Reduce canalisation and create channel diversity to reduce speed of flood transmission.
59. Re-meander rivers (where they have been artificially straightened) to help reduce speed and height of flood peaks.
60. Encourage targeted re-vegetation of riverbanks through livestock exclusion and assisted regeneration.
61. Restore riparian vegetation to assist in reconnecting rivers with floodplains and to provide greater instream ecosystem complexity.
62. Increase up-stream structural diversity (such as through the re-introduction of beavers).
63. Reduce canalisation and create channel diversity to reduce speed of flood transmission.

Coastal areas

64. Re-connect river systems to coastal wetlands through controlled breaching of river levees or construction of river control structures that allow periodic flooding of wetlands.

Agricultural land

65. Use soil conservation measures (such as cover crops, wind breaks, deep-rooted plants and minimum or conservation tillage) to increase soil structure and infiltration rates.
66. Increase soil organic matter by incorporating green manure, slurry or incorporating crop residues to increase water infiltration (although high quantities of soil organic matter can lead to soil complexes with impeded drainage).
67. Reduce soil-water repellency (e.g. avoid burning, and enhance soil microbial activity) to limit run-off and increase soil-water capture.
68. Plant trees / hedges /perennial grass strips to intercept surface run-off.
69. Reduce stocking rates of livestock.
70. Reduce soil compaction by machinery, by reducing machinery use, using lighter machinery, low pressure tyres or controlled traffic techniques
71. Alleviate soil compaction by sub-soiling.
72. Plant biomass crops in locations where they can enhance water interception (such as slopes).
73. Increase average sward heights in pasture to reduce surface run-off, perhaps by adjusting stock type or density.
74. Use cultivars with deeper rooting systems to maximise rainfall use.
75. Balance the use of evergreen and deciduous trees to enhance seasonal water regulation.
76. Modify cultivation practices (e.g. siting of animal feed sites, ploughing regimes) to avoid ready downslope transfer and loss of water.
77. Reduce use of chemical fertilisers where they reduce soil organic matter.

Urban settings

78. Plant green roofs/walls to encourage interception of rainfall.

79. Establish rain gardens (planted depressions or swales allowing runoff from impervious urban areas to be absorbed).
80. Greater use of balancing ponds to contain surges and release water slowly.
81. Use underground water storage systems.

EROSION REGULATION

Interventions to maintain restore or enhance the role of ecosystems in reducing erosion of soil and sediments and in encouraging maintenance or growth of the same.

Forests

82. Retain and restore forest cover on steep slopes.
83. Retain vegetation on margins of water courses.
84. Limit use of heavy machinery in forestry operations.
85. Carry out felling or forest clearance at appropriate seasons.
86. Leave leaf litter and dead wood on the forest floor, prohibit or limit salvage logging.
87. Practise alternatives to clearfell, such as continuous cover forestry.

Terrestrial wetlands

88. Re-vegetate bare peat to prevent peat oxidation.
89. Use geo-textiles to arrest peat erosion.
90. Practise controlled removal of vegetation to reduce the risk of wild-fire.

Freshwater

91. Encourage re-vegetation of riverbanks (such as through stock exclusion, and/or direct planting).
92. Increase up-stream structural diversity.
93. Re-establish and/or encourage beaver populations.
94. Manage sediment problems (fine and coarse) at source (e.g. on agricultural land) rather than through dredging.
95. Replace hard engineered river stabilisation with softer alternatives (e.g. willow-based).
96. Allow for natural erosion processes rather than trying to prevent them (e.g. set back river defences and allow natural river migration within the defence line).

Coastal areas

97. Protect remaining intertidal muds, saltmarshes and mangrove communities, seagrass beds and vegetated dunes from further degradation, fragmentation and loss.
98. Re-establish and restore previous intertidal habitat by depoldering or coastal realignment to increase resilience to wind and storm waves.
99. Encourage increased use of mangroves within and around existing extensive tropical aquaculture ponds.
100. Retain coastal forest and beachridge vegetation to minimize sedimentation problems on nearby reefs.
101. Create new intertidal habitat through afforestation, or planting of saltmarsh or seagrass at appropriate elevations in the tidal frame.

102. Maintain, restore and create coastal wetlands of sufficient areal extent to allow natural cycles of erosion/sedimentation to compensate one another within the wetland complex.
103. Re-connect river systems to coastal wetlands through breaching of river levees or river control structures to re-introduce river sediments to coastal wetlands.
104. Introduce dredged spoil material from estuarine waterways to coastal wetland surfaces.
105. Allow erosion of soft rock cliffs (cease armouring and stabilization), coupled to un-interrupted alongshore sediment transport, to supply coarse sediments to beaches and offshore banks and fine sediments to coastal wetlands.
106. Allow natural alongshore dynamics of large-scale coastal sediment accumulations (nesses, spits and cuspate forelands). Assist if necessary with sand and gravel by-passing and re-charge operations.
107. Use beach nourishment (repetitive artificial replenishment of beaches) to rebuild eroding beaches.
108. Maintain dunes and the beaches fronting them, in part by allowing sediment exchange across beach-dune boundaries.
109. Actively repair and construct sand dunes.
110. Adopt measures for topsoil inversion and deliberate dune destabilization (including introduction of appropriate grazing levels) to rejuvenate stabilized dune systems.
111. Control groundwater abstraction that affects water and nutrient flows through wetlands and accelerates subsidence.
112. Reduce direct threats to biogenic reefs (notably coral reefs, but also shellfish, vermitid and algal reefs) from unsustainable fishing practises.
113. Reduce proximate and remote threats to reefs from watersheds through appropriate measures to minimize agricultural chemicals, livestock waste, urban and industrial effluents entering rivers and estuaries.
114. Restore or create shellfish reefs in coastal locations where they may enhance sediment deposition
115. Restore or enhance coral reef growth or recovery using artificial substrates, electro-accumulation or coral transplantation at reef scales.
116. Avoid construction work in tropical wet seasons to minimize excessive terrestrial sediment inputs into the nearshore zone.
117. Control anchoring through provision of fixed moorings and anchorage zones in areas of soft sediments to reduce structural damage to reefs.
118. Locate access channels through reefs to minimize impact on reef hydrodynamics and sediment transport.

Agricultural land

119. Encourage ploughing across rather than down slopes subject to floods.
120. Use strip tillage.
121. Plant cover crops in inter-row strips.
122. Maintain permanent plant or crop residue cover.
123. Use minimal tillage / direct drilling to increase soil structure and infiltration rates.
124. Avoid harvesting in wet conditions.
125. Reduce soil compaction by machinery, by reducing machinery use, using lighter machinery, low pressure tyres or controlled traffic techniques.
126. Plant trees / hedges /perennial grass strips to intercept surface run-off.
127. Provide livestock with hard-standing access to watercourses to prevent erosion of stream-banks.

128. Provide livestock with water pumped to troughs set away from water bodies, to prevent erosion of stream-banks.
129. Reduce stocking rates of livestock (e.g. through pasture rotation) and consider timing of grazing, to prevent over-grazing.
130. Control over-abundant wildlife to reduce competition for grazing and overall grazing pressure.
131. Encourage soil management practices to develop surface-vented macropores to trap surface-ponded and reduce runoff by routing water into the rootzone.
132. Include buffer strips and site farm gates to prevent eroded material leaving fields.
133. Install small dams in ditch systems, to prevent eroded material leaving farmland.

Urban settings

134. Use phytoremediation and phytostabilisation on contaminated sites.
135. Use of permeable surfaces and vegetation where possible in hard landscape construction.

WATER PURIFICATION AND WASTE TREATMENT

Interventions to enhance the role of ecosystems in removing chemical and particulate compounds from the water, including the breakdown of toxic wastes and the assimilation of chemicals and particulates into soils or marine sediments.

Terrestrial Wetlands

136. Use engineered reedbeds/wetlands for tertiary treatment of effluent.
137. Target ponds/wetland creation to trap sediment/pollution runoff in farmed landscape.
138. Create marginal wetlands to trap and/or cycle nutrients.
139. Dam to restore upland bogs to reduce dissolved and particulate organic carbon and coloured humic substances leaving catchments.
140. Replant wet woodland to provide enhanced nutrient uptake.
141. Re-vegetate bare peat.

Coastal areas

142. Protect remaining intertidal habitats, especially saltmarshes and mangroves,
143. Re-establish and restore previous intertidal habitat by depoldering or coastal realignment to reduce particulate contamination of water, eutrophication and toxic pollution in coastal waters.
144. Encourage increased use of mangroves within and around existing extensive tropical aquaculture ponds.
145. Restore or create shellfish reefs to restore active filtration of suspended sediments and removal of nitrates and other pollutants.

Marine environment

146. Use bioremediation at locations of intense pollution, notably oil spills, through nutrient amendment (biostimulation), bioaugmentation, photoremediation and oxygen enhancement.

Agricultural land

147. Plant trees/hedges/perennial grass strips to increase nutrient uptake.

148. Plant biomass crops in locations where they can enhance nutrient uptake.
149. Restore grassland/low input arable in drinking water catchments.
150. Intercrop with legumes.
151. Increase soil organic matter by incorporating green manure, slurry or incorporating crop residues to enhance carbon storage.
152. Produce and integrate biochar into agricultural soils.
153. Use hyper-accumulator phytoremediation plants to remove contaminants from the soil, or to reduce their bioavailability.
154. Reduce use of veterinary pharmaceutical products including antibiotics and hormone regulators/growth promoters.

Urban settings

155. Create ponds and wetlands to collect, store and clean water before gradual release into water courses (Sustainable Urban Drainage Systems).
156. Reduce output and improve treatment of industrial and municipal effluent through biodegradation and bioconversion.
157. Improve remediation of wastes before disposal in soil or water by greater use of biological, physical and chemical methods.
158. Improve treatment of contaminated land through phytoremediation.

DISEASE REGULATION

Following the Millennium Ecosystem Assessment, this section covers regulation of human infectious diseases, hosts and vectors. We used the criteria: does this intervention enhance or protect the capacity of the ecosystem to regulate human diseases? Interventions to enhance regulation of diseases of crops and trees are included under Pest Regulation.

Forests

159. Remove invasive plants, with particular attention to those that are favourable environments for ticks and other vectors, Or that present risks for poisoning or other harm through ingestion or contact.
160. Protect and expand forested area to maintain species diversity in order to reduce disease transmission either via predator-mediated control or dilution of competent hosts.
161. Construct habitat corridors to promote predator populations over large areas in order to regulate host populations.

Agricultural land

162. Reduce use of veterinary pharmaceutical products including antibiotics and hormone regulators/growth promoters.
163. Use soil conservation measures (such as cover crops, wind breaks and minimum or conservation tillage) to reduce wind erosion and hence airborne particulates.
164. Reduce stocking rates of livestock to minimise opportunity for pathogen spillover and pressures on virulence/selection.
165. Plant fruit trees or provide other forms of roosting and feeding habitat (for bats) away from livestock areas in order to minimise transmission opportunities
166. Reduce agrichemical inputs to reduce development of pest resistance and to maintain biodiversity in target and non-target systems, especially aquatic systems.
167. Provide bat houses and bird feeders to promote establishment of species for mosquito (or other insect vector) regulation.

168. Improve the connectivity of non-crop habitats to enhance dispersal of predators of disease host species.

169. Decrease the level of land-use intensity in the landscape, e.g. through large-scale conversion to organic farming.

170. Reduce sources of standing water and hence limit the establishment of vector populations.

Urban settings

171. Reduce output and improve treatment of industrial and municipal effluent through biodegradation and bioconversion.

172. Improve remediation of wastes before disposal in soil or water by greater use of biological, physical and chemical methods.

173. Protect urban green spaces to encourage biodiversity and the establishment of vector-feeding species, in particular.

174. Use permeable surfaces and vegetation where possible in hard landscape construction in order to reduce sources of standing water and limit the establishment of vector populations.

175. Provide bat houses, and bird feeders and housing, to promote establishment of species for mosquito (or other insect vector) regulation.

176. Locate vegetation and other natural features on rooftops and outside of homes to support stress reduction.

PEST REGULATION

Interventions to enhance the role of ecosystems in reducing the damage to crops and livestock caused by pests and diseases. The interventions listed for each habitat type consider regulation of pests or diseases causing damage within that habitat type, but includes interventions both within that habitat and in the surrounding landscape.

Forests

177. Reduce use of insecticides (especially broad spectrum) to maintain abundance and diversity of natural enemies and alternative hosts for entomopathogens.

178. Increase resistance of trees by forest management (e.g. thinning for bark beetle pests).

179. Use natural regeneration with seed trees.

180. Practise continuous cover forestry.

181. Promote mixed tree species stands to increase diversity of natural enemies and to reduce density of host trees for pests.

182. Promote deciduous trees, repellent for conifer insect pests and preferred as food by browsing herbivores, in conifer stands.

183. Avoid high proportion of susceptible age classes of forest stands at the landscape level (e.g. over-mature conifer stands susceptible to bark beetle attacks).

184. Use dispensers releasing attractants to enhance densities of natural enemies and competitors at attacked trees or stands.

185. Enhance densities of generalist natural enemies, and competitors, by providing breeding substrates exclusively utilized by non-pest prey species (e.g. tree species or parts of cut trees).

186. Avoid sanitation cutting of trees from which pests have emerged while natural enemies remain.

187. Avoid thinning to reduce the risk for infestation of the stand by pathogens (e.g. root rot).

188. Plant a diverse range of nectar and pollen-providing plants (including shrubs) to increase efficacy of omnivorous natural enemies.

189. Use food spray to increase efficacy of omnivorous natural enemies.

190. Release native natural enemies or competitors (augmentative biological control) to increase their population sizes.

191. Favour large predators (e.g. by reducing hunting) to reduce populations of browsing herbivores.

Agricultural land

192. Create grass margins / beetle banks to promote predatory invertebrates.

193. Leave field margins unsprayed and uncropped.

194. Divide crops into smaller areas.

195. Increase the perimeter-to-area ratio of agricultural fields to facilitate spillover of natural enemies of agricultural pests.

196. Rotate crops to reduce build-up of crop-specific pests and pathogens.

197. Deploy flower strips, or plants with extra-floral nectaries to promote omnivorous natural enemies (e.g. parasitoids and hoverflies).

198. Use mulching to provide shelter and alternative food for natural enemies, and to suppress weeds.

199. Intercrop with plants that repel or confuse pests and/or attract natural enemies and that reduce dispersal of pathogen propagules.

200. Plant a trap crop that is more attractive to the pest than the crop.

201. Use push-pull technique: combining plants repellent for the pest within the field with attractive plants (trap crop) around the field.

202. Conduct periodic harvesting, leaving strips of the crop as refuges for natural enemies.

203. Plant a cover crop that maintain populations of natural enemies in the crop, make it more difficult for pests to locate crops, reduce dispersal of plant pathogens and suppress weeds.

204. Reduce tillage to conserve soil-dwelling natural enemies.

205. Reduce use of insecticides (especially broad spectrum), to maintain abundance and diversity of natural enemies and alternative hosts for entomopathogens.

206. Reduce herbicide use to increase the availability of nectar, pollen and alternative prey for natural enemies of agricultural pests.

207. Provide bird perches for predatory birds to rest and to look for prey.

208. Ploughing under of live (green manuring) and dead organic material to provide shelter and alternative food for natural enemies of pests and to make the soil more suppressive against plant pathogens.

209. Provide holes in the soil to enhance habitat for spiders.

210. Practise timely cutting of non-crop plants utilized by natural enemies (for food, shelter etc) to encourage dispersal into the crop.

211. Use dispensers releasing attractants to enhance densities of natural enemies and competitors in the crop.

212. Use artificial food-sprays (carbohydrates and protein) to enhance food availability for natural enemies within the crop.

213. Release native natural enemies or competitors (augmentative biological control) to increase their population sizes.

214. Provide set-aside areas of natural habitat on farmland.

215. Increase heterogeneity in agricultural landscapes, including natural habitat remnants.

216. Improve landscape-scale connectivity between natural or non-crop habitat remnants to enhance dispersal of natural enemies of pests.

217. Increase the availability of shelter belts, hedgerows and other woody habitats in the landscape to provide habitat for natural enemies.
218. Manage hedges and habitat corridors to benefit natural enemies (keep unsprayed, fill gaps, plant flowering hedge plants).
219. Increase the availability of perennial crops in the landscape (e.g. through crop rotation with ley) to enhance natural enemies.
220. Decrease the level of land-use intensity in the landscape, e.g. through large-scale conversion to organic farming.
221. Restore flower-rich natural habitats such as species-rich grassland in farmed areas (including linear sites such as road verges, beneath power lines or on field margins) to benefit omnivorous natural enemies of pests.

POLLINATION

Interventions to maintain or enhance biodiversity-mediated pollination.

Forests

222. Protect existing areas of forest from further clearance or degradation
223. Restore natural forests through managed regeneration or benign abandonment.
224. Maintain areas with open under-storey and gaps in forests/woodland.
225. Protect large native trees.
226. Conserve dead and down trees as nesting sites.

Agricultural land

227. Restore flower-rich natural habitats such as species-rich grassland in farmed areas (including linear sites such as road verges, beneath power lines or on field margins).
228. Change intensity of grazing, cutting or burning to increase flowering.
229. Reduce shrub cover through grazing, cutting or burning.
230. Protect and enhance trees/hedges/perennial grass strips to provide suitable materials or vegetation for bee nesting and hibernation.
231. Provide set-aside areas of natural habitat on farmland.
232. Increase heterogeneity in agricultural landscapes, including natural habitat remnants.
233. Improve landscape-scale connectivity between natural or non-crop habitat remnants.
234. Manage hedges and habitat corridors to benefit pollinators (keep unsprayed, fill gaps, plant flowering hedge plants).
235. Protect bat roosts, where bats are important pollinators.
236. Create bare ground (well-drained) for ground-nesting bees.
237. Provide soft earth for bees to hibernate in.
238. Use drip- or spray irrigation rather than flooding.
239. Provide nest boxes or nest sites (drilled holes) for cavity-nesting solitary bees.
240. Reduce tillage (benefits ground-nesting bees).
241. Leave field margins unsprayed and uncropped.
242. Plant a diverse range of nectar and pollen-providing plants, as well as caterpillar food plants, and leguminous fallow crops, such as clover.
243. Reduce fertilizer, pesticide and herbicide use generally.

244. Reduce management intensity on permanent grassland (in particular reduce fertilizer inputs).
245. Restrict certain pesticides, such perhaps as neonicotinoids.
246. Apply pesticides at night.
247. Avoid applying pesticides during flowering.
248. Apply pesticides at ground level.
249. Avoid microencapsulated formulations that mimic pollen.
250. Keep bodies of water (ponds and ditches) pesticide-free to provide habitat for pollinating flies, water sources for bats and butterflies, and insect food for hummingbirds.

Urban settings

251. Encourage planting of appropriate resource plants and caterpillar food plants in gardens and municipal areas.
252. Retain areas of rough ground or old built structures for nesting habitat.

DISASTER RISK REDUCTION

Interventions to maintain, enhance or restore the ability of ecosystems to reduce the impacts of natural hazards including storm surges, hurricanes, floods, fires, tsunamis and the impact of rising sea levels.

Forests

253. Protect the area and condition of existing forest areas from clearing and degradation.
254. Impose strict limitations or bans on the use of fire to manage agricultural land adjoining forested areas.
255. Limit or carefully manage salvage logging to prevent dangerous build-up of fuel loads.
256. Reforest degraded land and encourage benign abandonment of low productivity or disused land.
257. Encourage enrichment planting in degraded and regenerating forests.
258. Afforest specific mountainous zones to prevent landslides, avalanches and rockfalls.

Terrestrial wetlands

259. Use wetlands to create emergency flood capacity.
260. Maintain and enhance natural wetlands.
261. Install small dams in surface drains to reduce hydraulic connectivity and improve habitat structure to slow overland flow.
262. Restore floodplain forest or other semi-natural features, such as wet grassland, to increase hydraulic roughness and so slow conveyance and enhance storage of floodplains.
263. Reconnect rivers with floodplains to enhance natural water storage.
264. Practise controlled removal of peatland vegetation or use appropriate grazing to reduce the risk of wildfires.
265. Limit use of fire in agriculture on or near peat soils.

Freshwater

266. Encourage re-vegetation of riverbanks (such as through stock exclusion, and/or direct planting).
267. Restore riparian vegetation to assist in reconnecting rivers with floodplains and to provide greater instream ecosystem complexity.

268. Increase up-stream structural diversity (such as through the re-introduction of beavers, or restoring boulders and large woody debris in upland rivers) to increase flood interception potential.

269. Reduce canalisation and create channel diversity to reduce speed of flood transmission.

270. Re-meander rivers (where they have been artificially straightened) to help reduce speed and height of flood peaks.

271. Relocate dikes to make more space for the rivers.

Coastal areas

272. Protect remaining intertidal muds, saltmarshes and mangrove communities, seagrass beds and vegetated dunes from further degradation, fragmentation and loss.

273. Re-establish and restore previous intertidal habitat by de-poldering or coastal realignment, to provide both renew defence against incident waves and enhance storm water storage.

274. Create new intertidal habitat through afforestation, or planting of saltmarsh or seagrass at appropriate elevations in the tidal frame.

275. Prioritise protection or restoration of mangroves in areas close to human settlement.

276. Set back estuarine defences to enhance storage to accommodate tidal surges.

277. Retain or acquire a coastal buffer zone to allow coastal barriers (gravel ridges, beaches and dunefields) to 'roll-over' landward under sea level rise and storms.

278. Introduce dredged spoil material from estuarine waterways to coastal wetland surfaces.

279. Allow erosion of soft rock cliffs (cease armouring and stabilization), coupled to un-interrupted alongshore sediment transport, to supply coarse sediments to beaches and offshore banks and fine sediments to coastal wetlands.

280. Allow natural alongshore dynamics of large-scale coastal sediment accumulations (nesses, spits and cuspate forelands). Assist if necessary with sand and gravel by-passing and re-charge operations.

281. Use beach nourishment (repetitive artificial replenishment of beaches) to rebuild eroding beaches.

282. Maintain dunes and the beaches fronting them, in part by allowing sediment exchange across beach-dune boundaries.

283. Actively repair and construct sand dunes.

284. Adopt measures for topsoil inversion and deliberate dune destabilization (including introduction of appropriate grazing levels) to rejuvenate stabilized dune systems.

285. Re-connect river systems to coastal wetlands through controlled breaching of river levees or use of river control structures to re-introduce river sediments to coastal wetlands.

286. Control groundwater abstraction that affects water and nutrient flows through wetlands and accelerates subsidence.

287. Afforest specific coastal zones to prevent tsunamis

Agricultural land

288. Plant trees/hedges/perennial grass strips to intercept surface runoff.

289. Use minimal tillage / direct drilling to increase soil structure and infiltration rates.

290. Increase soil organic matter by incorporating green manure, slurry or incorporating crop residues to increase water infiltration.

291. Reduce soil-water repellency (e.g. avoid burning, and enhance soil microbial activity) to limit run-off and increase soil-water capture.

292. Reduce stocking rates of livestock.

293. Reduce soil compaction by farm machinery.
294. Alleviate soil compaction by sub-soiling.
295. Increase average sward heights in pasture to reduce surface run-off, perhaps by adjusting stock type or density.
296. Use cultivars with deeper rooting systems and cover crops to maximise rainfall use and reduce runoff.

Urban settings

297. Increase use of Sustainable Urban Drainage Systems.
298. Put streams in daylight
299. Reduce garden paving.
300. Increase use of green roofs/walls.
301. Increase tree planting in urban locations.
302. Increase use of balancing ponds and underground storage systems.
303. Use permeable surfaces in hard landscape construction to provide aquifer recharge.
304. Increase use of recreative green areas along the river in urban zones to limit potential damages of flooding and to reconnect citizens with rivers and increase people awareness of flood risk.

SOUNDSCAPE MANAGEMENT

This section considers means of reducing the impact of noise on society, focusing particularly on urban settings and areas in the vicinity of motorways.

305. Plant trees/bushes between roads and housing
306. Use running water to mask aversive sounds in public places.
307. Ensure food sources and safe shelter for song birds.

HEALTH

This section considers means of improving physical and mental health in urban settings.

308. Make green spaces attracting to access.
309. Link schools/work to housing through green spaces.
310. Increase biodiversity within green areas (shown to reduce stress).

ANNEX 4: EXAMPLES OF NATURE-BASED SOLUTIONS

While there are many examples of nature-based solutions for addressing a range of different situations (see the range of actions at the end of Annex 4) it is difficult to find examples where the economic, social and environmental benefits are quantified, especially the social and environmental benefits where monetary evaluation is not always applied or traditional economic approaches are not appropriate. Some examples on urban policy and/or business initiatives that aim to promote nature-based solutions are also included.

The Big Tree Plant: urban street trees and community orchards

Theme (s): Sustainable urbanisation, climate change adaptation and mitigation, risk reduction and resilience

Measures: planting of trees along streets and in other urban locations, particularly in economically deprived areas

Short description: The program is motivated by an appreciation of diverse ecological, social and economic benefits provided by urban trees. Trees can help improve air quality and reduce energy consumption by providing cooling shade in the summertime. They are an aesthetic amenity that can support psychologically restorative experiences to residents both when outdoors and when indoors while looking out from their homes. Perhaps for these reasons, trees and other greenery around homes can boost property values. Tree planting and maintenance are understood as community activities that get people out of the house and active, together with their neighbours. The Big Tree Plant program seeks to plant 1 million trees within a period of 5 years (2011-2015).

Costs & benefits: Costs include over 2 million GBP from the Forestry Commission and over 3 million GBP in matching funds. It is hard to give exact figures for monetary benefits, but relevant estimates are available. For example, potential health benefits can be realized via multiple pathways, including air quality improvements, stress reduction, and increased physical activity. Willis and Crabtree (2011) estimate that the annual value of decreased morbidity and mortality from a 1% unit reduction in the percentage of sedentary people in the UK at 1.44 billion GBP, much of this due to reduced mortality from coronary heart disease. Tyrväinen and Miettinen (2000) applied hedonic price analysis to Finnish data to estimate that a dwelling with a view of trees cost roughly 4.9% more than a similar dwelling without tree views.

Location & partners: London and other communities in the UK; further information in reports available at the website below.

Sources and further information:

- Forestry Commission, http://www.forestry.gov.uk/england-bigtreeplant
- Willis K, Crabtree B (2011): Measuring health benefits of green space in economic terms. In Nilsson K, Sangster M, Gallis C, Hartig T, De Vries S, Seeland K, Schipperijn J. (Eds.), Forests, trees, and human health (pp. 375-402). Dordrecht: Springer.
- Tyrväinen L, Miettinen A (2000): Property prices and urban forest amenities. Journal of Environmental Economics and Management 39, 205-223

Sustainable Urban Drainage Systems (SuDS)

Objective/Theme: risk reduction & resilience/sustainable urbanisation

Solutions/measures: increasing infiltration and retention features (NBS, green infrastructure) in urban areas such as permeable surfaces, filter strips, filter and infiltration trenches, green roofs, swales, detention basins, underground storage, wetlands and/or ponds

Short description: A sustainable drainage system (SuDs) is designed to reduce the potential impact of new and existing developments with respect to surface water drainage discharge and entails a sequence of practices and facilities. These practices, which rely on natural processes like evaporation, infiltration, and plant transpiration, can effectively and affordably complement traditional "grey" infrastructure, and provide a wide range of benefits. SuDS substantially reduce the overall amount of water entering local storm sewers or surface waters and reduce flooding-related impacts,

Costs & Benefits: Reduced stormwater runoff and pollution, as well as energy and water treatment costs, diminished impacts of flooding, improved public health, and reduced damages to public infrastructure and associated repair costs and damages to private and public property, creating amenity values in urban areas

Examples:

- In the **stormwater management programme in the City of Philadelphia:** Philadelphia's plan to reduce combined sewer overflows, calls for an investment of $2.4 billion over the next 25 years in public infrastructure (Green City, Clean Waters). The net benefits of using surface techniques has been estimated at almost $3 billion compared with less than $100 million for the piped alternative. The $3bn figure includes many diverse benefits such as: changes to property values; green jobs created; reduction in greenhouse gas emissions; and reduced crime (MWH 2013).
- **Retrofitting SUDS in an urban regeneration area, Augustenborg / Malmö (Sweden):** The total sum invested in the area added up to around SEK 200 million (€22 million). According to Rainwater run-off have decreased by half. The image of the area has improved. Biodiversity has increased by 50 % (green roofs have attracted birds and insects and an open stormwater system provides a better environment for the local plants and wildlife. The impact on the environment decreased by 20 %. Unemployment rate has fallen from 30 % to 6 %. The turnover of tenancies has also decreased by 50 %. Key actors in this initiative include MKB housing company, the City of Malmö as well as individuals (GRABS 2010)
- In the case of **"Severn Trent Water Ripple Effect investigation"** city-wide benefits of retrofitting SuDS through the creation of green streets (not including the benefits relating to a reduction in the number of heat-related deaths, and enhanced biodiversity and health) were quantified at £1.5 billion over 40 years. For the site at Stoney Road, there is a benefit of over £906,000 or 7.5 times the site costs of £121,000. If water reuse infrastructure was added to store and recycle runoff locally for irrigation and toilet flushing, the benefits would increase dramatically to nearly £8.3 billion across the city and nearly £3 million at the site scale (AECOM & Severn Trent Water 2013; MWH 2013).

Location & partners: As identified in the examples above.

Sources and further information:

- Aecom & Severn Trent Water (2013): The Ripple Effect - Building resilience of urban water systems to climate change. Technical Report: The Case for Birmingham and Coventry.
- MWH (2013): CIRIA Research Project RP993. Demonstrating the multiple benefits of SuDS – A business case (Phase 2). Draft Literature Review (October 2013)
- Green City, Clean Waters: http://www.phila.gov/WATER/SUSTAINABILITY/GREENCITYCLEANWATERS/Pages/default.aspx
- GRABS (2010): http://www.grabs-eu.org/membersarea/files/malmo.pdf

Reclaiming urban space from roads

Objective/Theme: Sustainable Urbanisation

Solutions/measures: A) Calle 30 Project & Madrid Rio Project; buried road motorway - restoration of the Manzares River and creation of accompanying areas of green space; B) Seoul Cheonggyecheon River: Removal of two-tier overpass and exposure and restoration of river channel accompanying areas of green space

Short description: A) The Calle 30 Project buried 43km of its M-30 multilane motorway (construction of the world's longest urban tunnel). The Madrid Rio project restored the Manzares River and formed accompanying areas of open parkland, gardens and promenades. The Madrid Rio project ably demonstrates the value in a bold approach to reclaiming urban space from roads to fashion multifunctional urban environments for people that are healthier, quieter and more beautiful and can also promote economic benefits via tourism. B) Mayoral candidate Lee Myung-bak focused his mayoral election campaign on restoring the Cheonggyecheon River in Seoul. The river was erased by a three-lane stretch of elevated highway creating one of the most congested and polluted areas of the city. Following his election the area was completely transformed with the return of the river bringing with it 3 miles of fresh running water with open space and tree-lined pedestrian walkways. Summing up this transformation in his book "What Has Nature Ever Done for Us?", the environmentalist Tony Juniper suggests it reflects a growing appreciation of the essential role that green infrastructure and nature play in city design.

Costs & Benefits:

a. Decrease in noise pollution, greenhouse gas emissions, and accident rates. Increase in quality of life (increased public space, paths and playgrounds for sports and leisure, increased social cohesion, more efficient transport system), environmental benefits include increased the creation of an ecological corridor and increased water quality. Greater mobility. The site has become a first class tourist attraction, and model for other cities. Cost: The Calle 30 Project ~ € 3.7 billion. The Madrid Rio project € 370 million.
b. The park now attracts 64,000 visitors a day. Whilst the beauty of the park is a major draw, this landscape lowers ambient temperatures to 3°C lower than the city average, land prices have soared and biodiversity increased by 639% along this new blue-green corridor. Cost was US $280million.

Location & partners: A) partners: municipality, citizens' outreach program, public-private partnerships with Madrid businesses; B) Seoul, South Korea; Government funded, multi-partner project

Sources and further information:

- http://www.madrid.es/UnidadesDescentralizadas/RelacionesInternacionales/Publicaciones/CatalogoBuenasPracticasIngles/Townplanninginfrastructures/Madrid%20R%C3%ADo%20ENG.pdf
- http://ecrr.org/Portals/27/Cheonggyecheon%20case%20study.pdf
- http://www.fbbva.es/TLFU/microsites/river/pdfs/cap13.pdf

Biotope Area factor

Objective/Theme: Sustainable Urbanisation

Solutions/measures: Local regulation

Short description: The city of Berlin has introduced an effective landscape programme. As a response to the shortage of green space in the city, Berlin developed the 'Biotope Area factor (BAF)' which is a regulation that measures the proportion of green space to the entire development to create more green space within densely built up urban locations. The BAF was formulated for inner-city districts of Berlin by a large number of experts who agreed on the necessary proportion of green space for different development types based on the layout of buildings. The key aim of the BAF is to ensure that a given proportion of a particular site is left undeveloped, i.e., covered by vegetation. The strategy therefore aims to retain high densities of development whilst also developing the city's GI. Whilst the BAF has been introduced into spatial planning as a nature conservation measure, it also improves the microclimate, air quality and impacts of climate change such as the occurrence of heat and the risk of flooding from more intense rainfall.

Costs & Benefits: increasing drainage capacity of urban soils, improved replenishment of the groundwater, reduced pollution caused by run-off, prevention of urban flooding, reducing heat island effect, recreation, provision of plant and animal habitats

Location & partners: Berlin and other partners.

Sources and further information:

- http://www.stadtentwicklung.berlin.de/umwelt/landschaftsplanung/bff/index_en.shtml
- http://www.stadtentwicklung.berlin.de/umwelt/landschaftsplanung/bff/download/Auszug_BFF_Gutachten_1990_eng.pdf

The MA 48's Climate Facade

Objective/Theme: CCAM, sustainable urbanisation

Solutions / measures: to "green" a façade

Short description: The goal of this project was to "green" the façade of a building of the Vienna Magistrate ("MA 48"), an area of 850m^2 within four months, thereby creating ecological niches and habitats for many kinds of insects and birds, and having positive effects on the surrounding indoor and outdoor climates. With this measure, a technical solution (e.g. air conditioning) can be avoided, keeping energy consumption in check and avoiding greenhouse gas emissions and addressing inter alia the "heat island effect". The project functions as a gateway for the implementation of additional measures. In addition, a practical guide for façade greening was developed.

Costs & Benefits: climate regulation in the immediate area, carbon storage, habitat creation and networking, improved quality of life; measurements have shown that the building's heat loss in winter was reduced by up to 50%. The summer cooling through the "green skin" was equivalent to that of about 45 air conditioning units (with 3000 watts and 8 hours of operation each) or four 100-year-old beech trees, which would be required for the entire area of the building.

Location & partner: Vienna Magistrate ("MA 48"),University for Soil Science (BOKU Wien), local population

Sources and further information:

- http://www.gruenwand.at/files/188_Seite_28_Fachzeitschrift_fuer_Architekten_04.2012x.pdf
- http://www.ecologic.eu/sites/files/publication/2014/eco_bfn_nature-based-solutions_sept2014_en.pdf

Planting trees to reduce air pollution and improve health

Objective/Theme: Air pollution is a serious problem with more people moving to towns and cities combined with increased traffic.

Solutions/measures: There are a range of measures including the important one of reducing the source of the pollution. It has become increasingly clear that appropriate tree planting can be effective in reducing levels of air pollution in urban areas.

Short description: Provide incentives to encourage the planning of lines of trees in areas where high densities of pollutants and people coincide

Costs & Benefits: The cost is in the planting of and caring for the trees. Tree species vary considerably in their capacity to reduce air pollution. Some trees species can even emit volatile organic compounds that can contribute to creating polluting gases so having a negative impact. Research in the United States (Nowak et al 2014) assessed the health consequences of trees intercepting particulate matter and absorbing gaseous pollutants. Trees were estimated as reducing air pollution by 17.4 million tonnes (range: 9.0-23.2 million t) in 2010 with benefits including the avoidance of over 850 deaths and 670,000 incidences of acute respiratory symptoms, resulting in a saving of $6.8 billion (range: $1.5-13.0 billion). The benefit of trees for the Greater London Authority was estimated as removing between 852 and 2121 tonnes of particulate pollution annually (Tallis et al 2011), with greater contributions from coniferous species. Similarly for the West Midlands McDonald et al (2007) estimated that PM10 levels could be cut by 19% by increasing tree cover from 3.7% to 16.5%. In some cases there could be other benefits associated with having trees in urban areas, for example by encouraging exercise, increasing well-being, encouraging investment into areas that have been made more attractive, reducing localised warming and increasing biodiversity.

Location & partners: This could be carried out in a wide range of urban areas where the multiple benefits are greatest. The details have been shown to matter so there is a clear need for this carried out based on the best available evidence, whilst also improving knowledge through experimental practice. The partners could include transport authorities, local and national government, health authorities, and businesses and others interested in local regeneration.

Sources and further information:

- Nowak, D. J.; Hirabayashi, S., Bodine, A., & Greenfield, E. (2014) Tree and forest effects on air quality and human health in the United States. Environmental Pollution. 193: 119-129.
- Tallis, M., Taylor, G., Sinnett, G. & Freer-Smith, P.(2011) Estimating the removal of atmospheric particulate pollution by the urban tree canopy of London, under current and future environments. Landscape and Urban Planning. 103, 129–138
- McDonald, A.G. et al (2007). Quantifying the effect of urban tree planting on concentrationsand depositions of PM10in two UK conurbations. Atmospheric Environment.41(38): 8455–8467.
- http://www.es.lancs.ac.uk/people/cnh/UrbanTreesBrochure.pdf

Wallasea Island Wild Coast project

Objective/Theme: CCAM

Solutions/measures: To offset historical habitat loss and demonstrate adaptation to flood risks due to climate change and sea level rise, through creating new/restoring intertidal habitats.

Short description: Wallasea Island was re-claimed from the ocean over 400 years ago and converted to agricultural land. 'Grey' infrastructure flood defences were constructed, but have recently been found to no longer be economically viable. This makes continued public expenditures unlikely and puts the surrounding 12,100 ha floodplain at risk. The aim of the project is thus to combat the threats from climate change and coastal flooding by restoring 133ha mudflat, 29ha lagoons, 276ha salt marsh, 109ha coastal grazing marsh, 53ha saline lagoons, 15ha of rotational arable fields ('wild bird cover'). It will also help to address the ongoing regional flood risks.

Costs & Benefits: The RSPB bears the majority of costs with additional funding coming from Crossrail, a joint venture between Transport for London and the Department for Transport, which will deliver the waste material and carry out the majority of the construction work.

Costs (estimated) - over £5m. for land purchase on Wallasea Island; physical implementation works of around £17.5m. Future work (possibly costing £12m. or more) to deliver and manage habitats. Management and administration activities are estimated to be on the order of £190,000 annually.

Benefits - Benefits identified included: habitat creation/compensation to compensate for losses in Crouch and Roach estuaries, flood protection to avoid the flood damage risks, allow 2Mm^3 water to enter and leave on higher (i.e. 'spring') tides, increased flood storage, enhanced protection of the west of the island, recreation e.g. fishing, socio-economic e.g. oyster beds, climate change mitigation (carbon sequestration) and adaptation.

Benefits (estimated) - carbon sequestration £1.7 million over the next 50 years; avoided expenditures for flood defence infrastructure over 10 years (ca. £5 – £10 million) and from the avoided loss of built assets on Wallasea worth £3.1 million under moderate flood event scenarios; 16.6 net jobs created in the local economy and up to 20.9 in the wider region over a 10-year period.

Location & partners: Royal Society for the Protection of Birds (RSPB) in cooperation with public authorities (e.g. Environment Agency, UK Department of Environment, Food and Rural Affairs), contractors and landowners.

Sources and further information:

- eftec (2008): *Wallasea Island Economic Benefits Study: Final report submitted to the East of England Development Agency*.
- RSPB and ABPMer (2008): *Wallasea Island Wild Coast Project - creating a new coastal nature reserve. Environmental Statement*.
- RSPB Wallasea Island Wild Coast project http://www.rspb.org.uk/discoverandenjoynature/seenature/reserves/guide/w/wallaseaisland/

Room for the river in the Netherlands – the city of Nijmegen

Objective/Theme: Improved risk management and resilience

Solutions/measures: Making space for water

Short description: For centuries, European countries have built higher and higher dykes to protect cities from floods. In the Netherlands, where ten million people are exposed, this way to manage floods was particularly developed until the end of the 20th century. The rise of awareness that this strategy could lead to unbearable costs without a guarantee for people's safety, as the 1993 and 1995 floods showed, generated new political reflections. A new plan called "room for the river" was established and a new strategy emerged: making more space for water to better prevent floods by lowering the level of high water and to offer spatial quality to the area reconnecting people and rivers. Some measures of this plan are nature-based solutions. The city of Nijmegen is one of the areas where the programme took place. Nijmegen has been built on the south bank of the Waal river. On the opposite side of the river, the city of Lent was protected by a dike which contributed to narrowing the river to form a bottleneck prone to flooding. The project involved two main measures: (1) the relocation of the dike 350 meters inland, (2) the digging of an ancillary channel in the floodplain enabling the creation of a new island. Both actions will make more space for the river and for nature.

Costs & Benefits: The cost of this ongoing project which has to be finished in 2016 is €359 million. It offers multiple benefits. The first one is the reduction of the water level by 35 cm and therefore an improvement of risk management. This project brings also new potential for the development of the city, by the creation of an urban river park with possibilities for recreation and nature. This park is thought of as the future heart of the city of Nijmegen.

Location & partners: 17 partners are carrying the national plan through the country: provinces, municipalities, water boards and the Rijkswaterstaat. The Ministry of Infrastructure and Environment is responsible for the implementation of the program.

Sources and further information:

- http://www.ruimtevoorderivier.nl/english/

The Living Garden Concept

Objective/Theme: CCAM/risk reduction & resilience/sustainable urbanisation/restoration

Solutions / measures: The creation of green and sustainable spaces where water, soil, energy, biodiversity and edible greenery are taken into account through training.

Short description: In the recent years there has been a trend in fully paved gardens. Given climate change and the effect on biodiversity this is not a desired development. Garden owners are open to more green gardens, but they do not know what kind of sustainable elements to bring in and think that these cost more and require more maintenance. The concept of The Living Garden shows how to create green and attractive sustainable gardens. Gardeners use this concept in their relationships with (potential) clients to advise them about green opportunities. The concept is now also used by landscapers and landscape designers to create green public spaces. The concept of The Living Garden is an initiative of the Dutch Garden and Landscape Contractors Association (Brancheverenigning VHG).

Costs & Benefits (Environmental, Social, Economic): The benefits of The Living Garden concentrate on environmental aspects such as water retention, heat stress prevention and the stimulation of biodiversity. Also the effect of greenery on people's health must be taken into account. All members of the Dutch Garden and Landscape Contractors Association use the concept within their work as much as possible. Thousands of practitioners have been trained in the meaning of the concept and the way to apply it in private gardens and public spaces. The benefits are not yet available.

Location & partners: The concept of The Living Garden is developed by the Dutch Garden and Landscape Contractors Association in cooperation with its members. Clients could be either private garden owners as well as municipalities.

Sources and further information:

- http://www.vhg.org
- Facebook: LanglevendeTuin

Soil myco-restoration

Objective: Restoring ecosystems

Solutions: Mycoremediation for the decontamination and rejuvenation of soil

Description: The Seventh Environment Action Programme, which entered into force on 17 January 2014, recognises that soil is a non-renewable resource, and that soil degradation is a serious challenge. It provides that by 2020 land is managed sustainably in the EU, soil is adequately protected and the remediation of contaminated sites is well underway and it commits the EU and its Member States to increasing efforts to reduce soil erosion, increase soil organic matter and to remediate contaminated sites.

Soil decontamination is an expensive process depending on pollution types and site characteristics. Although a large variety of techniques for soil remediation are being commercialized by leading European companies, very few of the current industrial techniques are environmentally friendly, respecting the soil biodiversity and soil's organic matter content.

Academic research and pioneering industrial projects demonstrated the effectiveness of bio-inspired technologies, replicating and simulating the ecosystem's natural restorative capacity in solving the most complex soil pollution situations, while enhancing the soil biodiversity and resilience. These technologies use the remarkable ability of some fungi to degrade recalcitrant and also highly toxic molecules.

Fungal bioremediation of soil relies on the industrial-scale production of fungal biomass upcycling low valued organic waste that is subsequently applied to the contaminated soil.

Costs and benefits: Fungal bioremediation technology opens innovative nature-based solutions for the treatment of recalcitrant soil pollution, thus avoiding transportation cost to transnational treatment and storage sites, as well as the use of energy costly and non-environmentally-friendly technologies. The scheme (a) offers a cost-effective rehabilitation of degraded land;(b) offers a competitive ecologically alternative; (c) provides an effective elimination of the pollution; (d) restores and enhances the soil biodiversity and health; (e) recycles its main reactant (fungal biomass); (f) cycles and valorizes low valued organic waste.

Locations: Brussels, Belgium/ France / Helsinki Finland / Nederlands / USA

Sources and further information:

- H. Singh, Mycoremediation: Fungal Bioremediation. John Wiley & Sons, 2006.; H. Harms, D. Schlosser, et L. Y. Wick, « Untapped potential: exploiting fungi in bioremediation of hazardous chemicals », Nat. Rev. Microbiol., vol. 9, no 3, p. 177 192, mars 2011.; E. Winquist et al.(2014) Bioremediation of PAH-contaminated soil with fungi - From laboratory to field scale International Biodeterioration & Biodegradation 86 (2014) 238e247
- http://www.aalto.fi/en/current/current_archive/news/2014-05-12/
- http://www.theecologist.org/News/news_round_up/2406831/fungi_clean_contaminated_soils.html

Phytoremediation

Objective: Restoring ecosystems

Solutions: Nature Inspired and Supported phytoremediation

Description: PHYTORESTORE, leader on the market, is specialized in treating pollution (water, air and soil) by plants (phytorestoration) and realizes Filtering Gardens® and natural swimming pools all over the world, which are landscaped reconstructed wetlands which purify water, removing pollution. Phytorestore consists of specialists in the fields of chemistry, engineering, hydrology, hydrobiology, environment, architecture and landscape for any kind of ecological solutions.

Costs & benefits: Plant-based methods have many advantages. They generally cost less than conventional processes, particularly with respect to operating costs.

Location and partners: Phytorestore is a French company, with projects worldwide.

Sources and further information:

- http://www.phytorestore.com
- http://www.cefe.cnrs.fr/fr/recherche/ines/subnamed/1051-desc/281-claude-grison
- http://www.sciencedirect.com/science/article/pii/S147481770705022X

The Green City initiative

Objective: Sustainable urbanisation

Solutions/measure: The aim is to activate stakeholders to work together at the international level in the realisation of green solutions with regard to climate, environment, biodiversity, health and social matters.

Short description: Green City Foundation, already established in different European countries, aims to promote the societal and economic values of urban greenery – not meant to be regarded only as a decoration, but as natural infrastructure that adds to the quality of the living climate, to urban biodiversity, and to human health and wellbeing. The Green City Foundation is a movement, as well as a community of stakeholders. Its main activities are organising campaigns and dialogues between stakeholders. The Green City Foundation serves as a platform for exchanging scientific initiatives, and a network to facilitate research, design, creation and maintenance of green spaces.

Cost & Benefits: The costs of the Green City Foundation are limited to funds for campaigning and organizing network activities. These activities are not bound to measurable goals, but are done to start the movement for the development of a green and sustainable city. Bringing together the knowledge and experiences of different stakeholders, the Green City Foundation could be considered a kind of living lab, translating inspiration into concrete actions in sustainable urbanisation.

Location & Partners: The Green City Foundation exists in different European countries. They form a network to exchange ideas in order to strengthen the activities in their respective countries.

Sources and further information:

- http://thegreencity.com

"Growing with the sea" – the timely adaptation of the Biotope Area factor Sea to sea level rise

Objective/Theme: CCAM, risk reduction & resilience and restoration

Solutions / measures: Restoration, natural coastal protection, support for natural dynamic sedimentation processes

Short description: The Wadden Sea on the North Sea coast of Germany is a unique habitat of about 10.000 km² of mud flats, shallow pools, dunes and salt marshes, but are seriously threatened in the long term by sea level rise and certain impacts of climate change. Thus, these valuable habitats in the transitional area between land and sea - and eventually even entire islands - could be lost. The aim is to protect the Wadden Sea from destruction by sea level rise and thereby to protect the integrity of this world cultural heritage site in its entirety, which can only be achieved in cooperation with coastal protection. Several projects, case studies, and pilot measures were launched.

Costs & Benefits: Improved ecosystem resilience, reduced flood risk, species and habitat conservation and increase in biodiversity, resilient infrastructure, improved pollution control, recreation and benefits for tourism

Location & partner: World Wildlife Fund (WWF) Germany, Federal state of Schleswig-Holstein. In cooperation with the Schleswig-Holstein Ministry for Energy Transition, Agriculture, Environment, and Rural Areas, affected communities in the region

Sources and further information:

- http://www.wwf.de/watt/klima

Sigma Plan

Objective/Theme: Restoration of Degraded Ecosystems, Improved Risk Management & Resilience

Solutions/measures: Watershed management

Short description: The Sigma Plan is about developing a sustainable Scheldt rivershed, managing all the features of the river in a balanced way. The first priority of the plan is flood protection, followed by restoration and the development of the protected nature of the Scheldt region, improving the possibilities for recreation, and simultaneously taking account of the economic functions of the region (shipping, countryside economy). Finally, the Sigma Plan is developed in such a way that the disadvantages to agriculture are kept to a minimum.

Costs & Benefits: The flood control area requires significantly more space. There is also some effect on local agriculture, but support measures are available to mitigate the effects on the affected farmers. Benefits comprise increased tourism and the restored wetlands form an excellent hiding and nesting place for various birds, In addition, mud flats and marshes form a natural buffer that protects the population against floods: they collect sand and sludge, reducing the need for dredging. They further purify the water, and bring the natural food chain back into balance.

Location and partners: River Scheldt, Flanders, Belgium; Flemish Authority (W&Z)

Sources and further information:

- http://www.sigmaplan.be/en/

Biobased geological CO_2 storage

Objective: CCAM

Solutions: the oxalate-carbonate pathway (OCP): turning sunlight into stone

Description: Biobased geological CO_2 storage is a sustainable, bio-inspired solution for carbon sequestration, and an alternative or complementary way to existing Carbon Capture and Storage (CCS) techniques. Existing subterranean storage techniques, which consist of injecting high-pressure gaseous CO_2 into deep geological layers, are exposed to leakage risks and are very energy demanding. The explored biological CO_2 sequestration opportunity is the biomineralization of carbon by microorganisms, in particular the natural properties of some bacteria to combine calcium and CO_2 to produce calcareous rocks. A technology involving this carbonation process is considered sustainable and environmentally safe, as the CO_2 is captured in a stable mineral structure. Moreover, the project includes the aspects of valorization of the produced calcium carbonate.

Costs and benefits: The carbon sequestration potential of the OCP depends greatly on the tree species, the tree's age and the availability of calcium in the tree's surroundings. On average up to 21 kg of CO_2 can be stored as $CaCO_3$ per tree and per year. Hence an agroforestry project where 200 "OCP trees" per hectares are planted could result in up to 4.2 tons of CO_2 stored as $CaCO_3$ per hectare, per year, in addition to the carbon stored as biomass (plants, soil organisms, decaying organic matter). More generally and when compared to "classical" reforestation schemes, the OCP trees have the big advantage of fixing part of their carbon as limestone (carbon carbonate): if dead trees eventually release CO_2 during their decay (known as leakage in the REDD discussions), limestone is stable in dry soils for at least thousands of years. Other side benefits: improvement of soil fertility, thus positively impacting on the bio-availability of soil elements such as potassium, sodium, and potentially phosphorus; soil biodiversity; water retention. It presents also all the advantages of forest preservation and reforestation, including their positive impact on water regulation and climate. Local economy and food security: the OCP-displaying tree ecosystems could be used in agroforestry schemes to not only store carbon as mineral rock and biomass, but also for wood production coupled with sustainable & local agricultural practices, for the benefit of local people.

Location and partners: EPFL Lausanne, Switzerland – European Program CO2SolStock

Sources and further information:

- http://co2solstock.org/
- http://www.biomimicry.eu/nos-actions/le-projet-arbres-sauveurs/
- https://arbressauveurs.wordpress.com/

ANNEX 5: E-CONSULTATION ON NATURE-BASED SOLUTIONS, 12 NOVEMBER 2014

The European Commission, in co-operation with the European Platform for Biodiversity Research Strategy (EPBRS)[78], organised on 12 November 2014 an e-consultation as part of an ongoing multi-stakeholder dialogue that contributes to framing a comprehensive EU Research & Innovation policy framework for Nature-based solutions. Input to the e-consultation was developed by the Horizon 2020 Expert Group on Nature-Based Solutions and Re-Naturing Cities. Four discussion sessions included: (a) Improved Risk Management and Resilience; (b) Restoration of Degraded Ecosystems; (c) Climate Change Adaptation and Mitigation; and (d) Sustainable Urbanisation.

More than 330 participants, representing industry and SMEs, local to EU level governance, research and academia, as well as non-governmental organisations contributed actively to the discussions. The results have fed into an ongoing consultation process, and more specifically the Stakeholder Workshop 'Nature-Based Solutions and Re-Naturing Cities' (8 December 2014, Brussels).

During the e-consultation, there was strong recurrence of certain themes across the different discussion sessions. More specifically:

- It was repeatedly stated that Nature-based solutions is still at the concept phase. Hence, the **definition**, as well as the **relationship with other (related) concepts** (e.g.: ecosystem services, green infrastructure) and initiatives (e.g.: Millennium Ecosystems Assessment) **need further clarification**. A clear operational framework is needed.

  "My advice is to clarify the term Nature-Based Solutions, explain the added value of Nature-Based Solutions and explain the differences with the Ecosystem Services concept. Avoid a new buzz word that is again unclear"

- The need to adapt a **broader holistic framework and thinking**, to promote systemic solutions and system resilience was frequently identified throughout the four sessions.

  "Need to identify means to implement Nature-Based Solutions other than through legislation"
  "Identify governance tools for long-term decision-making that weighs human well-being, not just economic benefits"
  "Linking Public Health agendas with Nature Agendas"

- The need to think and work within a **full multi-level stakeholder spectrum and perspective** was emphasised. All actions under nature-based solutions should involve all stakeholders, and apply multi-level management, with a special focus on local communities. Community building was identified as a key success factor. The challenges identified include maintaining a long-term perspective, integrating multiples values and ensuring risk acceptance by various stakeholders.

  "Integrate research with management and society. Support adaptive management, adaptive research, participatory research, etc."
  "My advice is to try and balance short-term wins with long term gains; it's important to keep all the stakeholders engaged in the process. It's also critical to show tangible value wherever possible"

- A main common challenge for nature-based solutions, identified during the discussions, is to **increase awareness** within a broader public, including policy, business, science and society. This appeared all the more challenging to the participants given the unclear definition. Communicating practical examples and education were considered fundamental.

  "Explore how to best engage the community. Many successful Nature-Based Solutions are self-funded initiatives that pay for themselves or voluntary sector aided"

[78] Jurgen Tack (Research Institute for Nature and Forest, Brussels) organized the e-consultation on behalf of EPBRS; the Expert Group provided input, Florin Popa, Pierre Huybrechts and Estelle Ballian (Belgian Biodiversity Platform) contributed to the analyses; Allan Watt (Centre for Ecology & Hydrology), along with three experts from the Expert Group moderated the different sessions and the team of Synthetron provided the technical platform and support.

"Awareness raising through existing good business examples"
"My advice is to consider the importance of education simultaneously to innovation – key to long-term change and impact"

- There is an urgent need to **make the business case** for nature-based solutions. The economic dimension and opportunities were perceived by the participants –at this point in time- hard to identify. Long-term perspective versus short-term profit, benefits of nature-based solutions, business interest as well as difficulties with funding multi-purpose actions need to be addressed.

"The same standards will not be applicable - a new approach must be found"
"Cost benefit analyses must be extended to also embrace non-economic values to ensure sustainability of decisions in the long-run."
"As important as the HOW MUCH is the WHO: who benefits and who bears the costs"

The complete report from the e-consultation on Nature-Based Solutions is available from: http://ec.europa.eu/research/environment/index_en.cfm.

ANNEX 6: STAKEHOLDER WORKSHOP 'NATURE-BASED SOLUTIONS AND RE-NATURING CITIES', 8 DECEMBER 2014

The Stakeholder Workshop 'Nature-Based Solutions and Re-Naturing Cities', held in Brussels on 8 December 2014, was part of an on-going multi-stakeholder dialogue which aims at contributing to developing a Research & Innovation (R&I) agenda on Nature-Based Solutions (2014-2020). The objective of the workshop was to encourage discussion on the most promising strategic opportunity areas for an EU R&I agenda on Nature-Based Solutions, as well as specific R&I actions required to achieve these opportunities. The workshop was attended by 61 participants. The discussions were developed on the basis of preparatory work by the Horizon2020 Expert Group on 'Nature-Based Solutions and Re-Naturing Cities' and input from the e-Consultation on Nature Based Solutions, with discussions focusing on four goals:

- **Sustainable Urbanisation** focused its discussions on resilient cities, health & well-being, and urban Living Labs.
- Discussions in the **Restoration of Degraded Ecosystems** session focused on using Nature-Based Solutions for regulating pollution and natural resource management, integration of urban planning and land restoration, integrating sustainable agriculture and climate change adaptation and mitigation.
- The **Climate Change Adaptation and Mitigation** session emphasised the need for a holistic approach and focused on the use of green infrastructure for protection from gradual (slow) climate change impacts and from extreme weather events, and on bio-mimetic solutions.
- **Improved Risk Management and Resilience** focused on extreme water level and prevention. There was significant overlap across all four sessions. For example, urban issues and agriculture were discussed within the context of all four goals/challenges.

Overarching issues and plenary discussions resulted in the following conclusions:

- **Adopt an integrated and holistic regional landscape approach**. There was an overall consensus on the need to adopt an integrated and holistic urban/spatial planning approach. This is also the case for cities, which are not independent of the wider environment / landscape / seascape (and the people that live and work elsewhere). Programmes for research and innovation on Nature-Based Solutions should therefore also address the interconnectedness and the interdependencies between urban and non-urban areas (and people).
- **Innovate with "living labs" and diverse stakeholders.** The idea of "living labs" for innovation and experimentation on Nature-Based Solutions, both within and outside the urban context, was raised several times at the workshop. Such living labs can provide the ground for inter- and trans-disciplinary research and innovation; however the issue of interconnectedness with the broader landscape should not be ignored. Nature-Based Solutions deliver benefits to diverse stakeholders, hence the full stakeholder spectrum and their multiple values need to be considered.
- **Value the multiple benefits.** The need for research and innovation on the valuation of the multiple benefits of Nature-Based Solutions – also in the longer term, as well as into assessment tools was also a recurring message. Indeed, the valuation (monetary and non-monetary) of the multiple benefits of Nature-Based Solutions and the development of performance indicators, standards, technical and scientific reference models for Nature-Based Solutions is necessary for their wider and systemic implementation.
- **Create the suitable institutional and financial frameworks**. Research and innovation into governance practices including decision-making processes, constraints and opportunities related to institutional and regulatory frameworks, as well as the development of new financial instruments are all necessary to create a market for Nature-Based Solutions.
- **Map and build-on existing knowledge, and innovate**. Research and innovation on Nature-Based Solutions should include novel approaches, while also learning from and building on existing tools and methods, knowledge, databases and networks. Connecting existing networks as well as "learning by comparing" are additional strategies that are recommended.

The complete report of the Stakeholder Workshop on Nature-Based Solutions and Re-Naturing Cities can be downloaded from: http://ec.europa.eu/research/environment/index_en.cfm.

ANNEX 7: BACKGROUND, AIMS & OBJECTIVES OF THE HORIZON 2020 EXPERT GROUP ON NATURE-BASED SOLUTIONS AND RE-NATURING CITIES

The Expert Group that collaborated for this report was formed in 2014 according to the provisions of the Horizon 2020 Work Programme 2014-2015, for Societal Challenge 5 "Climate action, environment, resource efficiency and raw materials". The Group was specifically formed to support the European Commission with expert advice and analyses on past activities, assess policy relevant state-of-the-art scientific knowledge and innovation, engage in forward looking reflection and contribute to establishing a coherent EU Research and Innovation reference policy framework and agenda for Nature-Based Solutions and Re-Naturing Cities.

In this framework, the Group worked on the following issues:

- Identification of the societal challenges to which nature-based solutions present the clearest competitive advantage - in terms of environmental, social and economic benefits - in terms of sustainability, cost-effectiveness, large-scale deployment, innovation and market potential, avoidance of lock-in options;
- Development of an overview of the qualitative and quantitative evidence base of the benefits of nature-based solutions, and identification of systemic and knowledge gaps, which an EU R&I policy framework initiative can help to bridge;
- Evaluation of the EU added value of a R&I nature-based solutions initiative, including opportunities for (further) up-scaling the current level of application and defining incentives to overcoming legal, institutional, economic, cultural, behavioural, etc. barriers;
- Identification of relevant actors and stakeholders, and development of recommendations on an effective strategy to optimise engagement and mobilisation and promote innovation buy-in and up-take[79].

As part of their work, the Group met three times, on July 16th 2014, October 3rd 2014 and January 7th 2015. External expertise was drawn upon for the second meeting, and through larger consultation initiatives. More specifically, experts from the Group were involved in an e-consultation (November 12th 2014) and a Stakeholder workshop (December 8th 2014). The findings from these consultation processes were integrated in the recommendations produced by the Group.

[79] Further information on the activities, as well as on the Terms of Reference of the Horizon 2020 Expert Group on Nature-Based Solutions and Re-Naturing Cities can be retrieved from: http://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetail&groupID=3164

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Nature-based solutions simultaneously provide environmental, social and economic benefits by bringing more nature and natural features and processes into cities, landscapes and seascapes.

The Horizon 2020 Expert Group on 'Nature-Based Solutions and Re-Naturing Cities', chaired by Dr. Wilhelm Krull, Secretary General of the Volkswagen Foundation, was established under the 2014 Work Programme for the Societal Challenge "Climate action, environment, resource efficiency and raw materials". Dr. Pam Berry, Senior Research Fellow at Oxford University, rapporteur, and 12 other renowned experts, engaged in forward-looking reflection on future orientations for EU Research and Innovation for nature-based solutions and re-naturing cities. This report presents their main findings.

Studies and reports

Publications Office

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