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Cover picture: Green wall and recreational channel in the sunset in Malmö, Sweden (N. Kabisch)

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1 Summary

Climate change has significant impacts on society and biodiversity. Urban inhabitants are likely to experience climate change impacts most directly because currently around 54 per cent of the world's population and already 73 per cent of all Europeans reside in cities. Technical solutions are only one aspect of climate change adaptation and mitigation, while nature-based solutions can foster functioning ecosystems as essential backbone to climate mitigation and adaptation. Management that focusses on green infrastructure as measure towards greening cities has the potential to meet several goals across sectors and may also be cost-effective, healthy and sustainable. Nature-based solutions to adaptation and mitigation can therefore help to address both the 2020 targets of the Convention on Biological Diversity (CBD) as well as those of the Framework Convention on Climate Change (UNFCCC).

Set against this background, this report summarises much of the work done by the German Federal Agency of Nature Conservation (BfN) in cooperation with the Helmholtz Centre for Environmental Research-UFZ and the German Centre for Integrative Biodiversity Research (iDiv) in the frame of a research and development project on nature-based solutions (NBS) to climate change in urban areas. This report further includes work done by and for the Climate Change Group of the European Network of Heads of Nature Conservation Agencies (ENCA) in 2015 and 2016. The ENCA Climate Change Group is made up of experts in climate change and ecology from government nature conservation agencies across Europe. Current members of the group include representatives from nature conservation agencies in England, Germany, Switzerland, Wales, Scotland, Czech Republic, Finland, Spain, Netherlands, Norway and the Dutch province of Gelderland. The group is chaired by Natural England.

Through this, we hope to further promote the integration of research findings and implementation experiences of nature-based solutions for climate change adaptation and mitigation to help implementation into practice, to help city practitioners learn from the experiences of colleagues in other parts of Europe dealing with similar conditions, issues, threats and opportunities but also barriers to action.

To address these outstanding issues, the German Federal Agency for Nature Conservation (BfN) in collaboration with the Helmholtz Centre for Environmental Research-UFZ and the German Centre for Integrative Biodiversity Research (iDiv) convened an expert workshop on "Nature-based solutions to climate change mitigation and adaptation in urban areas and their rural surroundings – Successes, challenges and evidence gaps – towards management and policy recommendations" at the International Academy for Nature Conservation, Isle of Vilm/Germany, in March 2015. The objectives of the workshop were to display and explore good practice of nature-based solutions to climate change mitigation and adaptation in Europe's urban areas and their surrounding landscapes, and to analyse challenges and identify indicators of success. An explicit goal was to assess how the concept of nature-based solutions can help conservation to work across sectors in collaboration with e.g. urban planning, architecture, forestry as well as health. In particular, workshop participants discussed the following interlinked issues:

- Indicators for measuring the effectiveness of NBS for climate change mitigation and adaptation and associated co-benefits
- Knowledge-gaps relating to the effectiveness of NBS in cities
- Potential barriers for bringing NBS into action
- Opportunities facilitating action for NBS

In this report, section 4 refers to the workshop. Sub-section 4.1 first introduces the thematic background of NBS and describes main concepts related to nature-based solutions. This

includes the concepts of urban ecosystem services, nature-based solutions, ecosystem-based adaptation, green infrastructure, finally climate change adaptation, and mitigation in cities. Further, sub-section 4.2 presents the general objectives of the workshop. Sub-section 4.3. shows broad information about participants and progress structure. Subsection 4.4 then shows the results of the respective workshop discussion rounds.

An additional piece of research work was done to complement the conclusions of the workshop. This included an extensive review focussing in depth on selected aspects of NBS for climate change adaptation and mitigation in cites (section 5). In particular, four areas of existing evidence are presented: (i) Green roofs and facades as a NBS; (ii) the effects of NBS on biodiversity; (iii) urban parks and street trees as part of the green infrastructure of a city as a NBS to climate change mitigation and (iiii) environmental justice issues related to NBS. Results of the review are presented and summarized using tables and illustrative pictures.

Based on the gained knowledge from the review and building on the discussions from the expert workshop on the Isle of Vilm, a joint BfN/ENCA European Conference on “Nature-based Solutions to Climate Change in Urban Areas and their Rural Surroundings” was held in Bonn, Germany from 17 to 19 November 2015. It was the third event in a series of biannual “European Conferences on Biodiversity and Climate Change, ECBCC”, which started in 2011[1]. The German Federal Agency for Nature Conservation (BfN) organized the conference in co-operation with the Interest group on Climate Change of the Network of Heads of European Nature Conservation Agencies (ENCA), the Helmholtz-Centre for Environmental Research – UFZ and the German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig. A wide range of European experts from science, policy and practice convened to discuss the importance of nature-based solutions (NBS) to climate change in urban areas and their rural surroundings. Further emphasis was placed on the potential of nature-based approaches to also create multiple-benefits. Some of the latest scientific findings on effects of nature-based solutions to climate change mitigation and adaptation and their multiple co-benefits were presented in the plenary sessions. This was followed by interactive sessions focusing on eight specific themes ranging from “The role of biodiversity conservation for nature-based solutions for climate change”, to “Integrating grey, blue and green solutions” and “Rural-urban linkages” as well as “The role of social cohesion”, “Nature-based solutions from a transitions’ perspective” and “Economic aspects”. In addition, “Urban gardening and urban agriculture” were addressed. A special session was also dedicated to “Municipalities adapt to climate change”, where the focus was on good practice examples and the sharing of experience among community level actors. The conference was attended by more than 230 participants from 27 countries. Overall, 55 presentations were given in plenary and the interactive sessions, complemented by 36 posters that were displayed during the conference[2]. Discussions at the conference in the plenary and in the parallel interactive sessions led to a series of recommendations for putting forward the implementation and distribution of nature-based

[1] The first conference held in Bonn in 2011, explored options to enhance communication and co-operation between science, policy and practice and identified research priorities (see: http://www.bfn.de/0103_conferenzce-biodiversity.html). The second conference held in 2013, focused on adaptation of main European ecosystems and led to recommendations for climate change-adapted nature conservation in Europe (see: http://www.bfn.de/0103_conferenzce-biodiversity0.html).

[2] The conference documentation as well as related documents, including the conference proceedings, are available at: http://www.bfn.de/23056+M52087573ab0.html

solutions for climate change mitigation and adaptation in urban areas and their rural surroundings.

Building on the discussions at the above mentioned expert workshop on the Isle of Vilm as well as the results of the BfN/ENCA conference in Bonn, the ENCA Climate Change group further elaborated the recommendations which are presented in section 3 of this report.

2 Acknowledgments

We are extremely grateful to everyone who participated in the BfN '"Expert Workshop on Nature-based solutions to climate change mitigation and adaptation in urban areas and their rural surroundings" on the Island of Vilm/Germany in March 2015 and at the ENCA Climate Change group meeting following the 2015 BfN/ENCA conference in Bonn. All participants actively contributed to this report through discussions at the workshop, presenting and discussing case studies and commenting on the draft of the ENCA recommendations.

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3 2015 ENCA Climate Change Group recommendations for taking forward the spatial targeting and implementation of nature-based solutions for climate change mitigation and adaptation in urban areas and their rural surroundings

The Interest Group on Climate Change of the Network of Heads of European Nature Conservation Agencies (ENCA), and the BioClim project group funded by the German Federal Agency of Nature Conservation (BfN) developed the following recommendations based on the session outcomes and plenary discussions at the joint BfN/ENCA European Conference on "Nature-based Solutions to Climate Change in Urban Areas and their Rural Surroundings".

The conference took place in Bonn, Germany from 17 to 19 November 2015. These recommendations further build on the discussions of an expert workshop at the International Academy for Nature Conservation, Island of Vilm, Germany in March 2015. Both events were organised by the BfN in collaboration with the Helmholtz-Center for Environmental Research – UFZ and the German Centre for integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig.

The recommendations focus on ways forward (implementation, research and spatial targeting) to put into action nature-based solutions (NBS) for climate change mitigation and adaptation in urban areas and their rural surroundings. The recommendations highlight four key areas for action, to:

1. Increase the evidence base on the effectiveness of nature-based solutions (NBS) by providing examples of best practice that demonstrate the multiple benefits provided by NBS. This includes benefits related to climate change adaptation and mitigation, the conservation of biodiversity, and the provision of other ecosystem services for human well-being, including benefits to health.

   This can be achieved by

   - compiling case studies that demonstrate where cross-sector policy integration has led to cost-effective and efficient delivery of ecosystem services that have provided an equitable distribution of multiple benefits.
   - building a repository of good practice case studies that include evaluation methodology.
   - synthesizing existing and new information and communicating this effectively to all audiences from society, policy and science.

2. Foster research and monitoring to determine the best assemblages of species to achieve the most efficient NBS, including the optimization of multiple economic, ecological and social benefits and exploration of trade-offs created by NBS.

   This can be achieved by

   - Collection of new data in the field and the use of remote sensing to gather comprehensive data on additional benefits, to complement existing case studies and data.
   - focusing on how NBS can complement and be used in conjunction with technological solutions. Conservation and construction may both offer solutions, and scientific evidence is needed to quantify their relative performance in

terms of ecological functioning. This includes research that combines effects of the building sector (grey), water and storm-water management strategies (blue) as well as ecosystem services (green) and looks at them in an integrative manner.

- identifying and including all benefits in analyses of cost-effectiveness, whenever decisions about regulations and developments in urban and rural areas are made. This includes economic analyses of the costs of inaction as well as the possibility of catastrophic failure of purely technical solutions. The full range of social and economic impacts should be fully taken into account by studying the monetary and non-monetary values of NBS projects.
- focusing on health and environmental justice as central benefits (not only a co-benefit) of NBS implementation.
- analysis of case studies exploring success factors in the governance of NBS, including how the right people were reached, which kind of people, who finally took the decision to implement the action, as well as the analysis of failure e.g. why actors do not take decisions in favor of implementing nature-based solutions.

3. Foster wider application of NBS with partners from society and policy.

   This can be achieved by

- upscaling successful projects and transferring them to other cities.
- good communication processes among different stakeholder groups (e.g. decision makers, business, society) including a detailed description of the NBS implementation process, benefits, the solutions for certain problems, mistakes made and lessons learned to avoid them, specific context, stakeholders involved.
- Building alliances with different stakeholder groups by demonstrating alignment with their interests (e.g. health issues), in order to get non-conventional partners for NBS implementation from sectors formerly not involved in NBS. This can be supported by creating positive narratives that explain how investments in nature lead to (specific and general) gains for society.
- increased investment in new partnerships with businesses and society including community groups and people with diverse background in culture and education to find suitable settings and language. Sufficient financing and a shared understanding of objectives should be guaranteed e.g. by joint ownership of projects by decision makers and practitioners.
- When implementing NBS strategies, trade-offs and off-site effects to society and the societal context should be considered. Potential displacement of people should also be considered and avoided where possible. In particular, green space standards and political targets combined with social housing standards should be implemented in an integrative approach to planning the entire city.
- strong implementation promoted and led from the top down, including the implementation of the EU Green Infrastructure Strategy and its promotion as an instrument to enhance development and implementation of NBS in an integrated way; but also bottom-up governance that integrates local initiatives from the urban society. Inclusive planning and maintenance strategies and cit-

izen science can act as powerful approaches to better meet the demands of the diversity of stakeholders and develop truly multifunctional NBS.

4. Enable successful ecological restoration with benefits for biodiversity through NBS.

   This can be achieved by

   - connecting urban and rural green areas, which will promote NBS (such as temperature regulation) and also biodiversity by improving the connectivity of urban and rural ecological communities.
   - connecting matrix (built-up areas and areas under more intensive land use) and core areas (green areas such as conservation areas or urban parks) within cities: existing green areas should be protected and complemented by green elements within the matrix (green roofs, green facades, bio retention swales, green strips along roadsides, etc.) to promote the provision of ecosystem services and biodiversity.
   - While implementing the measures mentioned above, due consideration of the potential impact of invasive alien species (IAS) should be given in the design of NBS. For example potential IAS hotspots and pathways should be identified and – in cases where an invasive species is thought likely to benefit from a more connected landscape – potential advantages and disadvantages of enhancing connectivity should be considered carefully in NBS planning.
   - Preferably using native species of local provenance for NBS.
   - Climate change proofing NBS (e.g. species selection) to ensure that ecological function and biodiversity gain are resilient to future change. In some cases this might mean being more flexible about the provenance of species used.

General remarks:
One fundamental assumption which framed the discussions during the conference was the interconnectedness between climate change, biodiversity and human health and well-being. These interlinkages occur at various levels, as illustrated in a diagram on the "determinants of health" by Barton & Grant (2006, see citation below). The recognition of the integrated manner of social, economic and environmental issues is of outstanding importance for understanding the advantages of nature-based solutions.

Literature cited:
Barton, H. and Grant, M. (2006): A health map for the local human habitat. The Journal of the Royal Society for the Promotion of Health, 126 (6) pp. 252-253.
ISSN 1466-4240. DOI: 10.1177/1466424006070466
Available from: http://eprints.uwe.ac.uk/7863 or directly at
http://eprints.uwe.ac.uk/7863/2/The_health_map_2006_JRSH_article_-_post_print.pdf

4 Expert Workshop on “Nature-based solutions to climate change adaptation and mitigation in urban areas and their rural surroundings” (Isle of Vilm/Germany, March 2015)[3]

4.1 Background

In 2014, around 54 per cent of the world’s population resides in cities (United Nations, Department of Economic and Social Affairs 2014). This number is projected to grow even further to up to 66 per cent in 2050. Ongoing urbanization and the continuous increase in the number and size of cities lead to transformation of open land into enclosed landscapes (Seto, Fragkias, Güneralp & Reilly 2011). It is assumed that around 60 per cent of the global land area, which is estimated to be urban in 2030 has yet to be built up (Secretariat of the Convention on Biological Diversity 2012).

A range of interlinked pressures, such as land conversion, soil sealing and densification of built-up areas around the world pose significant challenges to ecosystem functionality and human well-being in cities. These processes may lead to biodiversity loss (for an overview see Goddard, Dougill & Benton 2010) and a reduction of environmental benefits that urban ecosystems provide (Haase et al. 2014; Kabisch, Qureshi & Haase 2015).

Climate change is additionally challenging Europe’s ecosystems, with potentially severe effects on biodiversity and ecosystem function in the future (Schröter et al. 2005; Grimm et al. 2008; Science for Environment Policy 2015). Climate change has also significant impacts on society. People are likely to experience climate change impacts most directly in cities and urban areas (White et al. 2005) through e.g. increased number of summer heat days.

Strategies and concepts that foster functioning ecosystems may counteract these challenges as essential backbone (European Commission 2015). This presents, however, also great challenges for nature conservation, which needs to take appropriate action into account to help the natural environment adapt despite uncertainty about the timing and magnitude of possible climatic changes and their consequences for complex natural systems. A range of principles have been developed for adaptation in conservation, and these are starting to become established in conservation thinking and planning (Bonn et al. 2014). In an urban context, there is now a clear need to go beyond these principles and explore what specific action might be required, and what the challenges and issues might be, in different places and for different ecosystems and species. An important aspect of this is to learn from action that is already taking place. Here, there is great potential to share information among different European countries and to learn from each other’s approaches and experiences.

Different concepts and approaches have been developed and are currently used in different policy contexts to show how urban nature can be used to tackle these challenges. These concepts are *urban ecosystem services*, *green infrastructure, nature-based solutions* or *ecosystem-based adaptation*. They are explained in detail in the following sub-sections.

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[3] For a detailed workshop documentation see: https://www.bfn.de/22641.html

4.1.1 Urban ecosystem services and green infrastructure

The framework of ecosystem services summarizes environmental and cultural benefits and many more and classifies them into different categories: provisioning services, regulating and maintenance services, and cultural services (Haines-Young & Potschin 2010). The term "**urban ecosystem services**" was used to highlight those benefits nature and ecosystems provide in urban areas (Bolund & Hunhammar 1999; Haase et al. 2014). They include e.g. local climate regulation through air cooling (Stewart & Oke 2012), air pollution control (Yin et al. 2011; Gómez-Baggethun & Barton 2013) and noise reduction (Bolund & Hunhammar 1999) through urban vegetation such as (street) trees, parks, green roofs and walls. Direct health benefits may include positive effects on mental and physical health through stress reduction, relaxation and general health enhancements when citizens reside in urban areas (Hartig, Mitchell, de Vries & Frumkin 2014; Völker & Kistemann 2011). Finally, the presence of green and blue spaces provides the opportunity to experience nature and to enhance public ecological knowledge and awareness in nature conservation (Lundy & Wade 2011; Miller, Hunt, Abraham & Salvini 2004).

The capability of urban green spaces to provide ecosystem services is further highlighted in the application of the "**Green Infrastructure**" approach. In its communication on "Building a Green Infrastructure for Europe", the European Commission broadly defines green infrastructure as "a strategically planned network of high quality natural and semi-natural areas with other environmental features, which is designed and managed to deliver a wide range of ecosystem services and protect biodiversity in both rural and urban settings." (European Commission 2013). Even more, multifunctionality of green infrastructure is highlighted because green infrastructure is also defined as "a spatial structure providing benefits from nature to people, […] to enhance nature's ability to deliver multiple valuable ecosystem goods and services, such as clean air or water." (ibid). Based on the definition from the European Commission but adapted for application in urban areas, the EU FP7 Project GREEN SURGE (Green Infrastructure and Urban Biodiversity for Sustainable Urban Development and the Green Economy, www.greensurge.eu) understands urban green infrastructure planning as "… a strategic planning approach that aims at developing networks of green and blue spaces in urban areas designed and managed to deliver a wide range of ecosystem services." (Hansen et al. 2014).

4.1.2 Nature-based solutions and ecosystem-based approaches to climate change adaptation and mitigation in urban areas

The Horizon 2020 Expert Group on "Nature-Based Solutions and Re-Naturing Cities" defined **nature-based solutions (NBS)** as "[…] 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. Many NBS 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." (European Commission 2015). Furthermore, a BiodivERsA Strategic Foresight workshop on NBS, refers to NBS as "[…] the use of nature in tackling challenges such as climate change, food security, water resources, or disaster risk management, encompassing a wider definition of how to conserve and use biodiversity in a sustainable manner. […] this concept intends to additionally integrate societal factors such as poverty alleviation, socio-economic development and efficient governance principles." (Balian, Eggermont & Le Roux 2014). Naumann et al. (2014) refer to nature-based approaches defined as ecosystem-based approaches particularly for climate change adaptation and mitigation: "In nature-based climate change mitigation, ecosystem services are used to reduce greenhouse gas emissions and to conserve and expand carbon sinks. In nature-based climate adaptation, the goal is to preserve ecosystem services that are necessary for human life in the face of climate change and to reduce the impact of anticipated negative effects of climate change (e.g., more intense rainfall, more frequent floods as well as heat waves and droughts).” Also IUCN has been and still is working on ecosystem-based adaptation to climate change since many years. Ecosystem-based adaptation is defined by IUCN as an “integrated approach to conservation, restoration and sustainable management of territories to enable people to adapt to climate change, and ultimately increase their resilience” (Doswald & Estrella 2015). Projects related to ecosystem-based adaptation have a primary focus on ecosystem management, restoration and conservation to increase resilience of people but also to risk reduction and vulnerability reduction. A number of projects mainly focus on ecosystem services, the conservation of biodiversity and impacts of long-term climate change (ibid). NBS and ecosystem-based approaches to adaptation and mitigation can help to address both the 2020 targets of the Convention on Biological Diversity (CBD) as well as those of the Framework Convention on Climate Change (UNFCCC).

This report mainly focusses on climate change adaptation measures as NBS in cities. However, global challenges with impacts on the society and on nature need to be seen in a wider context. Indeed, Vignola et al. (2009) point out, that environmental vulnerability to a changing climate is primarily a developmental issue rather than a sole environmental problem.

Climate change adaptation can be understood as the number of efforts to deal with the impacts of a changing climate (Shaftel 2016). It involves taking practical actions to manage risks from climate impacts, protect societies and strengthen the resilience of the economy. The overall goal for adaptation measure is to reduce vulnerability to climate change effects such as heat waves or extreme weather events. While climate change is a global challenge, heat waves and extreme weather events are most impacting on a local scale. Cities are therefore at the frontline of adaptation. Cities, regions and communities worldwide are already building their own climate development plans and strategies. This includes strategies for flood defences (e.g., New York Sustainable Stormwater Management Plan 2008), heatwaves adaptation prgrammes (e.g., Heatwave Plan for England), to improve water storage and use (e.g., California Water Action Plan) or complete strategies for urban development (e.g., Urban development plan for Climate Berlin).

The United Nations Environment Program (UNEP, http://www.unep.org/climatechange /mitigation/) sub summarizes all efforts to reduce or prevent emission of greenhouse gases as **climate change mitigation** efforts. Mitigation is, thus, understood as dealing with the causes of climate change by reducing emissions. As a multifaceted approach this understanding includes using new technologies and renewable energies to increase energy efficiency of existing equipment, but also changing management and consumer practices. They understand technical solutions such as high-tech subway systems but also soft, rather complex solutions such as new city development plans including the development and promotion of green infrastructure e.g. for bicycling and walking paths while also protecting green and blue spaces as natural carbon sinks. This understanding does, therefore, refer to nature-based solutions in cities as it combines technical with natural solutions and explicitly refers to natural elements in the urban environments such as urban forests or green agriculture sites.

Considering the role of NBS to climate change adaptation and mitigation necessitates a multi-sectoral and multiscale approach, involving all relevant stakeholders, such as local, regional and national administrations, research partners, businesses, local society and NGOs (Vignola et al. 2009). Climate change adaptation and mitigation measures not only work towards reducing vulnerability to both climate change impacts to society but can also directly and indirectly offer multiple benefits such as economic, social, environmental and cultural benefits. Urban forests, e.g., ameliorate the ambient temperatures in hot summer days, sequester carbon and also provide space for relaxation and recreation for city inhabitants (Haase et al. 2014).

These multiple effects are further discussed in this report.

4.2 Objectives of the expert workshop

There is evidence to what extent NBS help in adapting to climate change. However, there still exist knowledge gaps e.g. on the effects of NBS on biodiversity. Indicators are needed that show the usefulness of NBS and imply measurability of effects. There might as well be conflicts and trade-offs between NBS and the protection of biodiversity and possibly even negative side-effects for society. Participants of the expert workshop on “Nature-based solutions to climate change mitigation and adaptation in urban areas” intensively discussed these gaps in knowledge. Furthermore, the aim of the workshop was to showcase and explore good practice of NBS to climate change mitigation and adaptation in Europe’s urban areas while identifying indicators of success, governance challenges and related side effects. In particular, workshop participants discussed:

- Indicators for measuring the effectiveness of NBS for climate change mitigation and adaptation and associated co-benefits;
- Knowledge-gaps relating to the effectiveness of NBS in cities;
- Potential barriers for bringing NBS into action; and
- Opportunities facilitating action for NBS.

4.3 Methodology

The inter- and transdisciplinary expert workshop on “Nature-based solutions to climate change mitigation and adaptation in urban areas” took place at the Island of Vilm, Germany in March 2015.

The participating experts came from different important inter- and transdisciplinary fields of expertise. 34 experts from seven European countries represented research, policy and society. Researchers represented the field of urban planning, geography, ecology, biology and urban geography and sociology. Participants from policy work in national and city administrations, as well as the European Commission. Participants from society were from local NGOs and community groups (for detailed information on workshop programme see Kabisch et al. 2015). All participants convened and participated in a facilitated interaction and dialogue about NBS.

The workshop was structured in two full days with different sessions of framing keynote presentations, panel discussions and group activities and discussions. The first full day started with keynote presentations, which gave an opportunity to understand the concept of nature-based solutions against European developments, planning issues and perspectives from the EU. Keynote presentations were followed by a mapping exercise of current NBS activities. The aim was to identify current research projects, networks and activities, which have a certain relation to nature-based solutions to climate change adaptation and mitigation in European urban areas. In the afternoon session a series of short presentations aimed at presenting case studies related to different nature-based solutions and also giving young scientists the chance to present and to discuss their work. The morning session of the second day focussed on biodiversity issues and policy frameworks, which were presented through keynote presentations. The subsequent group exercise took a form of a world café (see Figure 1). Four pin boards were prepared for collecting information and facilitating discussions. Participants were asked to discuss and brainstorm on different issues for a 20min period on each topic. Pin boards were further facilitated by four of the participants who permanently stayed, took notes and facilitated discussions. Results of the group work were presented in a plenary discussion in the afternoon session. The final evening session was used for additional keynote presentations focussing on economic and urban gardening issues related to nature-based solutions in cities. The workshop was closed by an outlook on the European BfN/ENCA Conference in Bonn (17.-19.11.2015) including discussion of main questions to be addressed in the parallel sessions.

Figure 1: Working with pin boards during the workshop.

4.4 Workshop – Results

4.4.1 “Mapping exercise”: Overview on current NBS activities

In the first group discussions participants were asked to brainstorm on current activities regarding nature-based solutions for climate change adaptation and mitigation in cities at different scales from local to international levels. Responses were clustered according to four pillars of science, policy, practice and education/awareness raising (Figure 2).

Figure 2: Overview on current NBS activities on different levels.

Mentioned research projects and initiatives dealing with NBS, green infrastructure and also ecosystem services included European EU projects URBES (Urban Biodiversity and Ecosystem services, www.urbes-project.org), GREEN SURGE (Green Infrastructure and Urban Biodiversity for Sustainable Urban Development and the Green Economy, www.greensurge.eu), ARTS (Accelerating and Rescaling Transitions to Sustainability, www.acceleratingtransitions.eu), IMPRESSIONS (Impacts an Risks from High-end Scenarios: Strategies for Innovative Solutions, www.impressions-project.eu), the initiatives of AL-

TER-Net or the Network of heads of European Nature Conservation Agencies (ENCA) and relevant conferences such as the ALTER-Net conference on “Nature and Urban Wellbeing - Nature-Based Solutions to Societal Challenges” in Ghent in Mai 2015, the Green Week in Brussels in June 2015, or the European BfN/ENCA conference on “Nature-based Solutions To Climate Change in Urban Areas and their Rural Surroundings” in Bonn in November 2015. There was also a clear focus on national activities such as "Natural Capital Germany - TEEB DE" or research calls from the German Federal Ministry of Education and Research (BMBF). In the policy and in the practice pillar some regional and local initiatives were mentioned such as the Mayors Adapt initiative (www.mayors-adapt.eu). At the European, national and local level, a number of policies were mentioned such as the EU Biodiversity Strategy to 2020, the German National Strategy on Biodiversity or Berlin’s Biodiversity Strategy. Notably in the practice pillar, participants highlighted a number of concrete case studies where NBS have been implemented, e.g. the project “Green Living Room” in Ludwigsburg. They also included community projects and activities such as urban gardening in Berlin and other cities.

As a second task, participants were asked to address the following issues, which will be further elaborated in the subsequent chapters:

- What are climate change related impacts on the urban-rural environment and related impacts on city residents?
- What are examples and what is current evidence of nature-based solutions for climate change mitigation and adaptation in cities and their rural surroundings
- What are the challenges in bringing nature-based solutions into action?
- What are potential barriers to action for implementing NBS in urban areas?
- What are opportunities facilitating action to implement NBS in urban areas?
- What are indicators of success for bringing nature-based solutions into action?
- What knowledge gaps do still exist?
- What are future tasks to further the implementation of NBS to climate change in urban areas?

4.4.2 Climate change related impacts on the urban-rural environment and related impacts on city residents

In the discussion on climate change impacts on the urban-rural environment and related impacts on city residents participants should name the most severe climate change impacts (Table 1). A number of issues concerned with climate change impacts on **biodiversity** were mentioned. They concern the transport of pests and accompanying diseases but also changes in biodiversity (e.g., species migration and occurrence of novel ecosystems). Highest level of concern was identified to be in **floods** and **increased temperatures** and effects of droughts and heat waves. When it is about human well-being, both **physical and mental health effects** of natural hazards coming from climate change were mentioned such as increased mortality during heat waves or psychological illness related to stress of coping with disasters. A global perspective was discussed stressing that urban areas in different (bio-) geographic regions will face different impacts such as increased frequency and intensity of floods in some but intensified water scarcity in other regions. Different regions will thus also face diverging **social reactions**, with migration and war given as examples. However, the participants also identified potential positive impacts of climate change, such as decreased mortality in winter. Finally, **economic effects** from climate change have been discussed.

These effects include amongst other increased costs for the health care systems, insurances and energy supply.

Table 1: Climate change related impacts on the urban-rural environment and related impacts on city residents

Climate change impacts
Biodiversity /ecosystem functioning: Choice of management in surroundings affect species pool/biodiversity and ecosystem functioning Shifts in biodiversity and species compositions Introduction of alien species with potential negative effects for biodiversity and ecosystem functioning Changes in populations (numbers and distribution) Biota homogenization Novel ecosystems Synergetic effect with other drivers of biodiversity-loss Higher pressure of pest, diseases (e.g. allergies) and plagues (e.g. malaria, ticks) Salinisation and erosion of soils
Flooding /water scarcity: Flooding from combined surface water drains Lack of infiltration resulting in overflow Sea level rise-flooding Water scarcity / droughts due to extreme events
Heat: Fire /burning woods Increased temperature, heat waves Increasing energy demand (air condition, cooling) Droughts and flooding due to extreme events Desertification
Social and health effects: War / refugees / migration (due to environmental conflicts) Health risk for old people due to heat (increased mortality, morbidity) Lower mortality in winter Temperature raise possibly connected to more comfort Decrease of amenity value of public open space in summer Shifts in social composition poor vs. rich due to potentially uneven access to public green spaces Diseases becoming more severe (e.g., heart and lung diseases) Mental diseases, stress, increase in mortality
Economic effects: Costs for health systems, insurance, energy supply Economic impacts by floods, water need Break down of transport links (due to increased traffic on weekends with urban dwellers searching refreshment from hot cities in the countryside)

4.4.3 Evidence and examples of nature-based solutions for climate change mitigation and adaptation in cities and their rural surroundings

NBS significantly showed positive influence on climate change related impacts in a number of examples. One of the most pressing issues discussed during the workshop concerned the adaptation to floods and heavy rainfall events though NBS (Table 2). Sustainable urban drainage systems (SUDS) were mentioned as effective method to mitigate overflow and floods. Other issues concern NBS for temperature reduction, which included evaporation through vegetation in general but also specific solutions such as planting large trees for shade or implementing green roofs and walls.

A number of co-benefits were mentioned. Co-benefits are defined as benefits for urban citizens and are created through a NBS which was in the first order implemented for a different purpose. E.g. implementing large trees for temperature reduction may increase attractiveness of the area, foster human well-being or the re-connection of urban residents with nature.

Table 2: Evidence and examples of nature-based solutions for climate change mitigation and adaptation in cities and their rural surroundings.

Nature-based solutions
NBS for flood mitigation: Ecological restoration (floodplains and streams) Creation of habitat (shift to semi natural areas) Room for rivers, build back dikes Rain water harvesting and reuse combined with establishing sustainable urban drainage systems (SUDS) Flood retention measures within cities (ponds, rivers, green roofs and rainwater retention) Flood retention areas in rural hinterlands
NBS for temperature reduction and air purification: Temperature reduction by evaporation and shadow of trees (see Bowler et al. 2010; Breuste et al. 2013) Filtration of particular matter Regenerating and renaturing grey infrastructure/brownfield sites, former industrial areas Green corridors Green roofs and walls Energy-efficient cooling through plants and blue spaces reducing energy demand
Co-benefits of NBS to climate change in urban areas: Empowerment of people Community gardens and urban farming Reconnecting people to nature Cultural benefits, inspiration, satisfaction Improvement of human physical and mental health Space for social life Increasing the city’s attractiveness (benefiting also business and tourism) Connectivity of habitats

Nature-based solutions
Reduced crime / vandalism
Habitats for bees and other animals
Increase in property values (can be seen as positive or negative)
Buffering urban sprawl (establishing a green belt)
Increase biodiversity, soil protection, recreation
Attractiveness of the area (recreate)
Comfort to take the bike

4.4.4 Challenges in bringing nature-based solutions into action

A number of different challenges to successfully implement NBS were identified and clustered into seven different groups (Table 3 and Table 4). The first group of challenges relates to NBS and **social inclusiveness**: It was mentioned several times, that when implementing NBS all population groups should benefit, not only those having a higher social status. The accessibility to urban green spaces should be an indicator to be considered when designing and implementing them. Displacement of people should be avoided. Another heavily discussed issue was the challenge concerning **flexibility and time span of NBS projects**: Often, projects on research and implementation of NBS are only carried out for a certain (short) time but there is the need for a long-term funding of projects or at least for solutions about implementation and maintenance after the project and related funding end. Researching the design and early-stage implementation of NBS is not enough but monitoring the impact they have in human-environment relations over time is equally important. It was also stated that **current structures of policies** do not allow for changes in the direction of implementing NBS. This points to a lack of knowledge and possibly lack of interest and flexibility of decision makers. One of the main challenges, however, seemed to be the issue of funding for NBS (**infrastructural challenges**). Stated experiences from different cities highlighted that maintaining NBS over time in a period of austerity and shrinking budgets is an overarching concern. Overall, tight budgets and a general decrease of budget for qualified staff result in the reduction of expertise in applying NBS solutions to increase the resilience of cities to climate change.

Table 3: Challenges of bringing NBS into action – PART A

NBS and social inclusiveness	Challenges concerning flexibility and time span of NBS projects	Current structures in policies	Infrastructural challenges
Go in “black box cities” – do not overstudy or overshow championing cities. Involve all people and use an inclusive approach. Make NBS socially inclusive – go beyond accessibility concerns. No implementation of unjust social patterns. Avoid displacement and gentrification. Participation of local	*Lack of flexibility in research (to explore, learn, adapt).* *Lack of long-term research and lack of funding for long-term monitoring* *Cost/benefits are calculated in the short time scale (establishment high, maintenance low).* *Short term solutions are favoured.* *Long-term motivation of participants.*	Growth paradigm does not fit for shrinking cities. Tradition of growth vs shrinking towns - growth paradigm even dominates under condition of urban shrinkage. Lack of fellowship, seen for transfer of results into practice. Current interests and political aims. Need to convince decision makers about bet-	*Budgetary limitations– Money as a scars resource.* *Many funding programs vs shortage of time and personal staff.* *Lack of funding for involving of stakeholders.* *Time limitations of projects, e.g. loss of qualified staff.* *Lack of knowledge in decision making (education, awareness rising*

NBS and social inclusiveness	Challenges concerning flexibility and time span of NBS projects	Current structures in policies	Infrastructural challenges
people, stakeholders, not-usual-suspects Nature is not seen as a chance for quality and economic and social potential. Bring the science to the people - Explain scientific results to the public. Reach out to the relevant people and address their needs. Residents fear that their opinions do not feed into final decision. Can NBS be the mediums to create social and environmental justice bright spots?	*Employment of main actors in projects (short term vs. long-term).* *Follow-up of projects/initiative (maintenance).*	ter/attractive solutions. Lack of adequate suitable institutional frameworks. Sectoral approaches need to be overcome. Neglecting the reality and urgency of the situation. Voluntary task for town administrations. Planning regulations change slower than social needs. Lack of political support. Lack of interest to link multidisciplinary issues. Anti-fragile planning processes and slow change - “We have always done it like that” Topics like the one of qualified staff, demographic chance, establishing new jobs will always be more important. Lack of knowledge by decision makers and funders. Using NBS as a trigger to rethinking urban planning and government processes (co-production and co-design).	*needed).* *Concerns about maintenance of NBS.* *Terminologies feeding into the planning from science.* *Infrastructure development together with school projects.* *Long-term monitoring data missing.* *Scale issue (big cities feel more pressure to act).* *Cities are not interested in qualitative data.* *Lack of regional and national based scientific knowledge, most studies at local scale.* *Produce more empirical data.*

Several other challenges have been discussed (Table 4). They further include a **lack of interdisciplinarity** in NBS research projects. It was mentioned, that social science and natural science are often not well integrated in research projects and need to be further intersected with other disciplines e.g., engineering which is of particular interest for NBS projects. Other challenges include a **mismatch of interest to develop open land** and the **perception of NBS by different actors**. The first relates to the vision that European cities may develop as *compact* city. The compact city approach follows dense residential development with comparatively less green. But at the same time, cities want to increase quality of life and increase their urban green spaces. The last challenge relates to the perception of NBS. It seems that NBS are not well supported in planning institutions, because urban planners and policy makers may not be aware of the benefits as the public may also not be.

Table 4: Challenges of bringing nature-based solutions into action – PART B

Lack of interdisciplinarity	**Mismatch of interest to develop open land**	**Perception of NBS by different actors**
Not sufficient integration of human/social science and natural science in research projects. Intersection between disciplines e.g. science vs engineering. Examine the city not as homogeneous NBS to be across city not on sites, incoherence. Social sciences view solutions as political objects → what does this mean for NBS new environmental politics? Missing technological/engineering knowledge in our group.	Value/price of areas in cites often very high. Visions of European city (dense, little green). Property issues (who owns the territory? Private properties?) If develop brown fields sites temporarily – local people want to keep them but council developers want to develop them. Buy in of insurance companies, banks. Legal/regular prohibitions NBS facing other investment.	*Lack of wider public demand for NBS* *Low knowledge of NBS among the public and their multiple benefits* *Low support not enough awareness* *Not only educate kids but make them active citizens* *Image of sustainability in schools (think they have to change their lifestyles)* *Image (that recycling is not the best quality)* *Convincing pupils to engage and to take up nature-based projects*

4.4.5 Potential barriers for implementing NBS to climate change in urban areas

A significant number of different potential barriers to action for implementing NBS were mentioned during group work. They have been clustered into five different groups (Figure 3). A potential barrier to action is the **fear of the unknown** by several stakeholders including policy, practice but also residents. It considers both uncertainties and risks of implementing NBS and the resulting changes this may bring in planning. Due to its nature, NBS must be handled differently than other approaches and requires new and other implementation and maintenance criteria. Additionally, NBS have not yet received assessments of their effectiveness in dealing with climate mitigation and adaptation targets such as carbon offsets that may also create a performance unknown. This may be related to the lack of awareness regarding climate change induced problems and the benefits NBS can bring. With local urban policy officers and planners often being risk averse, these unknowns create roadblocks for the uptake of NBS in cities.

A second barrier includes the disconnection between **long-term and short term** benefits. Changes in administration, for example, often need a long-term process which also involves costs. This is contrary to an often rather short-term thinking of local politics. In some cases, responsibilities for the maintenance of the project remains unspecified, which poses a risk to the continuity of delivering the desired socio-economic and environmental benefits in the long-term. Even in cities where long-term policy plans undergo adaptive monitoring for taking up new innovative solutions, it is often the case that scientific validated options and knowledge are not ready at the time the policy windows are open for new ideas. In parallel, there is also a discontinuity between short-term actions and how they relate or build up to long-term plans and goals. A number of projects researching NBS more generally and looking at implementation aspects more specifically only exist for a certain (short) time; there is, however, the need for long-term projects (particularly regarding solutions about how to address implementation and maintenance after the project and related funding end). This is mirrored in the activities working to develop long-term ecological research (with research sites established all over the world; see http://www.ilternet.edu) into long-term socio-ecological research (Ohl et al. 2010). The focus is suggested to not only rest on researching the design and early-stage implementation of NBS, but also to enable a monitoring of the impacts they have in terms of human-environment relationships over time.

Another barrier is the **lack of awareness** regarding climate change induced problems and the benefits NBS provide to city residents. Often, problems are connected to the general infrastructure of administration. Funding is often not available, thinking is based on traditional structures/departments and the focus is often rather on economic-growth oriented issues (creating jobs, attract investments) while less attention and money is left for the development of urban green and the related benefits of NBS even in a context of economic and demographic decline.

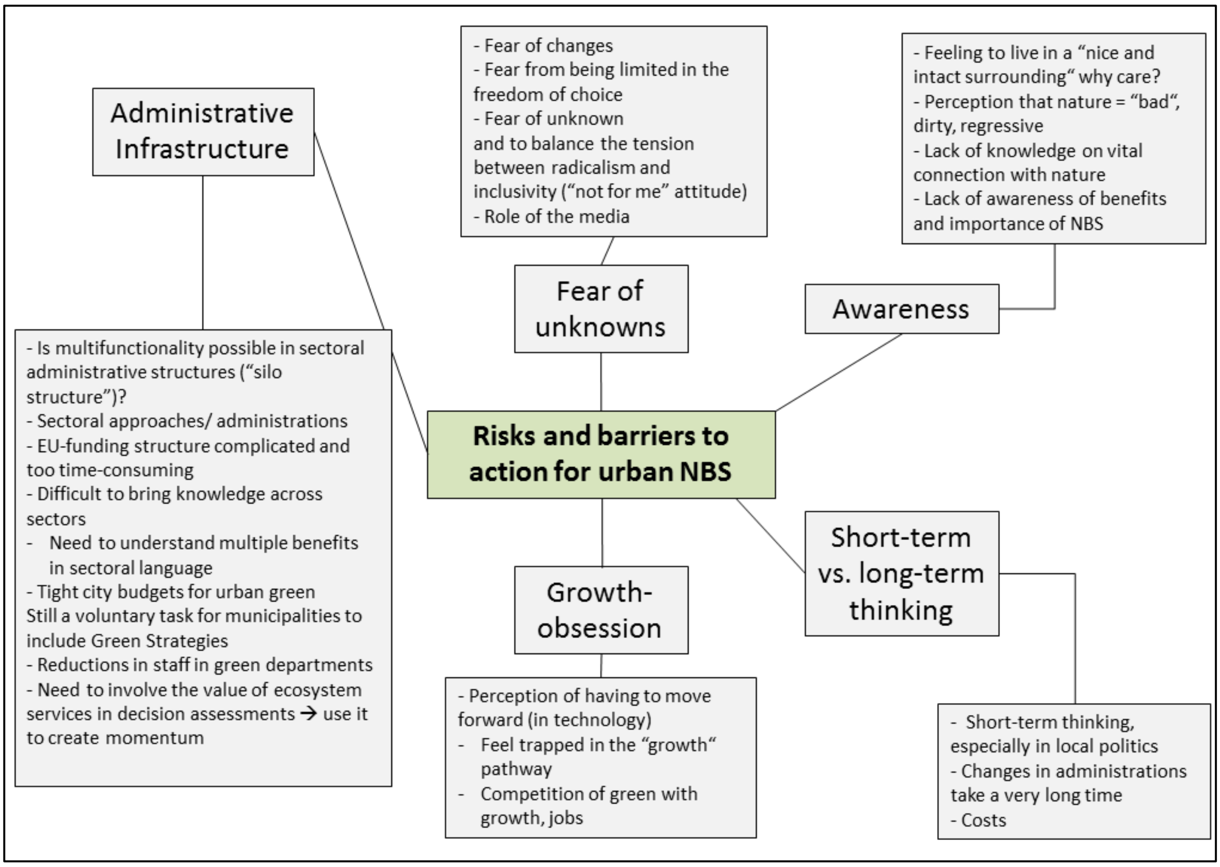


Figure 3: Barriers to action for implementing NBS to climate change in urban areas.

Another major barrier to action refers to the existing **administrative infrastructure**. This concerns traditional structures of city departments often having their own "sectoral language". Knowledge is thus trapped in sectoral silos. Furthermore, city departments have defined fields of duty and restricted responsibilities, where multifaceted fields of responsibilities or projects such as NBS often may not fit into given decision making structures. Relating to this, an associated barrier to action also refers to "strong stakeholders" with whom a city or municipality has to set up interactions; they include other public bodies such as housing associations, investors or developers.

The last barrier concerns the **growth obsession**. Even in the context of economic and demographic decline, cities promote growth strategies and growth-dominated visions that we capture as 'the growth obsession barrier'. Increase in built-up area including spaces for commerce, infrastructure, etc. seems to be the main focus for development, even under conditions of population decline (Haase et al. 2013). The focus remains on economic growth-oriented issues (creating jobs, attract investments), while less attention and money remains for the development of urban green spaces and the related benefits of NBS. City budgets for green development and maintenance of green spaces often face severe budget constraints while staff and related expertise is decreasing (Baur et al. 2013, Davies et al. 2015, Kabisch 2015). Tight financial and time budgets combined with reductions in staff and expertise may also lead to not using existing funding options for green space implementation projects. EU-funding instruments are available for cities, but they are complicated to apply for (requiring additional administrative staff and time) and - more importantly- require co-financing, which many cities cannot afford.

4.4.6 Opportunities facilitating action to implement NBS to climate change in urban areas

There were, on the other side, a number of opportunities discussed that might facilitate bringing NBS into action (Figure 4). One of the opportunity areas is about valorizing and exploiting the **existing tacit and expert knowledge** of policy makers, policy advisors, urban citizens, researchers and urban planners about NBS in cities and **bringing this knowledge together**. Knowledge gained through experiences with implementing successful projects where urban green spaces were introduced, improved in quality or restored as well as lessons learned from less successful projects is deemed as being instrumental for effectively employing NBS in urban planning. This knowledge is, however, only attainable to be put in practice when new actors engage with those networks which created or acquired the experiences. Engaging and further extending those communities via the introduction and invigoration of the promises of the NBS concept can be essential for the quick uptake and integration into existing knowledge and for overcoming tensions between different stakeholders and fostering engagement with multiple knowledge-holders.

Multiple proposals were generated for facilitating knowledge valorisation at the workshop. For example, it was suggested to support the empowerment of NBS ambassadors to promote NBS and engage in a science-community advocacy for NBS by making NBS benefits and risks communicable to citizens and politicians alike. NBS ambassadors can serve as environmental icons and be promoted as '**rock-stars**' with the skills and talent to create new narratives about NBS and act as 'belief-managers' who volunteer to not only bring the message, but also lead and support the debate.

Another opportunity area is about the establishment and utilization of **new modes of governance** in which policy officers collaborate with citizens, businesses and civil society but also NGOs. This collaboration aims to connect demands for action with responsible actors or partnerships for action and jointly ensure good governance practices adhering to transparency, legitimacy and openness. The partnering of different actors may reduce barriers or constraints for adopting NBS as well as for their implementation in cities (Frantzeskaki & Tilie 2014). In particular, partnerships that significantly try to involve the urban government are crucial for opening space for innovative approaches and solutions like NBS. This can lead to fertile ground for experimentation and may even for a fast transferral from concepts to action.

In line with the above factors, new partnerships for local and trans-local governments may create conditions for new business and finance models by divesting from dominant solutions (e.g., investments in optimizing efficiency of grey infrastructure as the one and only focus) and by leveraging private and public funding in strengthening NBS.

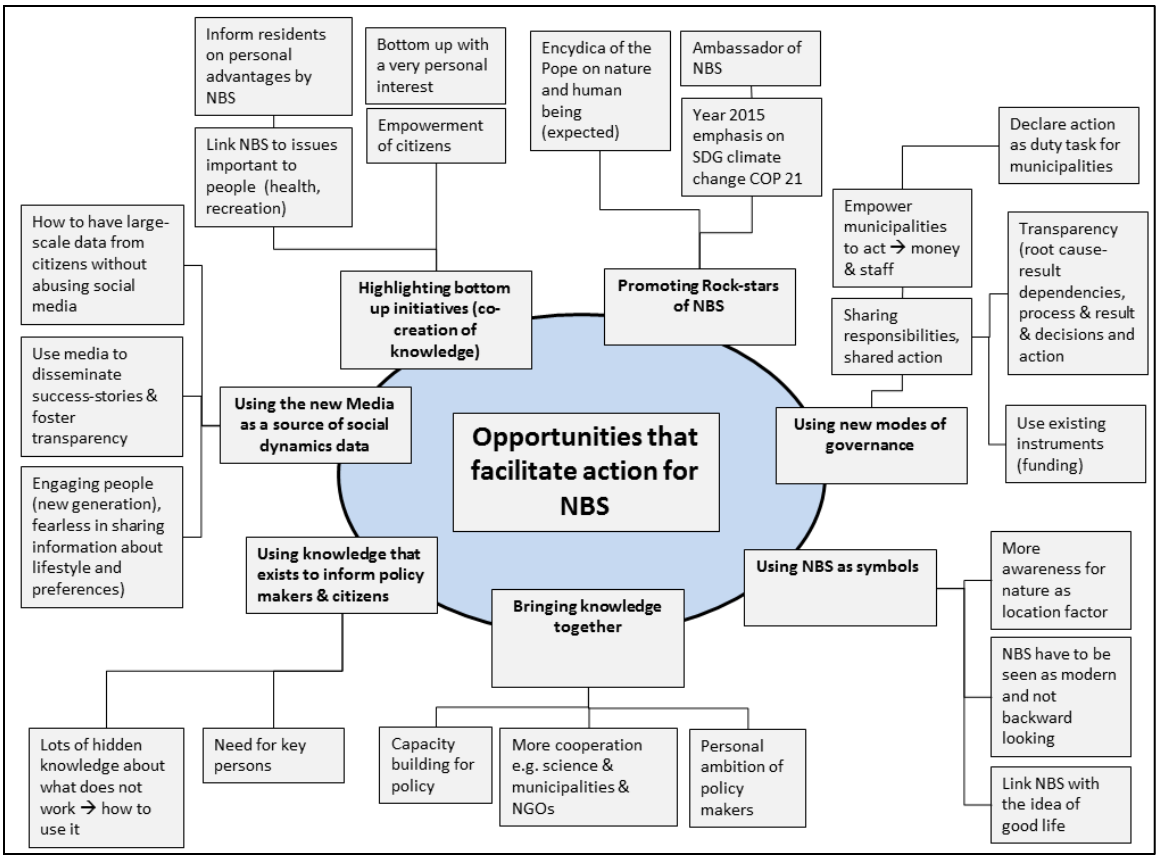


Figure 3: Opportunities facilitating action for NBS.

4.4.7 Indicators of success for bringing nature-based solutions into action

One of the fundamental needs in the field of NBS has been outlined as establishing targeted indicators. An indicator is defined here as a measure or metric based on verifiable data that condenses complexity and conveys information (Haase et al. 2014). Indicators could be used for efficiently measuring, analysing, monitoring and communicating NBS. In terms of communication, indicators could help to track and impart how natural areas in cities provide benefits in terms of adapting to climate change, and therewith to support human well-being. Indicator values may also inform decisions and actions by providing convincing arguments for decision makers in urban administrations to, for example, consider NBS in budget allocations.

In the discussion on indicators during the workshop, indicators based on measurable data were mentioned. These indicators were grouped into four main clusters: integrated environmental performance, indicators of health and well-being, indicators of transferability and monitoring, and finally indicators, which show citizens involvement (Figure 5).

Integrated environmental performance indicators predominantly relate to regulating ecosystem services, such as climate regulation measured by temperature reduction, air quality regulation through a decrease of air pollutants, and flood control by mitigating extreme events and increasing local water retention. Some indicators mentioned refer to biodiversity, such as the share of vegetation cover. This points to a general increase in urban green spaces, which also includes the percentage area of brownfield sites that have been developed into near natural green spaces. In a comprehensive review that focuses on studies assessing urban ecosystem services, Haase et al. (2014) showed that indicators for local climate and air quality regulation and carbon sequestration and storage were predominantly applied in a number of studies, while fewer studies used indicators for cultural or provisioning services. The lack of data availability was discussed as one reason for this. Furthermore, indicators related to ecosystem disservices of green and blue infrastructure were discussed. Ecosystem disservices can be defined as ecosystem functions which are rather negatively perceived for human well-being (Lyytimäki & Sipilä 2009; von Döhren & Haase 2015). Related indicators are increased air humidity or increasing numbers of mosquitos.

Indicators related to health and well-being concern the co-benefits of NBS and include physical and mental health indicators as well as the spatial availability of green and blue spaces. Physical and mental health indicators were suggested to measure the number of people participating in sport activities and specific health benefits, such as reduced rates of respiratory diseases or obesity. A number of studies have illustrated the positive health effects from living in close proximity to green spaces (Hartig et al. 2014). Mental health has also been suggested to be measured through happiness-indicators for life satisfaction ratings (Carrus et al. 2015). In addition, indicators addressing social and environmental justice issues were proposed at the workshop, such as measurements of green space availability through the number or share of residents affected by displacement or increasing segregation. The installation of new or restoration of existing green spaces might be beneficiary as a NBS for climate change adaptation or mitigation, but may simultaneously lead to increases in land prices and rent due to increased attractiveness of the area. In turn, those residents for which the green space would be most beneficial sometimes cannot profit from the natural area due to displacement processes (Wolch et al. 2014).

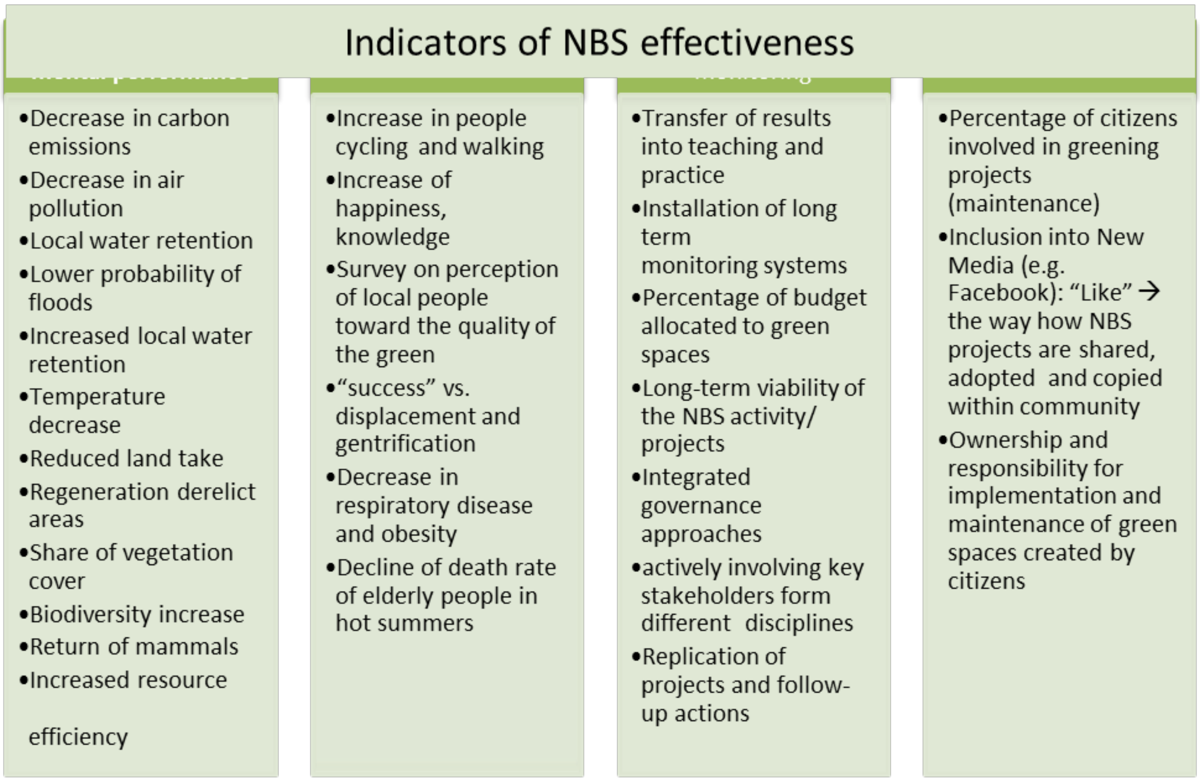


Figure 4: Indicators of success of nature-based solutions in cities.

The remaining two sets of indicators relate to the processes of developing and managing NBS. Experts in the workshop suggested that one set of indicators relate to (the number or percentage of) **citizens' involvement** in green implementation projects and citizens owning or maintaining a green space (Shandas & Messer 2008). Indicators related to citizens' involvement may also include measurements on how information on NBS are shared and adopted in the community. This could by measured by the information gained through new media, such as Facebook and the number of "likes" for a certain topic or post.

Finally, the fourth set of proposed indicators related to the **transfer of model projects into general practice and monitoring**. This set may include implementation measures and integrated governance approaches, measured by the number of stakeholders coming from different sectors involved in planning and implementation as well as the number of policy officers and planners that employ the concept of NBS for policy practice in terms of forming planning agendas, plans and integrating it in the planning discourse. Some aspects were intensively discussed, including timing, financial aspects and monitoring. Monitoring relates to concerns of whether or not monitoring is encouraged, for example of a strategy's implementation, and - if yes - for how long this is foreseen. Indicators relating to a city's administrative budget include the percentage of budget allocated to green space planning, implementation, maintenance and monitoring of implementation projects and strategies.

4.4.8 Knowledge gaps relating to both future environmental changes and the effectiveness of different management actions related to nature-based solutions in cities and their rural surroundings

Knowledge gaps remain with regards to a number of issues surrounding the effectiveness of NBS for climate change adaptation and mitigation and their impacts on the natural and social environment. In particular, four main knowledge gaps were identified (Figure 6), relating to: 1) the effectiveness of NBS; 2) relationship between NBS and society; 3) design of NBS; and 4) implementation aspects.

The first group of knowledge gaps relates to **effectiveness of NBS**. Evidence bases concerning trade-offs and synergies between NBS for climate change mitigation/adaptation and biodiversity, human health or aspects of economy as well as social issues are not complete so far (Hartig et al. 2014; World Health Organization and Secretariat of the Convention on Biological Diversity 2015). There is already profound scientific evidence on the linkages and causal effects between urban green spaces and human health and well-being. Nevertheless, these relationships still need more substantial evidence regarding the degree of causality and effectiveness. Furthermore, knowledge on the impacts of climate change on biodiversity and its linkages to ecosystem services and the effectiveness of NBS in cities is limited. This might be because biodiversity is exposed to multiple stressors simultaneously in cities. This includes stressors such as high levels of pollution, fragmentation, and disturbance (Niemela 1999).

The second knowledge gap relates to the relationship between **NBS and society**, that is, the stakeholder involvement and impact of human-nature interactions. This considers altering lifestyle, beliefs and preferences, but also place-impacts such as displacement and gentrification. Questions were raised regarding approaches for how to involve stakeholders from planning administration and residents in long-term projects as well as if all residents can benefit from implemented NBS or if benefits are only accessible to a selected portion of the population. Societal relations also concern knowledge gaps relating to the identification of an optimal way of communicating positive and negative examples (failures) of NBS.

The third knowledge gap focusses on the **design of NBS** and the question of how existing knowledge from architects and engineers being more of a technical nature can inform design and integration of NBS alongside existing grey infrastructure. There is a knowledge gap on how NBS should be implemented to best serve multiple purposes in parallel (e.g., "Green

Living Room Ludwigsburg" TURAS-project, http://www.turas-cities.org/case_study). Although knowledge is already available on the implementation of such solutions at the city level, still questions remain: which technical knowledge and skills are required for multifunctional urban planning and how can this knowledge be included and interlinked with knowledge on environmental and social systems to produce the best possible synergies for e.g. climate adaptation and mitigation?

A final knowledge gap relates to the **implementation of NBS**. Urban administrations may lack information on legal organization instruments and requirements for the implementation of NBS. For an administration it may not always be clear what kind of NBS fits best with city development goals. There is evidence needed on how to deal with competing land uses due to differing goals of land owners in growing cities. When city populations are increasing and new residential space needs to be developed and open space becomes under pressure, the question arises of how green spaces can ideally be further developed and maintained within the context of climate change adaptation and mitigation. Here, strategic planning of green infrastructure will be instrumental to integrate NBS into a multifunctional and connected system of green and blue spaces. Improved knowledge is needed on the administrational instruments for implementing NBS. Good-practice strategies for planning and implementation of NBS and for generating more knowledge on their cost-efficiency in comparison to more conventional (engineered) approaches need to be provided.

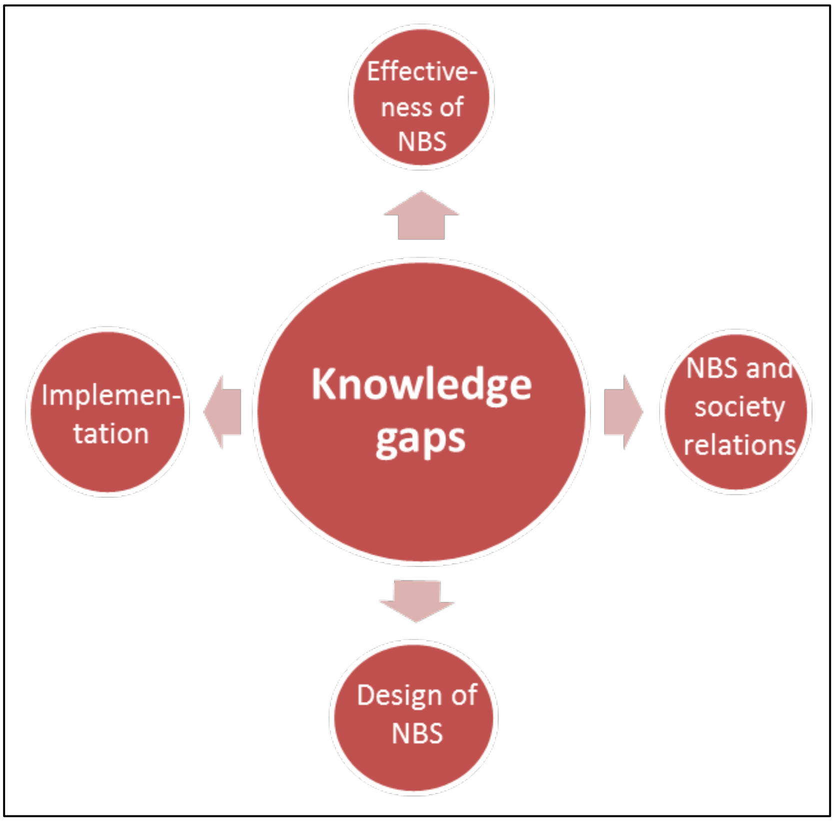


Figure 5: Knowledge gaps relating to both future environmental changes and the effectiveness of different management actions related to nature-based solutions in cities and their rural surroundings

4.4.9 Future tasks to further the implementation of NBS to climate change in urban areas

The expert workshop on NBS for climate change adaptation and mitigation in cities and their rural surroundings brought together experts from various disciplines including experts from natural and social sciences as well as representatives from city administrations and the European Commission. A number of issues were discussed intensively in two days based on input from keynote presentations and group activities.

A summary of future tasks includes the following issues and further needs:

- A **greater evidence base** related to the effects of climate change on biodiversity in cities but also about successful implementation and functioning of nature-based solutions for climate change adaptation and mitigation is needed.
- **Further research** is necessary to assess the effectiveness of NBS and to compare it with technology-based solutions when being implemented for the purpose of addressing climate change adaptation and mitigation. Although a number of applied examples already exist (Secretariat of the Convention on Biological Diversity 2009, Naumann et al. 2011, 2014), significant additional research should be conducted to develop a sound evidence base and highlight efficient implementation, functioning and cost-effectiveness aspects of NBS in cities. Considering the latter, multiple co-benefits have to be included in these calculations as well as the potential time lags occurring before the benefits and advantages of using NBS become evident. Also, while learning from failures would be desirable, obtaining information on these aspects is very difficult. Concerning specific green infrastructure elements, more research is needed which clearly illustrates significance through indicators. Despite the increasing implementation of approaches for example to the management of local stormwater which complement conventional sewage systems with NBS, a comprehensive understanding of the complementary benefits of technical solutions and NBS is still missing. A similar recommendation comes from the H2020 Expert group on “Nature-Based Solutions and Re-Naturing Cities” who call for “[...] more comprehensive evidence base on the social, economic and environmental effectiveness of possible nature-based solutions […]” (EC, 2015: 21). Here, we go one step further and ask for good practice examples on the integration of expert knowledge from engineers, architects and landscape designers to include their (technical) knowledge in discussion rounds on urban green space planning for NBS. Potential options on how to overcome the barriers in the cooperation between these disciplines for integration of NBS with technical solutions have been discussed.
- Moreover, sound **evidence related to the impacts of climate change on biodiversity** and its linkages to NBS and ecosystem services in cities has to be taken into account. For instance, higher urban temperatures based on the urban heat island effect were shown to be a main stressor to which urban biodiversity is exposed, but the impact of climate change related temperature increases on biodiversity remains unclear. More evidence is needed concerning the role of urban biodiversity for climate change adaptation and mitigation. This relates to concerns about the number and diversity of species in cities and their effect on city resilience towards climate change and which aspects of biodiversity are relevant for ecosystem service provision (habitat diversity, species richness, functional diversity, else). NBS might not always be provided by diverse systems, but also by single keystone species. In this respect, more research is needed for the identification of synergies and trade-offs amongst biodiversity and ecosystem services as well as disservices of green and blue infrastructure.

- **Consideration of all population groups** in cities when studying and implementing nature-based solutions to guarantee equal access to the benefits of NBS. This also relates to the inclusion of a “social perspective” in the research on, discussion about, implementation and managing of nature-based solutions in cities. When promoting urban green and blue areas through NBS, the **co-benefits that citizens receive** from urban nature are often highlighted. However, NBS may not always be beneficial for all population groups in the same way, some benefits may take several years or decades to come into full effect and some may come along with trade-offs. Improved availability of urban green spaces may not increase social coherence, as promoted in the Final Report of the 2020 Expert Group (European Commission 2015). Instead, improvements and increases in the size and quality of urban green spaces might go hand in hand with increasing land prices and rent (Dooling 2009, Seymour et al. 2010, Checker 2011). In turn, this could lead to the potential displacement of population groups who cannot afford the higher prices and for whom the green space would be most beneficial. It can thus be questioned if NBS lead to a reconnection of people to nature in cases where raising rent prices force them to move to areas with a lower residential quality. New modes of governance are thus necessary to take into account an integrative and transdisciplinary participation of diverse residents, thereby counteracting displacement processes. Integrated approaches are required to make sure that housing at affordable prices is provided while simultaneously bettering the environment.

5 Review on key issues related to NBS for climate change adaptation and mitigation in urban areas

In order to further elaborate on and to deepen the understanding on issues raised during the workshop (see section 4) the following literature review summarizes current knowledge on selected key issues related to NBS for climate change adaptation and mitigation in urban areas. The impacts of climate change and urbanization particularly on biodiversity are briefly introduced in the first part of the review. Then, green roofs and facades as NBS are addressed in the following. The next part of the review focusses particularly on urban parks and street trees as part of the green infrastructure of a city as a NBS to climate change. The last part of the review relates to NBS and health as well as environmental justice issues.

5.1 Impacts of climate change and urbanization on biodiversity

Climate change is expected to become one of the most important drivers of biodiversity loss and change in distribution patterns (Parmesan & Yohe 2003). While land use and land use change are currently the main drivers of biodiversity change (Sala 2000), and possibly masking climate related effects, also interactions and trade-offs between a number of drivers of change are likely (Brook, Sodhi & Bradshaw 2008). The current knowledge on biodiversity responses on these different drivers such as land use change, urbanization and climate change, suggests, although being scattered, extensive changes to distribution, abundance and phenology patterns of species and local extinctions or additions to species communities in urban areas.

The effect of urbanisation on species richness varies, as (McKinney 2008) could show for a range of non-avian species. While species richness is often reduced in areas with extreme urbanization, such as city centres, species richness may decrease or increase in areas of moderate levels of urbanization, such as suburban areas. McKinney (2008) also discusses how some “urban-adapted” species become common in cities worldwide, and a number of native species, which can cope with the changing conditions, can become locally and regionally abundant at the expense of other indigenous species. In addition, cities may also be hotspots for invasion of non-native species. Von der Lippe and Kowarik (2008) showed in a review that the representation of alien species in numbers shows a close relationship to the urban structure decreasing from city centre to outer city parts. The effects of climate change on overall species richness, local abundance of species that are adapted to warmer conditions (Lindström et al. 2013; Thomas et al. 2006), as well as patterns in phenology (Karlsson 2014; Walther 2010; Cleland et al. 2007) have been shown by several authors (Thomas et al. 2004). Climate change effects will be amplified in urban settings (Luo et al. 2007; Grimm et al. 2008), so that cities can serve as early ‘warning’ demonstration sites for potential changes in the wider landscapes.

The conversion of open, rural land into built-up land is one of the irreversible human impacts on the global biosphere, which is particularly visible in urban landscapes (Seto & Reenberg 2014). This conversion affects local climate and habitats, and threatens biodiversity. Typically, the result of the spread of urban landscapes is a reduction in biodiversity. However, with the encroachment of urban areas into rural habitats, urban green spaces are becoming an increasingly important refuge for native biodiversity (Goddard et al. 2010). Building on a review by Goddard et al. (2010) Table 5 summarizes the main impacts coming from urbanisation processes on habitat and the resulting biological effects.

Table 5: Impacts of urbanisation on habitat and the resulting biological effects (adapted from Goddard et al. 2010)

Reference	**Impact of urbanization on habitat**	**Biological effect**
McKinney (2008)	Loss of habitat loss, disturbance and fragmentation	*Biotic homogenisation due to decreased species richness* *Peaked species richness at specific levels of urbanisation, particularly for birds and plants*
Niinemets & Peñuelas (2008) Wania, Kühn & Klotz (2006)	Import of species in human dominated landscapes	*Domination of floras by exotic species, causing increased species richness relative to rural areas, but decreased native plant diversity. Invasion of species to surrounding semi-natural habitats*
Kaye, Groffman, Grimm, Baker & Pouyat (2006) Shen, Wu, Grimm & Hope (2008)	Increased air temperatures and changing atmospheric chemistry (i.e. elevated CO2, NOx, aerosols, metals and ozone)	*Changes in nutrient cycling, primary production and plant growth*
Grimm et al. (2008)	Increase in impervious surfaces affects hydrology patterns of urban watersheds	*Decreased biodiversity, high nutrient loadings and elevated primary production resulting in an 'urban stream syndrome'*
Shochat, Warren, Faeth, McIntyre & Hope (2006)	Altered productivity, competition and predation	*Changes in trophic structure and food-web dynamics*
Partecke & Gwinner (2007) Mockford & Marshall (2009)	Altered environmental conditions such as changes in air quality or ambient sound	*Local adaptation and evolution caused by behavioural, morphological and genetic responses (changes in bird song due to noise)*
Clergeau, Croci, Jokimäki, Kaisanlahti-Jokimäki & Dinetti (2006)	Changes in landscape composition and configuration	*Homogenisation by decreasing the abundance of ground nesting bird species and bird species preferring bush-shrub habitats. Urbanisation appears to be a cause of taxonomic homogenisation of the avifauna but the effects of latitude and urban habitat diversity may make generalisation difficult.*

Some studies clearly indicate the effect of urbanization processes in combination to other drivers of change on biodiversity. Costanza, Terando, McKerrow & Collazo (2015) conducted a scenario analysis of the impacts of climate change, urbanization and management on future dynamics of the longleaf pine ecosystem. They clearly demonstrated the importance of accounting for multiple ecosystem drivers together for informing ecosystem management. They highlight that future effects of urbanization may even outweigh the effects of climate change.

In the next section, we review the contribution of green roofs, green facades and urban parks as concrete NBS implementation options to climate change adaptation and mitigation. We focus on those three, as they have been research recently in a number of studies and are particularly important in the urban context (European Commission 2015).

5.2 Assessment of Nature-Based solutions for climate change adaptation and mitigation

Today, cities form islands of higher local air temperatures compared to their non-urban surroundings. This so-called "urban heat island effect" is due to different land cover: Urban land cover mostly includes sealed areas such as buildings and roads, which absorb sunlight and emit it as heat. Peri-urban and rural areas surrounding cities generally present higher shares of vegetation and uncovered soil which in turn can better cool the air through evaporation. As we live in an urbanized world where at current more than 50 per cent of the world population already lives in cities (United Nations, Department of Economic and Social Affairs 2013) and urban expansion is supposed to increase further, sustainable ways which base on green and blue areas are needed to adapt to and decrease the local heat island effect. Such green and blue areas can be part of the green infrastructure of a city and can act as NBS to climate change. In the following three sub-sections, we focus on the effects of green roofs and green walls as well as urban parks as NBS.

5.2.1 Green roofs

Green roofs are supposed to provide a number of economic, environmental and ecological benefits, which can be regarded as a nature-based solution to climate change adaptation and mitigation. The benefits include moderation of the described urban heat island effect but also stormwater runoff, air purification through the absorption of dust and smog, carbon dioxide sequestration, space for food production and the provision of habitats (Arabi, Shahidan, Kamal, Jaafar & Rakhshandehroo 2015; Baik, Kwak, Park & Ryu 2012; Santamouris 2014; Susca, Gaf & Osso 2011a). Scientific research publications on green roofs significantly increased within the last two decades and encompass different scientific fields from environmental engineering, architecture, ecology, and others. Li & Babcock Jr. (2014) found in a review more than 400 scientific papers dealing with green roofs. Among them 43 per cent deal with thermal effects of green roofs and 16 per cent with runoff quality.

The observed higher temperatures in cities compared to their non-urban surroundings are also expected to intensify energy problems of cities and to negatively impact on the quality of life of city residents. As explained above, the reasons for the heat island effect are supposed to lay in the physical structure of the cities. In particular, building materials are mostly impervious. Further, the material of urban buildings is often dark in colour and in combination with the canyon structures of dense cities radiative energy of the sun is trapped. The reduction of the surface temperature of buildings through the implementation of green roofs is an option to improve the thermal conditions of cities through lowering the surface temperatures because of their thermal performance and the reduction of the absorption of sun radiation. This was further highlighted in a recent review on the mitigation potential of urban heat island effect through green roofs by Arabi et al. (2015, see Table 6).

Concerning the heat mitigation potential for a whole city level only some studies are available. For Singapore, Wong et al. (2007) stated that the cooling effect of a green roof depends on the distance from the roof. A maximum temperature difference of 4.2K of the ambient air was reported for 30cm distance from the roof. Authors conclude that green roofs may be most effective when the building height is below 10 m.

To counteract the heat island effect, different mitigation technologies were proposed, developed and implemented. These technologies focus on the use of vegetative cover of green roofs while also non-natural technologies are tested comparatively. Those non-natural technologies are named as *high reflective roof*, *white roof* or *cool roof*.

Table 6: Studies of the effect of green roofs on temperature reduction in cities (own review and adapted from Arabi et al. 2015)

Reference	**Method**	**Result**
Harazono, Teraoka, Nakase & Ikeda (1990)	*A rooftop vegetation system was developed on a university building and consisted of artificial substrates and equipment for water supply. This system was tested over one year.*	Absolute humidity in the surrounding air increased, air temperature in the room decreased with the rooftop vegetation in summer. Heat flux through the rooftop decreased with the rooftop vegetation.
Bass, Krayenhoff, Martilli & Stull (2002)	*Simulation. Use of Mesoscale Community Compressible (MC2) model, land use grid cell data, urban canyon model for Toronto, Canada.*	A green roof strategy consisting of grass-roofs (only 5% of the total city area) reduced temperatures by up to 0.5°C. Similar results were obtained for the same degree of white roof coverage. Irrigating green roofs in the high-density areas produced a much more intensified cooling effect: 1-2°C temperature reduction.
Rosenzweig et al. (2006)	*Regional climate model in combination with observed meteorological satellite and GIS data for New York City, US*	Green roof can decrease the near surface air temperature between 0.4 and 1.8°C. Green roofs offer more cooling per unit area than light surfaces, but less cooling than curbside planting.
Wong et al. (2007)	*Satellite imagery analyses, simulation approach, GIS and field measurements for the buildings of the National University of Singapore*	Simulation results indicate that a rooftop garden has the potential of cooling energy savings for buildings and that buildings near or surrounded by green space have lower ambient temperature than those farer away.
Chen, Ooka, Huang & Tsuchiya (2009)	*Coupled simulations of conduction, radiation and convection for Tokyo, Japan*	Installing grass roofs on medium and high rise buildings has a negligible effect on the street level air temperature.
Castleton, Stovin, Beck & Davison (2010)	*Review the literature on energy savings*	Implemented on buildings with poor insulation values green roofs significantly decrease energy use in both in summer cooling and winter heating. Modern buildings (built according to the UK building regulations of 2006) have better roof insulation resulting in no additional energy saving effects by green roofs. The thicker the soil substrate on the roof, the better the heat gain/loss into/out of the building. In cases of wet soil, heat has been shown to be drawn out of a building because of high evapotranspiration effects.
Santamouris et al. (2012)	*Literature review*	Different benefits of green roofs focusing on mitigation of urban heat island

Reference	Method	Result
Smith & Roebber (2011)	*Weather research and forecasting model coupled with an urban canopy model applied for Chicago, US*	Vegetative rooftops reduce evening and night-time temperatures by 3°C through increased albedo and evapotranspiration. Increase in moisture resulting from transpiration leads to only marginal cooling when apparent temperatures are considered.
Scherba, Sailor, Rosenstiel & Wamser (2011)	*Field experiment and energy balance models*	Replacing a black roof with a white or green roof resulted in a substantial decrease in the total sensible flux of 50%
Susca, Gaf & Osso (2011b)	*Multi-scale approach including analysis of the field data recorded in different areas in New York City and* *a comparison of the temperatures recorded in the core of the city (Columbia University) and in a widely forested area (Fieldston in the Bronx);* *- evaluation of the difference of heat fluxes through three roofing systems (black, white, green);* *- application of a climatological model*	There is an average of 2°C difference of temperatures between the most and the least vegetated areas based on the transformation of black into green building roofs.
Sun, Lee, Lin & Lee (2012)	*Numerical model ENVI-met and verified using field measurements adapted for Taiwan*	Roof greening is ineffective for human thermal comfort near the ground. The maximum cooling effect of green roofs on ambient air temperature was 1.6°C

High reflective roofs focus on high reflective materials to increase the albedo of cities while also reducing the absorption of heat and light at daytime. Both, non-natural technologies and green roofs are supposed to decrease the surface temperature of building roofs and thus, to also lowering the heat flux to the atmosphere.

Some studies have been conducted to compare the effect of different types of roof such as a manmade black roof, a high reflective and a green roof. For New York City, Susca et al. (2011b) found that using both the reflective and the green roofs lead to energy savings through reduced energy use of offices underneath compared to the black roof. Georgescu, Morefield, Bierwagen & Weaver (2014) conducted different urban expansion scenarios across the US to model the effect of non-natural (cool) roofs compared to green and cool/green hybrid roofs. Authors found that cool roofs had a greater cooling effect than green roofs, especially in drier regions such as California. They indicated that even the hybrid version combining green and cool roofs performed slightly better than green roofs. It was, however, highlighted that cooling was increased in winter times by cool and green/cool roofs, which may lead to higher energy use to heat up buildings. This may then lead to an offset of the saved energy by reducing air condition use during summer. In general, significant variations according to geographic location were identified (ibid).

In a very recent review, Santamouris (2014) analysed a number of papers on the mitigation potential of both cool (reflective, non-natural) and green roofs. Analysing case studies from US cities (Chicago, New York) and Asian cities (Tokyo, Hong Kong) and cities of other parts of the world Santamouris (2014) came to the following conclusions:

- The mitigation potential of reflective roofs is higher than the mitigation potential of green roofs when the albedo of the reflective roof is ≥ 0.7 during a peak period.

- The climate is one of the main factors which effect mitigation potential. From the different studies coming from different areas of the world it is concluded that in sunny climates, reflective roofs provide more mitigating benefits while in moderate to colder climates green roofs are more effective.
- When albedo values lower than 0.5 are considered, green roofs performed much better than conventional black roofs.
- The height of the building plays a crucial role as well. Green roofs on high-rise buildings seem to have a very limited effect on mitigation potential.
- The building characteristic influences the contribution of a roof to energy savings. Effect of green roofs on energy savings decreases the better the insulation of the building is.

In sum, there seems to be no one best solution for implementing green or reflective roofs when the overall aim is to mitigate climate change. The respective benefit depends on local climate, the design of the green roof, the building characteristic and energy use (Santamouris 2014; Georgescu et al. 2014).

Concerning green roofs and air pollution Li & Babcock Jr. (2014) analysed 52 publications in an in-depth review in terms of green roof performance against runoff quality and greenhouse gas CO_2sequestration. Authors highlighted that the concentrations of major pollutants such as phosphorus and nitrogen vary highly for different green roofs and that they can simultaneously affect runoff quality. Authors identified that the main factors influencing water runoff quality are growth media composition, depth, plant species, precipitation properties and maintenance protocols.

Air quality improvement through green roofs was further assessed by Baik et al. (2012) using a computational fluid dynamics model, which focusses on passive, non-reactive pollutants. Results showed that for a simple building configuration using a street canyon the cooler air produced through the green roofs flows into the canyon, which increases street canyon flow. The street canyon flow than enhances pollutant dispersion near roads and thus decreases pollutant concentration. Authors also measured the values for a real urban morphology (Seoul, South Korea) and found that a green roof improves the quality of the air near roads while depending on the ambient wind direction.

Green roofs have also been communicated as a potential space being used for urban agriculture defined as growing plants and raising animals within urban areas. A study by Orsini et al. (2014) evaluated a project of rooftop vegetable farming on public buildings in Bologna, Italy. Authors modelled the potential vegetable farming productivity when all suitable flat roofs in the city would be used. In their results, they found that city's rooftops could meet 77 per cent of Bologna's inhabitants vegetables needs. Sanyé-Mengual, Anguelovski, Oliver-Solà, Montero & Rieradevall (2016) conducted stakeholder interviews in Barcelona to identify the perception of roof-top farming. They identified a high social value of the practice, and relate it to the traditional local meaning of urban gardening as a tool for leisure provision and other social meanings. However, they also identified institutional barriers including legislation but also economic investment interests.

In conclusion, cities will have to take into account a bundle of factors when implementing climate adaptation and mitigation measures through green roofs. These factors include geographic location, building characteristics, energy use, plant species used and precipitation properties. Beside pure climate adaptation and mitigation, notably green roofs have the potential to provide a number of additional benefits, which standard man-made black roofs but also reflective, cool roofs cannot provide. Such multiple benefits include the potential to provide habitats, retain stormwater, improve air quality, store CO_2, space for urban agriculture and recreation and thus, overall, increase quality of life of city residents.

Biodiversity is of importance for the effectiveness of NBS. This was investigated by Lundholm (2015), who assessed ecosystem functions of green roofs based on different plant species and functional groups. Lundholm used different plant systems with monocultures and mixtures and used one, three or five different life-forms. Heat mitigation potential and water capture was assessed as ecosystem services while the author also measured the albedo, evapotranspiration, and biomass. The author found no one-fits best combination but a differences in ecosystem service provisioning depending on which life-forms were used.

It was found that temperature reduction of the roof surface corresponds to a reduction in heat flux into the building. The author further found relationships between surface temperature, albedo, species richness and biomass variability. In systems with higher albedo values, species richness, and lower biomass variability, it was found that they had the lowest temperatures. The author could not identify that planting five life-forms with 15 species resulted in a better performance compared to the three life-form treatments with nine species. The author found that the best performing mixture concerning ecosystem service provisioning in the three life-form treatments was succulents, grasses and tall forbs. Authors further concluded that ecosystem service provisioning increased with the diversity of plant life-forms when specific species as the mentioned ones are considered. Thus, informed selection of plant species for green roofs will provide a significant increase in ecosystem service provision such as temperature reduction and reduction in greenhouse gas emission.

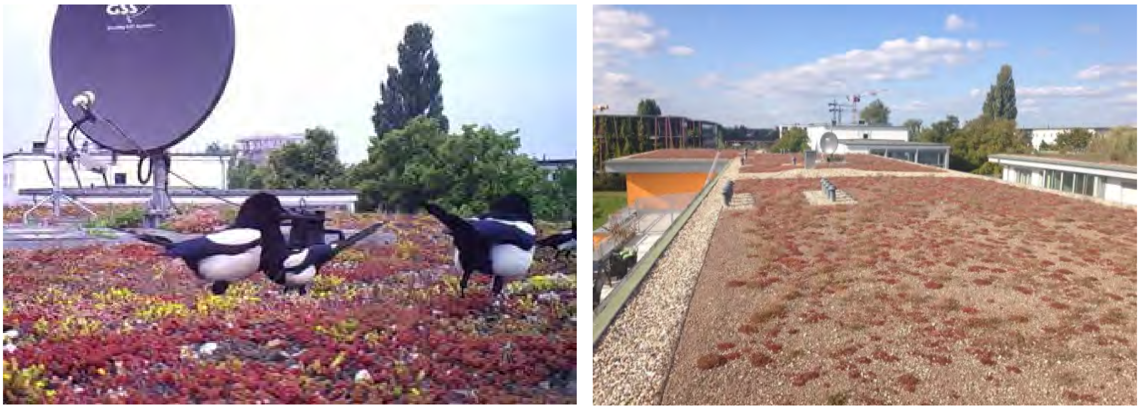


Figure 6: Magpies on an extensive roof in Berlin (Photo by Michael Strohbach, 2015)

5.2.2 Green walls for climate change adaptation and mitigation

In the chapter above the benefits of green roofs for mitigating the urban heat island effect and for improving quality of life by a number of multiple issues were highlighted. A number of these benefits also apply for green walls (Figure 8). These benefits include the potential to lower energy use in buildings, to provide habitat and thus support biodiversity, to clean the air, to mitigate stormwater run-off or to increase the aesthetic appealing of the building. The city of Vienna, Austria, is one of the first cities providing detailed information and a guideline on implementation of green walls in the city (Magistrat der Stadt Wien 2013). Using a number of expressive examples, the guideline illustratively explains the benefits of green walls and what is needed for their implementation. Detailed information is given about technical essentials (building characteristics, substrates, etc.) and green essentials (plant species, irrigation, etc.).

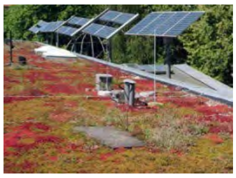
What is only now becoming in the focus of research and implementation is the use of green walls for noise attenuation. Only few studies dealing with the sound insulation potential of green walls have been conducted so far. Azkorra et al. (2014) identified a reduced sound level of 15 dB by using a modular green wall system. Although authors highlight that other solutions reduce noise by 30 dB or more such as double-glazing they think that implementing green walls has a good potential to reduce sound while also providing a number of multiple benefits.

Table 7 shows some selected green roof and green wall projects, related ecosystem service provision and costs of implementation.

Figure 7: Green walls in the German cities of Berlin (left) and Augsburg (right)

Table 7: Selected green roof and green wall projects as NBS, related ecosystem services provision and associated costs.

Place	Description	Picture
Vienna, Project MA 48 (2010)	• Green facade, climate façade project • Cooling effect through transpiration in summer, isolation of building in winter, increase of plant and animal biodiversity; up to 50% reduction of heat loss • Ecosystem service provision: providing climate regulation, habitat ecosystem services • Costs: € 400000 (400 € / m²) / Maintenance: € 800 / year • Further reading: www.ecologic.eu/sites/files/publication/2014/eco_bfn_nature-based-solutions_sept2014_en.pdf	 https://www.tuwien.ac.at/fileadmin/t/tuwien/fotos/pa/download/2015/gruene_fassade_MA48.JPG Copyright: TU Wien (free of charge)
London, Brown roof at Laban Dance Centre (2002)	• Extensive brownfield green roof on a commercial building • Ecosystem service provision: Habitat, climate regulation, runoff regulation • Further reading: https://www.buglife.org.uk/sites/default/files/Creating%20Green%20Roofs%20for%20Invertebrates_Best%20practice%20guidance.pdf • http://www.urbanhabitats.org/v04n01/london_full.html • http://www.livingroofs.org.uk/images/stories/pdfs/Biol_52_3_Kadas.pdf	 http://www.urbanhabitats.org/v04n01/london_fig4.html Copyright: dustygedge/livingroofs.org

Place	Description	Picture
Green roof; Gründach ufaFabrik Berlin.	• Photovoltaic (PV) panels were installed on an existing green roof of 400 m² • Green roofs reduce operation temperatures of the PV elements, leading to both increasing the energy yield and a higher biodiversity due to shading, runoff regulation • Ecosystem service provision: climate regulation, , habitat • Costs: €40 /m² • Further reading: http://www.rio12.com/rio02/proceedings/pdf/151_Koehler.pdf • http://marno.lecture.ub.ac.id/files/2012/01/MODEL-VEGETASI-ATAP-HIJAU.pdf	 http://www.ufafabrik.de/sites/de Copyright: ufaFAbrik Berlin e.V.
Basel (CH), Main Exhibition Hall (Messehalle Basel) Green Roof (2000)	• Green roof of 8000 m², one of the biggest green roofs in Switzerland, combining various substrates, vegetation types, structures to feature biodiversity. Also used for the installation of PV-panels • Green roof features urban invertebrate and bird biodiversity, reduces surface runoff, helps cooling solar panels • Ecosystem service provision: habitat, climate regulation, runoff regulation • Brenneisen (2006): *Space for urban wildlife: designing green roofs as habitats in Switzerland.* Link: http://www.urbanhabitats.org/v04n01/urbanhabitats_v04n01_pdf.pdf	 http://www.greenroofdesign.ch/media/GreenRoofDesign_060_m.jpg Copyright: Monica Ursina Jäger und Michael Zogg greenroofdesign.ch, 2009

5.2.3 Parks and street green as part of the urban green infrastructure as nature-based solutions for climate change adaptation

Urban parks and street green may play an important role in contributing to human well-being in cities. As a nature-based solution to climate change mitigation, they can provide thermally comfortable environments and, thus, may reduce vulnerability to heat stress (Figure 9). Urban parks and green spaces are referred to in scientific literature as 'park cool islands' (PCIs) (Spronken-Smith & Oke 1998).

Vegetation, particularly trees, alters microclimates and can cool the air through shading and evaporation from transpiration. Several studies have investigated the effects of urban green space, trees and shrubs on temperatures (see Breuste, Haase & Elmqvist 2013; Brown, Vanos, Kenny & Lenzholzer 2015; Hwang, Lum & Chan 2015, and Table 8). In an extensive review containing a meta-analysis of data from different studies, Bowler et al. (2010) found that, on average, an urban park can decrease ambient temperature about 1°C compared to a non-green site.

Some studies have assessed whether a park has any effect on the temperature of the surrounding neighbourhood area. Yu & Hien (2006) measured temperature on a gradient of 500 m from park boundary to the surrounding area in two large parks in Singapore. For both parks, temperatures gradually increased with increasing distance from the park. In a study of three parks in the city of Goteborg, Upmanis et al. (1998) showed that the night-time cooling effect of a park extended beyond the boundary up to 1 km, particularly for the largest of the parks (156 ha). A long-term study in London identified cooling of up to 4°C on a 440 m gradient from the park on summer nights (Doick et al. 2014). The effect that the air temperatures in parks and green spaces are typically lower than in the surrounding urban environment is shown in different studies from different climates: for subtropical areas (Jauregui 1990), in humid sub-tropical (Chang et al. 2007), in moderate oceanic (Spronken-Smith & Oke 1998), in Mediterranean (Spronken-Smith & Oke 1998), continental climates (Breuste et al. 2013), and oceanic climates such as UK (Doick et al. 2014).

There are several local influences on temperature reduction potential by urban vegetation. These influences have been discussed in a number of scientific studies (for an overview study see (Mathey et al. 2011). They include amongst others the amount of tree cover, amount of impervious surfaces in the area, time of day, antecedent moisture condition and topography. Even the benefits of green space change with the particular context, such as type of greening. In the following, we present an overview of studies, which show the potential temperature reduction by urban vegetation and different associated conditions.

Figure 8: Urban park with single trees and clusters of trees (Photos by D. Haase, left and Roland Krämer, right)

Effect of daytime

Temperature reduction potential of urban green spaces varies with time of measurement. In their review Bowler et al. (2010) found that measurements during the day (06:00–20:00) showed an average temperature reduction of 0.94°C between the urban temperature and the temperature in the park. This result is based on 16 studies. On the other side, measurements during the night (22:00–06:00) identified a slightly higher reduction of 1.15°C based on seven studies. The cooling effect into the surrounding areas can also be different related to daytime. At night cooling effects were identified to be smaller in studies comparing the difference between a park and its surrounding areas with 0.65°C than in studies where the temperature of the park was compared with an urban site elsewhere in the town or city with 2.26°C (ibid.).

Effect of park size and type of vegetation

Studies measuring temperature from multiple parks in the same urban area showed that larger parks were cooler. The studies also show the effects of different types of vegetation, particularly the difference between short vegetation, such as grass, and tree canopy cover. Results of studies further show that parks larger in size were either more likely to be cooler or that the cooling effects in the surrounding areas were greater. Chang et al. (2007) identified that parks of a size of more than 3 ha in Taipei were usually cooler than the surrounding urban area. In a study by Barradas (1991), the temperatures of five parks in Mexico City, ranging in size from 1.9 to 9.9 ha, were measured every week during the rainy season. The results suggested that larger parks tended to be cooler than their surroundings.

Effect of vegetation composition

Variation in the composition of vegetation within a park, such as the amount of tree and grass cover affects temperature reduction potential. Potchter, Cohen & Bitan (2006) compared five parks in Tel Aviv and found that the three grassy parks with few trees tended to be warmer during the day, compared to its surroundings, than the two other parks with greater tree cover. This effect may be due to a combination of the shade from buildings in the grass park's surrounding area and heat release from the grass. The study by Chang et al. (2007) reported that the percentage of tree and shrub cover explained differences in temperature between parks and their surroundings. Parks may also vary in the proportion of area without vegetation cover. Increased paved area within a park has been shown to positively correlate with the air temperature difference in studies in Mexico City and Taipei (Barradas 1991; Chang et al. 2007).

Several studies have focused specifically on the effects of trees, comparing temperatures in a site with trees, with those of a nearby treeless site. Results showed that daytime temperature beneath individual trees (Georgi & Zafiriadis 2006) but also clusters of trees (Souch & Souch 1993; Shashua-bar & Hoffman 2000) are lower than temperatures in an open area. Shashua-bar & Hoffman (2000) demonstrated that the specific amount of shading coverage was an important factor affecting temperature. Comparisons of temperature within more dense urban forests and non-green urban sites have also shown lower temperatures in the forested sites (Heisler & Wang 1998; Huang, Li, Zhao & Zhu 2008; Yilmaz, Zengin & Yildiz 2007). However, these studies also demonstrate that a tree canopy can retain heat at night (Souch & Souch 1993).

Table 8: Temperature effect of urban green space in different sites

Reference	**Site / Method**	**Main finding**
Doick et al. (2014)	5-month study to measure temperature profiles of one of central London's large greenspaces and in an adjacent street; statistical modelling	Exponential decrease in the extent of cooling with increased distance from greenspace Extent of cooling ranged from 20 m to 440 m into surrounding areas during nights. Mean temperature reduction over these distances was 1.1 °C in the summer months, with a maximum of 4 °C cooling observed on some nights.
Chang et al. (2007)	air–temperature measurements in and around 61 Taipei city parks	At noon in summer, parks with ≥50% paved coverage and little tree- and shrub-cover were on average warmer than their surroundings. Large parks were on average cooler than the smaller ones. At noon in summer, the parks were on average 0.81 K cooler than their surroundings. In summer nights, the parks were on average 0.29 K cooler. At noon in winter, the parks were on average 0.57 K cooler.
Shashua-bar & Hoffman (2000)	Measurements in 11 different wooded sites in the Tel-Aviv urban complex during the period July–August 1996; empirical model based on the statistical analysis carried out on 714 experimental observations gathered each hour from the 11 sites on calm days	Two factors explain over 70% of the air temperature variance inside the urban green space: partial shaded area under the tree canopy and the air temperature of the non-wooded surroundings. Geometry and tree characteristics count for 0.5 K temperature reduction. Average cooling was about 3 K at noon. At small green sites, the cooling effect is up to about 100 m in the streets branching out from the site.

Reference	Site / Method	Main finding
Spronken-Smith & Oke (1998)	Surface and air temperature observations in Vancouver, BC and Sacramento, CA. during summer. Remotely sensed surface temperature and air temperature from station and mobile (car and bicycle) traverses are combined.	Park type, the extent of irrigation and the presence of trees influence PCI development. Parks are typically 1-2 °C cooler, in ideal conditions nearly 5 °C cooler than surrounding spaces. Larger PCI are possible in Sacramento where irrigated greenspace can be 5-7 °C cooler. At night, surface geometry and moisture status influence surface cooling. Open parks without trees and dry soils cool the most.
Potchter et al. (2006)	Examination of climatic behaviour of different designs of urban parks during hot and humid summer conditions. Three different types of urban parks: park with grass and a few low trees, a park with medium sized trees and a park with high and wide-canopied trees.	Urban parks containing high trees with a wide canopy have the maximum cooling effect during daytime with a temperature reduction by up to 3.5°C.
Chen et al. (2009)	Four types of land cover, namely urban bare concrete cover, urban woods or the shade of trees, urban water areas and urban lawn, were selected to study their microclimate. The UHI was also analysed using air temperature data measured at four fixed observation spots in Nanjing, China, during hot weather from July to September, 2005. Dry and wet bulb temperature data were obtained by whirling psychrometers, and wind speed data by cup anemometers.	The microclimate of the different land cover types had significant differences among different observation sites. Compared with the bare concrete cover, the other three types of land cover showed the effect of dropping air temperature ranging between 0.2 and 2.9 °C. The UHI effect could be detected obviously by the air temperature difference between the urban centre area and the rural area. The average UHI intensity ranged between 0.5 and 3.5 °C. A strong UHI effect occurred around midnight; while about 2–3 h after sunrise the UHI began to decrease till midday time; and during 13:00–15:00, the UHI effect had a sudden increase and then decreased again; after sunset, a peak UHI effect was frequently observed during 18:00–21:00.
Souch & Souch (1993)	Bloomington, Indiana, Replicate trees in each of five categories were studied: sugar maple, pin oak and walnut individuals over grass, suggar maple individuals along streets over concrete, and sugar maple clumps over grass.	All trees showed that temperature is reduced and humidity is elevated under canopies. The greatest cooling effect (0.7 -1.3°C) occurs in the early afternoon. The selection of species is not significant, but street trees are significantly less effective in reducing temperature than either individual trees or clumps planted over grass. The clumps had no greater effect than the individual trees.
Upmanis & Chen (1999)	The air temperature pattern in three urban parks and their surrounding built-up areas was studied over a one and a half year period in Göteborg, Sweden using mobile and permanent stations on nights with clear skies and light winds.	The maximum temperature difference found between a park and a built-up area was 5.9°C (summer), and the extension of the cool park climate into the built-up area was over 1100 m from the park border. Both the extension and the magnitude of the temperature difference depended on the size of the park and the distance from the park border.

Tree species have been shown to vary in their ability to reduce air temperature, which may be due to a number of factors, such as tree size and tree canopy characteristics (Georgi & Zafiriadis 2006; Souch & Souch 1993). Two studies compared the effects of a single tree versus a cluster of trees on air temperature. In one of these, marginally higher temperatures were found under the single tree than the cluster, but only one site of each was measured (Streiling & Matzarakis 2003). In a replicated study (Souch & Souch 1993), no difference was found between single or clumps (3 or 4 trees) of Sugar maple trees in Indiana, USA. This study also compared air temperatures beneath the trees when growing on either a concrete or grass surface. Warmer temperatures were found beneath those in the street.

5.3 Nature-based solutions to climate change in urban areas and their role in improving city resident's health and fostering social-environmental justice

Increased air temperature due to climate change can lead to increased heat-related illness (Harlan, Brazel, Prashad, Stefanov & Larsen 2006) and mortality (Chen et al. 2014). During the 2003 heat wave in Europe, more than a half of the estimated 40,000 extra deaths resulting from extreme heat were among elderly people (García-Herrera, Díaz, Trigo, Luterbacher & Fischer 2010). There is also evidence for disproportionate heat-related health burdens associated with unequal distribution of green space in urban areas. In the city of Leipzig, Germany, the urban heat island effect is most significant in areas of high impermeable built-up density and low share of green space (Steinicke 2010). Urban green spaces have the potential to counteract heat related illnesses and mortality (Chen et al. 2014).

Figure 9: Children enjoying open space (left) and an example of an intercultural garden both developed on a redeveloped railway brownfield area in Berlin (right, photos by Nadja Kabisch).

Accessibility to or living close to an urban green space was found to have a number of additional positive health effects such as perceived general health and morbidity from diseases or stress (for an overview see Hartig et al. 2014). Green spaces further promote health by providing opportunities for physical activity (Barton & Pretty 2010; Hartig 2008) and by offering places for recreation, social interactions, and stress recovery with positive effects on both mental and physical health. Urban green spaces also provide ecosystem services, which decrease next to reducing the urban heat island other risk factors and mortality in vulnerable groups, by for example reducing noise and air pollution. Some studies identified significant linkages between distance to park and physical activity (Diez Roux et al. 2007; Evenson Wen, Hillier & Cohen 2013).

Access to green spaces is particularly important for children and their cognitive development, offering places to play and be physically active while fostering a genuine connectedness to the natural environment, influencing their future health and environmental awareness (Ogden et al. 2008; Vanos 2015; Wolch et al. 2011, Figure 10). Particular attention is paid to the relation between green space quantity or access and obesity (Ogden et al. 2008). Obesity is found to be especially detrimental to children's health (Dietz 1998) and their physical development. Although certainly a number of factors such as genetic prevalence play a role, the hypothesis addressed is that children having good access to urban green space from their home are more physically active and thus less likely to get obese. According to Wolch et al. (2011) not only park access but also access to recreational programmes were found to be significantly related to the development of childhood obesity.

However, within cities green spaces are often unequally distributed between groups of different socioeconomic status, age and ethno-racial characteristics (Byrne & Wolch 2009; Gobster 1998). Uneven access to urban green space has become an issue of socio-environmental justice (Kabisch & Haase 2014) and awareness of this problem has increased in terms of related negative health impacts across the life course (Dai 2011). Uneven distribution of and access to urban green spaces may be related to a number of interlinked factors including path dependency related to history, land use development, park management and design. Also in historical times green spaces and parks were created where the rich lived and/or typical replacements of the poor after the installation of large green spaces happened. Even today, the installation and development of urban green spaces such as parks increases attractiveness of a neighbourhood making it desirable for investments. In turn, raising house and rent prices can potentially lead to a displacement of those residents the green space was actually meant to be beneficial. Such effects are called "green paradox" (Wolch, Byrne & Newell 2014), "eco gentrification" (Haffner 2015; Patrick & Kowalski 2011), "ecological gentrification" (Dooling 2009) or "environmental gentrification" (Checker 2011).There exist some interesting examples of the "green paradox" where urban greenspace strategies meant as sustainability approaches resulted in paradoxical outcomes. One example is the New York High Line. The High Line was a train line spur from the 1930s to the 1980s and was left abandoned afterwards. In the early 2000s the area started to be redesigned as an aerial greenway attracting millions of tourists each year and becoming a space for biodiversity with a variety of birds or insects. With the greening of the High Line the area around became more attractive and thus experienced increasing property values by more than 100% (Patrick & Kowalski 2011) with negative consequences for low-income residents (Figure 11).

Figure 10: The High Line in Manhattan, New York City (photo by: Dagmar Haase)

The Cheonggye Restoration Project in South Korea is a similar example where the restoration of a central city area in the frame of a state-led project that stimulated land use changes in favour for housing that is more affluent and with the result of the displacement of industrial activities and low status population groups.

Table 9: Green implementation projects with potential of upsetting gentrification processes but also to avoid displacement processes.

Reference	Case study	Main finding / explanation
Patrick & Kowalski (2011)	New York High Line, US	The development of new parks on former industrial sites is inseparable from gentrification of adjacent neighbourhoods (West Village and Chelsea).
Dooling (2009)	City-initiated ecological design project, Seattle, US	Workshops among housed citizens to plan out future green spaces over the next 100 years: people created an ecologically sustainable city through the construction of green infrastructure focussing on the downtown core. New green spaces were inserted, replacing spaces occupied by shelters and low-income housing, which were removed in an effort to enhance the ecological functioning of the city. Problem: the implementation of an environmental planning agenda related to public green spaces lead to the displacement and exclusion of homeless people.
Lim, Kim, Potter & Bae (2013)	Cheonggye Stream Restoration Project, Seoul Central Business District, South Korea	The greening project has induced land use changes favouring more affluent households.
Wolch et al. (2014)	urban core, where densities are highest, parks are fewer, Hangzhou, China	New studies suggest that urban greening efforts may also be inflating property values. This may lead to gentrification and thus displacing lower-income earners.
Curran & Hamilton (2012)	Greenpoint neighbourhood in Brooklyn, New York, US	An alternative vision for urban sustainability “just clean enough”: as much of the environmental hazard as possible is removed in order to assure community health while still allowing for industrial uses on the waterfront for the explicit purpose of maintaining the area’s working-class population.
McKendry & Janos (2014)	Calumet region, Southeast Chicago, US	Community efforts to promote social and environmental justice which have the potential to redefine practices of green economic growth to incorporate social equity and community coherence. Rehabilitation of natural parcels including wetlands, waterways.

There are other examples, e.g. from Seattle (Dooling 2009), Chicago (McKendry & Janos 2014) or Brooklyn (Curran & Hamilton 2012) describing how simultaneously making older and typically low-income and/or industrial areas of existing cities more attractive, urban greening projects can alter housing opportunities for low income households completely and set off rounds of gentrification (Table 9).

In conclusion, the development of green spaces in cities today and in the past may contributed to some of the socio-demographic patterns we find today. We are in an ongoing process of patterns-reorganization of people in our cities and green is one determinant for that process. The interesting question is what effects do the prevailing pattern and thus, the existing green space distribution and accessibility parameters have on the health situation of most vulnerable groups of city residents – children, elderly, homeless people – and, what interventions might help in addressing the issue of socio-environmental justice. Future research should therefore focus on the following interlinked questions:

- How do we link nature-based solutions with the social situation of people in cities? What about the better-off and possible displacement of people considering side effects such as gentrification?

- How to accommodate people with equal access to green without accelerating displacement processes?

- What is the role in fostering social-environmental justice in cities in the context of climate change adaptation and mitigation? Does this consider integrative participation in planning processes and does it ensure a save and fair interaction among all population groups?

- How do we transfer knowledge of using nature-based solutions for climate change adaptation and mitigation to other cities of context with different cultures, mental models?

Nevertheless , some studies exist that highlight potential solutions on how to counteract potential displacement processes such as the Greenpoint neighbourhood in Brooklyn, New York, US (Curran & Hamilton 2012) or in the Calumet region, in Chicago, US (McKendry & Janos 2014) where social and environmental justice has been promoted and the current working-class residential population is tried to keep remained.

6 Conclusions

Urban ecosystems are possibly those that people most relate to and may experience in daily life. They have particular importance for local climate adaptation and related cultural services. Especially with rising urbanisation, urban ecosystems therefore become more and more important from a socio-ecological perspective. Cities with their hotter micro-climates may also serve as demonstration systems for NBS to climate change mitigation and adaptation. As reviewed in this report, NBS using green spaces have significant potential to decrease the vulnerability and enhance the resilience of cities and their residents in light of climate change. They may serve as proactive adaptation options for municipalities.

This report summarises discussion results about the importance of NBS to climate change in urban areas and their rural surroundings. Further emphasis is placed on the potential of nature-based approaches to also create multiple-benefits underlined with some of the latest scientific findings. Discussions considered current European policy in implementation of NBS, leading to recommendations for putting NBS into action.

The 2015 BfN workshop at Vilm and the 2015 BfN/ENCA conference in Bonn explored the various contexts in which NBS are relevant for climate mitigation and adaptation in urban areas. Indicators for assessing the effectiveness of NBS and related knowledge gaps were identified and intensively discussed. Furthermore, barriers to action and potential opportunities for increasing the scale and effectiveness of NBS implementation were explored. As an outcome of the workshop and the conference, the following main needs for future science and policy agendas have been identified:

(i) Produce stronger evidence on NBS for climate change adaptation and mitigation and raise awareness;
(ii) Adapt for governance challenges in implementing NBS by using reflexive approaches, which implies bringing together new networks of society, nature-based solution actors and practitioners;
(iii) Consider socio-environmental justice and social cohesion when implementing NBS by using integrated governance approaches that take into account an integrative and transdisciplinary participation of diverse actors. Taking these needs into account, NBS can serve as climate mitigation and adaptation tools that produce additional co-benefits for societal well-being.

Taking these needs into account, the review part of this report summarizes current knowledge on selected key issues related to NBS for climate change adaptation and mitigation in urban areas, namely green roofs and facades as well as urban parks and street green.

First, the contribution of green roofs and facades to nature-based solution to climate change adaptation and mitigation was assessed. In particular green roofs contribute to the cooling of the ambient air temperature with effects between 0.4 and 1.8°C (Rosenzweig 2006; Sun et al. 2012). The values differ according to a number of influence factors. These factors include geographic location, building characteristics, energy use, plant species used and precipitation properties. However, a number of additional benefits of green roofs have been highlighted which include the potential to provide habitats for wildlife, to retain stormwater, to improve air quality through capturing air pollutants and dust, to provide space for urban agriculture and recreation and thus, overall, increase the quality of life of city residents.

The review further assessed the contribution of urban parks and street green as a nature-based solution to climate change mitigation. Particularly trees are found to alter microclimates and provide cooling through shading and evaporation from transpiration. Urban parks containing high trees were identified to have a significant cooling effect during daytime with a temperature reduction between 0.5°C (e.g., in Tel Aviv, Shashua-bar & Hoffman 2000) and 5-7°C (in Sacramento, Spronken-Smith & Oke1998). The review showed, however, that several local factors influence the temperature reduction potential by urban vegetation. These factors include amongst others the area of tree cover, area of impervious surfaces in the area, time of day, antecedent moisture condition, irrigation and topography.

The last part of the review study focused on links between NBS to climate change in urban areas, resident's health and social-environmental justice. Increased air temperature due to climate change can lead to increased heat-related illness. Accessibility to or living close to an urban green space was found to have a number of positive health effects such as improved perceived general health and morbidity from diseases or stress. Urban green spaces also provide ecosystem services, which decrease next to reducing the urban heat island other risk factors and mortality in vulnerable groups, by for example reducing air pollution. However, the review also showed that within cities green spaces are often unequally distributed between different socioeconomic status groups, different age groups or groups with different ethno-racial characteristics. A number of studies, thus, were found to relate access to urban green space to socio-environmental justice and health impacts across the life course. The review identified that uneven distribution of and access to urban green spaces may be related to a number of interlinked factors including path dependency related to history, land use development, park management and design. Today, the development of a NBS project or urban green spaces in general increases attractiveness and may lead to raising house and rent prices leading in turn to gentrification processes. Some cases where this happened with consequent displacement of residents e.g. the New York Highline or the Cheonggye Restoration Project in South Korea.

Based on the results of the review study, the outcomes and discussions at the Vilm Workshop and the joint BfN/ENCA European Conference on "Nature-based Solutions to Climate Change in Urban Areas and their Rural Surroundings", the Interest Group on Climate Change of the Network of Heads of European Nature Conservation Agencies (ENCA), and the BioClim project group funded by the German Federal Agency of Nature Conservation (BfN) developed recommendations to take forward the spatial targeting and implementation of nature-based solutions for climate change mitigation and adaptation in urban areas and their rural surroundings.

Overall, it is recommended to share and implement them. This can be achieved through

a) increasing the evidence base on the effectiveness of nature-based solutions (NBS) by providing examples of best practice that demonstrate the multiple benefits provided by NBS. This includes benefits related to climate change adaptation and mitigation, the conservation of biodiversity, and the provision of other ecosystem services for human well-being, including benefits to health by

b) fostering research and monitoring to determine the best assemblages of species to achieve the most efficient NBS, including the optimization of multiple economic, eco-logical and social benefits and exploration of trade-offs created by NBS,

c) adopting wider application of NBS in collaboration with partners from society and policy,

d) enabling successful ecological restoration with benefits for biodiversity through NBS.

One aspect which was highlighted during the workshop and conference discussions was the interconnectedness between climate change, biodiversity and human health and well-being. These interlinkages occur at various levels. The recognition of the integrated manner of social, economic, environmental but especially health issues is of outstanding importance for understanding the advantages of nature-based solutions. As the linkages between NBS, urban green space in particular and health was highlighted several times during the workshop and the conference. It might therefore be useful to consider health in cities in more depth at further meetings.

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