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Cities coping with climate change

International experiences and best practices on climate change adaptation with relevance to Bulgarian cities

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Preface

This report originates from the project *Implementing innovative measures to mitigate and adapt to climate change in municipalities in Bulgaria*, and is funded by the “Environment protection and climate change programme” under the Iceland Lichtenstein Norway grants (the EEA financial mechanism 2014-2021). The project promoter is National Trust EcoFund (NTEF), Bulgaria, and the Norwegian project partner is the Norwegian Association of Local and Regional Authorities (KS). This report is one of the deliverables under activity 2 of the project, and has been put together by Western Norway Research Institute, as a sub-contractor to KS.

We want to thank Christian Larsen from KS for his efforts to facilitate our work. We are also indebted to NTEF by Irena Pencheva and Kamelia Georgieva for their conscientious and supportive management of the project. Not the least, we would like to thank the eight Bulgarian project partner cities, the municipalities of Sofia, Plovdiv, Varna, Burgas, Kurdjali, Ruse, Stara Zagora, and Sliven. Their commitment shown in the project kick-off seminar in March 2021 gives reason to hope that the climate adaptation work in the largest Bulgarian cities will make progress in the years to come, and that this will have ripple effects across the country. We wish you all good luck in your efforts, and hope that this report can be a source of inspiration.

Sogndal, Norway 25/11/2021

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Summary

Sustainable development as both a theory and a political concept has for long set the stage for how humanity should tackle global crises; poverty, loss of biodiversity, and climate change. The three challenges cannot be solved independently. Ignoring either climate, biodiversity or human welfare will jeopardize the totality. Urban planning and local resource management have to deal with all these challenges simultaneously, and synergies and conflicts between the various objectives are inherent in all actions taken to solve these crises. In this important task it is crucial to strive for synergies between climate adaptation, climate mitigation, citizens' well-being, and biodiversity conservation, and minimizing conflicts between these objectives. This report focuses primarily on the urgent need to adapt our cities and communities to climate change through the presentation of European cities' good practices on climate adaptation, but stresses also the importance of creating synergies between climate change mitigation, the provision of ecosystem services and well-being of all.

Climate change will cause more intense heat waves, exacerbating the urban heat island effect. Nature-based solutions, i.e., bringing more nature into the cityscape to provide shielding and regulation of the microclimate, help cooling the city. Such solutions come with multiple co-benefits such as climate change mitigation, reduced risk of flooding, and improved human well-being. Implementation of green and blue infrastructures may be challenged by conflicting objectives in urban planning. Collaboration and integration across sectors, institutions, and local communities help overcoming these barriers. Exposure and vulnerability to urban heat vary among different groups and parts of the city, making urban heat management a social policy field. To successfully reduce vulnerability to heat, improving housing, provision of air

conditioning, quality of health services, and access to clean water are examples of measures that may be as equal important.

Warmer and dryer climatic conditions may cause severe droughts and challenge water supply. Increasing water efficiency, i.e., adopting water efficient practices and technologies, diminish demand, and decreasing water leakages, entails a large potential to improve resilience to drought. Rainwater harvesting and on-site preservation of the natural hydrological system save pot water, improve the micro-climate, and mitigate urban flooding. Increasing water efficiency also reduce CO₂ emissions, and minimize environmental impacts and cost related to the development of new supplies. Municipal drought and water conservation plans may become tools for climate change adaptation if considerations on climate change scenarios and extreme events are included. By understanding how much water is available in a region, where it comes from and who uses it, one will be able to build effective local strategies to adapt to climate change.

In a climate characterized by extremes, river floods might occur more frequently, which together with more heavy precipitation increase the risk of landslides and increased erosion. Nature-based solutions, such as flood plains, wetland and woodland restoration, include multiple benefits, although the combination of both green and grey measures is often needed to ensure a certain safety level. Modelling different flooding scenarios is a good departure to identify solutions to deal with floods, prevent landslides and erosion. Supplying such models with local experiences of previous flooding events may improve the understanding of local river characteristics. When developing flood management schemes, the range of available solutions should be analysed carefully to combine structural, natural and policy instruments in the most effective way given the local conditions. Considerations of possible impacts on ecosystems from physical barriers between water courses and land should be taken.

Urban flood is in many cases the combined result of denser and more populous cities, old sewage infrastructure that treats stormwater in underground pipes, and more intense rainfall as a result of climate change. The cities of the world are facing a transition from closed and gray stormwater solutions, towards open, multifunctional, and nature-based solutions that are suitable for tackling the climate of the future. This can provide synergies with biodiversity, and give more liveable, attractive cities. Such a transition requires changes both at the technological, organizational and mental levels. In Oslo, this process has come a long way with the help of long-term strategic planning, combined with curiosity-driven technology testing, network building and dissemination work.

Within a warmer climate, the risk of vector-borne diseases may increase. Vector control is a complex issue, requiring a set of different approaches and measures, as well as involvement of different stakeholders and governing agencies. Paradoxically, nature-based solutions, which generally are at core in climate change adaptation, may improve the living conditions of e.g., mosquitoes, ticks and rats that potentially transmit diseases. This do not advocate for not bringing more nature into the cityscape. Rather, urban natural environments must be managed carefully to limit vector distribution and transmission of diseases. At a local level, management plans to deal with e.g., mosquito nuisance and disease control may be needed. Vector management require strict regulations of the use of pesticides, and a high level of ecosystem knowledge for good management with minimized negative impacts.

In the final chapter we discuss problems and prospects of coping with climate change in cities. We present a framework for climate risk assessment elaborated from the IPCC concept of climate risk as a function of hazards, vulnerability, and exposure. The framework may serve as a useful tool to better inform climate adaptation policies and measures without

compromising e.g., mitigation or biodiversity. Further we discuss the strengths and potential pitfalls of nature-based solutions as an approach to tackle climate change, and the vital synergy between combating air pollution and climate emissions. Finally, we look to the three realms of the 17 Sustainable Development Goals (SDGs) – biosphere, society and economy – which can serve as a useful guide for local decision-makers when conflicting interests are to be balanced through climate adaptation measures.

1 Introduction

1.1 Background

This report originates from the project *Implementing innovative measures to mitigate and adapt to climate change in municipalities in Bulgaria*. It aims to give international examples and best practices on how cities deal with climate change, and how they adapt to reduce their vulnerability to different types of climate risks. The report is meant to give illustrative examples based on available knowledge on practical adaptation measures in cities, that can serve as inspiration and a source of ideas for the Bulgarian partner cities in the project.

Today more than half of the world's population lives in cities, a proportion that are expected to rise above 70% by 2070. In Bulgaria, cities are already housing more than 70% of the country's population, and by 2050 the urban population will most likely exceed 80%. Despite being clearly vulnerable to the impacts of climate change, cities are also uniquely positioned to take leadership in adaptation and building resilience to climate change. With greater magnitudes and rates of climate change, there may be limits to the effectiveness of adaptation. By improved understanding, careful planning, and a long-term perspective when adapting to climate change, cities and societies can reduce the today's and future risks of climate change impacts.

1.2 How to use the report

This report contains examples on climate adaptation carried out in cities around Europe, and even other parts of the world. These cases are meant for inspiration, and should not be read as recipes on how to adapt cities to climate change. Climate change adaptation of societies is all-encompassing and requires cooperation and coordination across sectors, governmental levels, and broad stakeholder involvement. Climate change adaptation is as much about concrete physical interventions as about the change of mindset, day to day actions and traditions. Climate change adaptation is largely culturally conditioned and requires local

solutions. A specific approach to reduce water consumption in Burgas does not necessarily apply to Oslo.

Therefore, this report will not serve as a cookbook to reduce the various climate risks facing cities in Bulgaria. Rather, it can be used as a catalogue to get input and ideas about measures and methods that can work out in your own city. Probably none of the sample descriptions are directly transferable to cities in Bulgaria, nor to other cities for that matter. On the other hand, there may be measures, processes, methods or mindsets in the individual cases that can be found relevant, and that can be built on and adapted to the local context. Furthermore, this report presents only a rather few examples of efforts taken by various cities to adapt to climate change, and it must be emphasized that there are far more adaptation options, measures, and approaches to strengthen climate change adaptation in cities than what is presented here.

Throughout the text we have made references to a host of foreign sources of knowledge, also in other languages than English. We have decided to do so, as there is an option to read these reports and web pages by use of Google Translate.

1.3 Method

Scoping

To identify the climate risks of relevance and being able to narrow which themes to look for, we asked the representatives of the participating Bulgarian cities during the kick-off meeting of this project to identify their perceived climate change risks.

The information gathered was structured and analysed. Almost all (7 out of 8) stated urban heat as a significant risk. Secondly, heavy rainfall and flooding (both riverine and surface runoff) was pointed out as challenging (5 out of 8). Drought and water scarcity, and landslides and erosion were also identified as being significant in some cities. See Table 1 for all risks identified by the representatives.

Table 1: The participating cities' identification of various climate change risks.

Risk	Heat	Heavy rainfall	Flood	Drought and water scarcity	Landslides and erosion
Municipalities	Sofia Burgas Kardzhali Plovdiv Ruse Sliven Stara-Zagora	Sofia Burgas Plovdiv Ruse Sliven	Varna, Kardzhali Plovdiv Ruse Sliven Burgas	Burgas Plovdiv Sliven	Varna Kardzhali Sliven
Risk	Mosquito	Wind	Fire	Coastal erosion	
Municipalities	Ruse Sliven	Sofia Sliven	Sliven	Varna	

Almost all representatives mentioned air pollution as a major challenge. As reducing air pollution is more an issue of mitigation, the topic will only be treated indirectly as a co-benefit of various climate change adaptation measures.

The identified risks were further assessed in light of the Bulgarian National Climate Change Adaptation Strategy and Action Plan's (NASAP) thematization of climate change risks to Bulgarian cities. This document points to three main climate risks to urban environments. First, more frequent and prolonged episodes of extremely high temperatures causing the heat island effect, impacting densely populated and constructed cities the most. Second, extreme and/or prolonged precipitation causing floods and landslides, with large damages to urban environments and to those living in flood-prone zones. And third, high temperatures combined with draughts causing water stress, especially where water is a scarce resource and supply networks outdated with great leakage.

The risks pointed out by the representatives coincides with those highlighted by NASAP. This strengthen our assumption that the following themes of this example collection are, and will be, relevant and to a large extent covering of climate change risks in the participating Bulgarian cities:

- Urban heat
- Drought and water supply
- Flood, landslides and erosion
- Urban flood
- Vector-borne diseases

Within the scope of this report, we have not found place for treating wind, fire, and coastal erosion specifically, although their impact may be significant, and they will require great efforts of adaptation to avoid adverse outcomes. Some of the measures described in the examples may though be transferrable to dealing with wind, fire and coastal erosion, such as forecasting, surveillance, and public education on good behaviour during extreme weather. Increasing biodiversity, and nature restauration and conservation are examples that may lessen risk of fire, reduce coastal erosion, as well as improve benefits from ecosystem services, such as providing shelter from the wind.

Data sources

Given the scope and limitations of this project, we have limited the search for literature to networks and actors which present examples of climate change adaptation within cities and municipalities in Europe; examples which are considered being practices and examples to follow by other cities and local governments.

The main sources in our literature review have been:

- European and international organisations and networks' databases of cases concerning climate change adaptation (EEA, WeAdapt, C40, Covenant of Mayors)
- National databases of cases concerning climate change adaptation (UK, Sweden, Denmark, Spain)
- Best Practice reports on climate change adaptation from networks of experienced cities and municipalities (C40, Covenant of Mayors, ICLEI, other)
- Cases from Norway. In chapter 6, fact sheets on blue-green stormwater management issued by the municipality of Oslo, has been a particularly valuable knowledge source.

Where relevant cases are absent, as in the case of vector-borne diseases, we have searched for experiences outside Europe. In some cases, our sources are restricted to planning documents and strategic decisions.

The literature review we have carried out is a method to find concentrated information describing efforts taken locally to adapt to climate change. A challenge is that the cases are often presented broadly and as stories of success, and where critics, shortcomings, and inherent conflicts throughout the developing and implementation processes are not included. Consequently, some case descriptions (such as the examples from Vitoria-Gasteiz and Zaragoza) are thicker than others, depending on the source material available. Where existing and accessible, we have included academic literature and other source material concerning the case. Furthermore, language have in many cases been a barrier to supplementary source material.

Table 2 presents a general, coarse overview of the types of cases that are selected to this report. Two of the described cases (Wroclaw and Vitoria-Gasteiz) appear under more than one climate risk theme. It is worth noting that many of the described examples could have been categorized under other types of cases than shown here. The table indicates a broad thematic coverage of climate risk types and themes.

Table 2 Thematic presentation of selected types of cases.

Case selection

Type of case	Type of climate risk				
	Heat	Drought	Urban flood	Flood, landslides and erosion	Mosquito
How to monitor local climate change?		Zaragoza		Sundsvall	Perth
How to assess local climate change risks?	Trnava			Bergen Isola Vicentina	
How to adapt locally to climate change?		Wroclaw Zaragoza	Wroclaw Oslo	Isola Vicentina	
Co-benefits between cc adaptation and other sustainability aspects	Vitoria-Gasteiz		Vitoria-Gasteiz		
How to organise locally the work on climate change adaptation	Trnava	Zaragoza	Oslo	Bergen	
Adaptation and mitigation	Vitoria-Gasteiz Trnava	Zaragoza	Oslo	Isola Vicentina	

During the kick-off meeting of this project, the representatives of the Bulgarian cities were asked to express their expectations to this report. These were mainly to get insights and examples of effective and less costly climate change adaptation measures, management of green systems, good governance of climate change adaptation, how to include citizens and communities in climate change adaptation, and how to create public support for it.

We have selected cases that involve measures and methods of implementation that we consider relevant regarding the identified climate risks, and which largely correspond to the Bulgarian cities' needs and expectations.

So, what is a case? Whether a case should be titled a “best practice” could be debated. The illustrative aspect is the most important in this context, to display the cause-effect chain of climate change and society. Not all cases included in the report imply that physical measures have been carried out. Adaptation examples have also been chosen because they have raised awareness on a climate risk, or because they give insight into good governance practices concerning climate change adaptation.

To enable learning from the selected cases, criteria for the case selection have been exhaustive descriptions concerning initiative, strategy development, political anchoring, political and practical constraints on implementation, public involvement, costs and investment measures, and relation to other municipal plans and strategies. Due to a general lack of information in the data sources reviewed, all criteria are not fully met in every case selected.

1.4 Structure

The challenge of climate change is outlined in chapter 2. We first give a brief overview of the climate risk Bulgarian cities face, before we discuss the the need to unite the three dimensions of sustainable development when we approach the challenges of climate change. The chapter concludes with considerations about synergies and conflicts between climate policy and biodiversity protection.

Chapter 3 to 7 constitutes the main body of the report, the example collection of cities’ experiences on climate change adaptation divided into the different climate risk themes. Despite the different case characteristics and scope, we have aimed to present the cases as uniformly as possible as well as allow some variation in the descriptions based on the uniqueness of the cases. Based on the information available, the authors allow for analytical remarks under the headline “outcomes and lessons learnt”. “Cross-case learning points and discussion” towards the end of each chapter addresses the strengths and weaknesses of the cases and points to general trade-offs and synergies.

In chapter 8 we discuss problems and prospects of Bulgarian cities’ coping with climate change. We aim to shed light on the potential conflicts and synergies between climate change adaptation, mitigation and biodiversity conservation, and the inherent

conflicts of sustainable development. These are complex issues that somehow must be treated carefully and in a meaningful way locally to avoid maladaptation.

2 The challenges of climate change

2.1 Climate risk in Bulgarian cities

Climate change projections for Bulgaria

The National Climate Change Adaptation Strategy and Action Plan gives the following description of projected climate change in Bulgaria:

Climate change scenarios for Bulgaria show a trend toward increased frequency and magnitude of extreme weather events like heavy rainfalls, heat and cold waves, floods and droughts, hurricane winds, forest fires, and landslides, several of which are already experienced. The Department of Meteorology and Hydrology (NIMH-BAS) projects an increase of the average temperature from 1,6°C to 3,1°C by 2050 and 2,9°C to 4,1°C by 2080. The most significant temperature increase is expected during summer (from July to September). Precipitation during winter is expected to slightly increase but will be outweighed by decreasing precipitation during the summer season, leading to a significant reduction of the total water reserves in Bulgaria. Projections suggests a decrease in precipitation of 15 % by 2050, and up to 40 % percent by 2080.

Based on updated AR6 projections, maximum temperature in Mediterranean Europe is expected to rise with 4-6 degrees Celsius by the end of this century, given a 2 degree rise in global mean temperature (RCP8.5), as shown in the figure below.

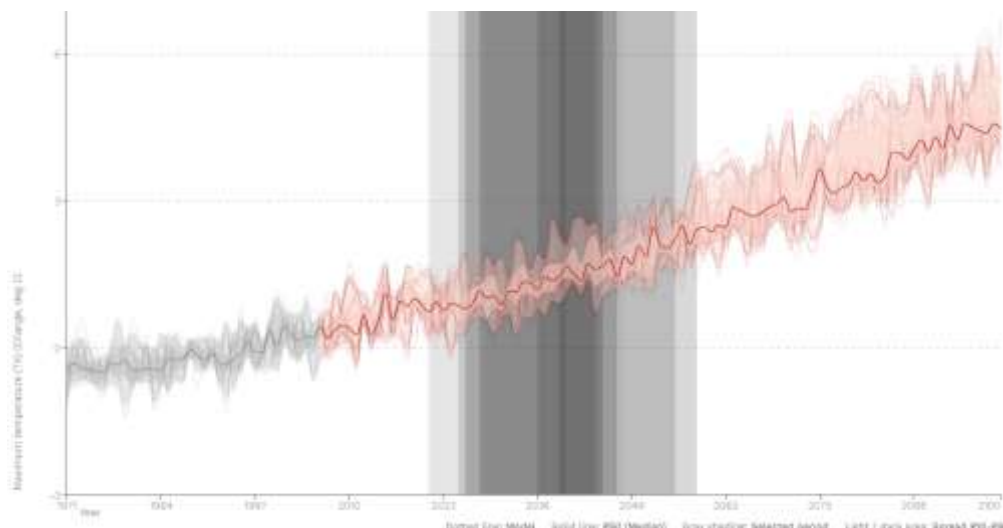


Figure 1 Change in maximum temperature (°C) in the Mediterranean Europe in a 2 °C warming scenario (RCP8.5) throughout this century, based on 46 models (CORDEX Europe). Source: IPCC Interactive Atlas (<https://interactive-atlas.ipcc.ch/>)

Vulnerability assessments

The National Climate Change Adaptation Strategy and Action Plan (NASAP) for Bulgaria identifies three main risks to urban environments as a consequence of climate change:

- **Extremely high temperatures causing the heat island effect;** which will last longer and occur more often, and impact densely populated and constructed cities the most.
- **Extreme and/or prolonged precipitation causing floods and landslides;** and cause huge damages in urban environments, whereas those living near watercourses and in flood-prone zones are the most vulnerable.
- **High temperatures combined with draughts causing water stress;** especially where water is a scarce resource and supply networks outdated with great leakage.

Further descriptions of the vulnerabilities of the different cities to climate change is outside the scope of this report.

2.2 Dimensions of sustainable development

Mitigation¹ and adaptation² of climate change are policy fields that have emerged over the last three decades in line with increasing knowledge about the global climate crisis. In parallel with the growing concern about climate change, *sustainable development* is both a political concept and theoretical framework that has evolved and, over the years, marked the debate on how humanity should tackle several global crisis. Among the pressing challenges that have been debated in light of sustainable development, we find both poverty, loss of biodiversity, and climate change. Quite recently the scientific community has reinforced its warnings that these three challenges cannot be solved independently, and that ignoring either climate, biodiversity or human welfare will jeopardize the totality (IPBES & IPCC, 2021).

Sustainable development is frequently presented as a concept consisting of three pillars or dimensions; the environmental, social and economic sustainability. Figure 2 illustrates how sustainable development only occurs when these three dimensions overlap. In other words: If one of these dimensions is neglected, sustainable development will not become a reality.

¹ IPCC defines mitigation to climate change as a human intervention to reduce the sources or enhance the sinks of greenhouse gases.

² IPCC defines climate adaptation (in human systems) as the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities.

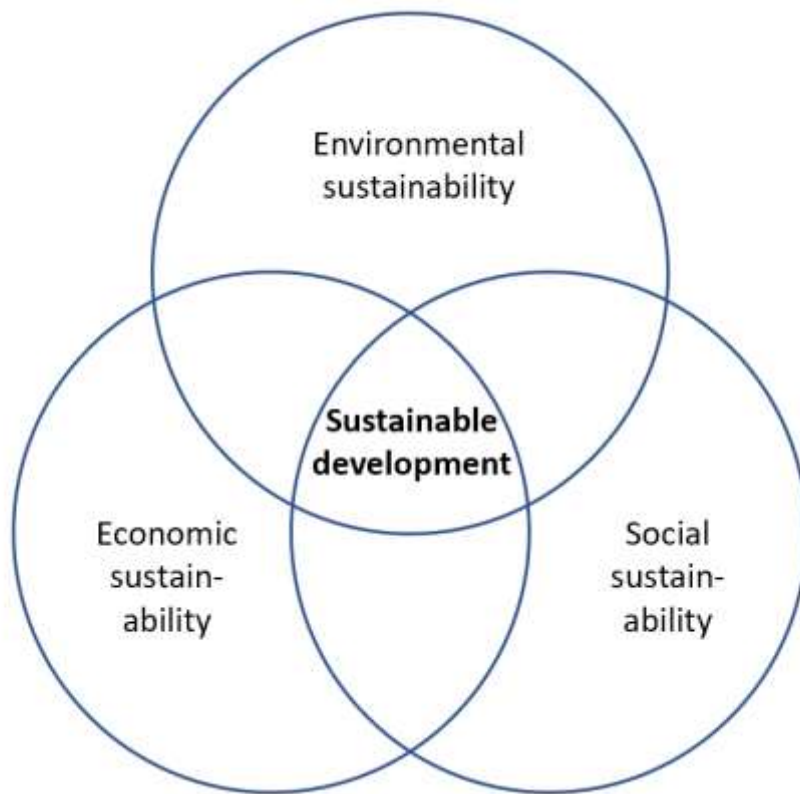


Figure 2. The three dimensions of sustainable development.

This conceptual model of sustainable development will be used for discussing climate adaptation strategies and measures that are presented in this report.

2.3 Climate and biodiversity: Synergies and conflicts

In continuation of the discussion about the three dimensions of sustainable development, it is appropriate to introduce the twin concepts *conflicts* and *synergies*. These relate to the need for a more holistic approach to our interaction with nature. In the literature several similar concepts are used, with slightly varying meanings. Hence the terms *conflicts* and *tradeoffs* are used interchangeably, while *synergies* and *co-benefits* often correspond to each other. In this report we stick to the terms conflicts and synergies.

Goal conflicts occur when policy measures that are implemented to pursue one policy goal, counteracts achievement of another goal. One example could be when widespread use of air cooling in periods of strong heat (climate adaptation) leads to

increased CO₂ emissions from producing electricity to run the air conditioning units (counteracts climate mitigation). This is also called mal-adaptation. Conflicting processes that go the other way round, i.e. mal-mitigation, are even more common. Such goal conflicts are widespread in the energy sector, where a number of strategies for producing carbon neutral energy imply biodiversity loss. Densification (urban compaction) in order to reduce transport volumes, is another mitigation measure that is associated with conflicts in the way that urban green areas become developed and sealed, causing biodiversity decline and reduced well-being. While it is important to avoid conflicts between goals in the climate and environmental fields, it is equally important to strive for synergies between climate adaptation, climate mitigation and biodiversity conservation. Potential for such synergies will be discussed in more detail in chapter 8.

3 Urban heat

3.1 Problem description

Raise in temperatures due to climate change pose risk to cities. Temperatures in cities are substantially higher than those of surrounding areas, a phenomenon called the urban heat island effect (UHI). The nature of urban built environment absorb heat due to its characteristics of high proportion of dark, impermeable surfaces like asphalt and buildings, poor air circulation and less green space and water surfaces. In addition, industry and human activity generate heat. On average, these factors make cities several degrees hotter than surrounding areas, a difference that is strongly exacerbated during peak temperature periods and heatwaves.

Heat waves and events of extreme temperatures are becoming more frequent and more intense. Extreme heat events lead to increased energy need for cooling indoors, increase in air pollution and damages to economic activity. Not least, extreme heat brings with it severe health issues, and ultimately increased mortality. Urban heat highlights the theme of social equity leaving the most vulnerable groups of citizens even more vulnerable to heat. Following this, there is an urgent need to cool down cities and densely populated areas.

Measures to reduce urban heat, such as green and blue infrastructure³ and reflective roofs and pavements, are proven efficient in terms of delivering benefits to cities and their residents. Adapting cities to extreme heat will pay off not only in means of decreased temperatures and saved lives, but improved air quality, daily life functioning of a city and its activities, and general well-being of the city's inhabitants.

³ Green infrastructure or green and blue infrastructure denote the use of the ecosystem services provided by vegetation and open watercourses as means of retaining water, purifying air and bringing nature and biodiversity into the cityscape.

3.2 Example: The Vitoria-Gasteiz' Green Urban Infrastructure Strategy (Spain)

Place name: Vitoria-Gasteiz, Spain

Type of location: City, 250 000 inhabitants

Vulnerabilities: Heat, flood

Measures: Expanding urban green infrastructure

Co-benefits: CCM, biodiversity, health & well-being, job creation



Sources: Climate-ADAPT (2018a)⁴, Environmental Studies Center (2014)⁵

Summary

The City of Vitoria-Gasteiz has long tradition in engaging with environmental issues in urban environments. With climate change the city will experience more heatwaves and heavy precipitation. To respond to these challenges the city has developed a comprehensive green infrastructure strategy, aiming to mitigate the risk of increased heat stress and flooding, and simultaneously improve biodiversity, mitigate climate change, and increase general well-being of its citizens. The green infrastructure project largely takes a public participation approach, with the idea that such a method will ensure solutions to real-life and experienced needs and challenges.

⁴ Case study in ClimateADAPT <https://climate-adapt.eea.europa.eu/metadata/case-studies/implementation-of-the-vitoria-gasteiz-green-urban-infrastructure-strategy>

⁵ The Urban Green Infrastructure of Vitoria-Gasteiz. Proposal document. 2014. <https://www.vitoria-gasteiz.org/docs/wb021/contenidosEstaticos/adjuntos/eu/34/21/53421.pdf>

Challenges

The city Vitoria-Gasteiz, located in northern Spain, faces climate change challenges as increase in temperature, changed precipitation pattern and increase in risk of flooding (Climate-ADAPT, 2018a). By 2100, maximum temperatures are expected to rise up to 3 degrees during summer, and longer and more severe heatwaves will occur more frequently. An expected increase of 30% of events with extreme precipitation will further increase the risk of flooding.

To meet these changes there is a need to increase and improve the quality of green spaces throughout the city that can contribute to the reduction of the heat island effect and other heatwave impacts, as well as prevent flooding and increase biodiversity in the city landscape, relevant to both climate change adaptation and mitigation.

Objective

In the early 1990s the city of Vitoria-Gasteiz started a project of restoring and recovering the outlying areas of the city, creating the so-called “Green Belt” of green corridors linking urban and peri-urban parks and landscapes. The city was the first in Spain to develop a Local Agenda 21, and local authorities have for long made significant efforts to improve habitability, mobility and green areas in the city, for what it was given the European Green Capital Award in 2012 (Aguado-Moralejo et al., 2013).

Prior to 2012 the city had already adopted municipal strategy documents such as the Biodiversity Conservation Strategy and the Plan to Mitigate and Adapt to Climate Change. Already being aware of the necessity of developing strategies and intervention projects that transform the city to a nature-connected one to become more resilient, The Green Capital Award encouraged the city authorities to strengthen their work on nature management and climate change mitigation and adaptation (Environmental Studies Center, 2014). Therefore, soon after the City Council launched the Green Urban Infrastructure Strategy. Its main objectives are to respond to climate change and other related global challenges such as loss of biodiversity by exploring the usefulness of green urban infrastructure solutions and urban ecosystem services.

Solutions and implementation

The Urban Green Infrastructure Strategy is comprehensive and consists of a wide range of planned interventions in all parts of the city, forming a green grid (Environmental Studies Center, 2014). The interventions mainly include the restoration, expansion and linking of parks and semi-rural areas surrounding the city (developing the Green Belt), connection of urban parks, vacant plots, and central buildings with ecological corridors such as tree lined streets and vegetations belts along water streams. The interventions are diverse and spanning from greening of vacant plots, conservation of native species and enhanced habitat functions in both existing and new areas, improved water management, promotion of green facades and promotion of ecological agriculture both in urban and semi-urban areas. The strategy emphasizes the use of native species and landscape architecture that require less maintenance and costs. Furthermore, the strategy emphasizes citizens engagement and initiatives of local transformation activities.

Transforming the Gasteiz Avenue into a green corridor

The redevelopment project with eco-design techniques of the Gasteiz Avenue and the installation of a green façade on the Europa Conference Centre, constitutes the most emblematic intervention (Climate-ADAPT, 2018a). This project aims to transform this



area into a green and energy-efficient urban corridor. This project has increased the space for people by constructing car-free streets, cycle and walking lanes, as well as

attractive meeting places, restored the river corridor along the avenue and increased the amount of vegetation, contributing to the ecological connectivity throughout the city. There is also made large improvements to urban water management, e.g. through the separation of the sewage network to prevent mixing with rainwater, installation of sustainable urban drainage system for infiltration and purification of stormwaters, installation of irrigation systems using rainwater for vegetation, parks and community gardens nearby. The avenue is turned into a green public space with improved environmental and sensorial qualities (Environmental Studies Center, 2014).

The renovation and extension project of the Europa Conference Centre started in 2011 and finished in 2015 (Vitoria-Gasteiz City Council, 2021). The utilisation of materials throughout the construction phase has stressed sustainability, thus life cycle, reuse and recycling considerations and selection of materials with less environmental impact and with high thermal inertia. Several measures have been taken to increase energy efficiency of the building, including the installation of a green façade. The façade with a total surface area of about 1500 m² has been covered with 33000 plants of 70 different species. The façade uses 80% native species, making it represent the local ecological environment. In general, evergreen, perennial species are selected to reduce maintenance costs and management. The façade is irrigated by rainwater collection systems on the roof.

The green façade has tripled the insulation level of the building. It further improves the air quality surrounding the building, reduces air pollution and contribute to carbon sequestration. Green facades create spaces for urban biodiversity and

improve the aesthetics and environmental quality of public spaces. Not least, the evapotranspiration of the plants reduces the urban heat island effect⁶.

Pilot projects of greening the neighbourhoods



Figure 4. The green façade of the Europa Conference Center. Source: vitoria-gasteiz.org

The strategy also suggests a vast number of interventions and pilot projects in the different neighbourhoods (Environmental Studies Center, 2014). The pilot projects test different measures for improving the ecological and environmental functionality of both green and vacant spaces, as well as ways of reducing the costs and workload related to their management and maintenance. Clear benefits from these interventions are reduction of air pollution, improved water management systems that reduce the risk of flood, improved regulation of the local climate and mitigation of the heat island effect.

⁶ The green façade of the Europa Conference Center https://www.vitoria-gasteiz.org/wb021/was/contenidoAction.do?idioma=en&uid=u_a32d4c0_146a31d77b7_7fbf

Many of the pilot projects take place in the Lakua (Lakuabizkarra) district (Environmental Studies Center, 2016). This is a neighbourhood with many green areas, which are maintenance-intensive and infrequently used. Here are also numerous vacant spaces owned by the municipality where planned facilities and developments have not taken place, resulting in dirtiness and a negligent appearance. Using the framework provided by the Urban Green Infrastructure of Vitoria-Gasteiz, various naturalization interventions have been planned for 50 spaces, including transitory uses for vacant plots, to improve environmental quality and connectivity, and to increase the use of outdoor public spaces.

One example is the planting of trees in the Lakua-Arriaga car park, a large paved public space at the entrance of the city. The objectives were to improve the environmental and aesthetic quality, increase shading, and improve the drainage capacity of rainwater to the aquifer. Strips with topsoil capable of supporting trees were provided between parking places, and 56 shade-providing London plane trees and 50 common whitebeam trees were planted. The trees in the car park is now providing shade and evapotranspiration, freshen the atmosphere, and improve infiltration of rainwater, thus relieving the sewage system.

Another example is the transformation of a 9000m² vacant plot in the Sierra de Andia Street, with a shallow topsoil and an untidy appearance, into an urban horticultural garden. The objectives of the project are to promote ecological horticulture and healthy food, favour social relations and public participation in the care and maintenance of the public space, and improve the aesthetic and environmental quality of the area⁷.

A participative approach

Communication and public participation are considered critical for the urban green infrastructure strategy to succeed (Environmental Studies Center, 2014). A

⁷ Descriptions of pilot projects in the Lakua district can be found in the report “The urban green infrastructure of Vitoria-Gasteiz district by district” <https://www.vitoria-gasteiz.org/docs/wb021/contenidosEstaticos/adjuntos/en/47/38/64738.pdf>

participative approach is taken, inviting social groups such as neighbourhood associations, citizens groups, the University, teaching centres, and other to participate in the design, creation, and management of different urban green infrastructure interventions. Also, the private sector and businesses are invited to collaborate and support financially, as well as conduct their own greenery projects in their areas. By involving the public, the likeliness of the green infrastructure to respond to existing objectives and sensibilities is considered high. In practice, some examples of participation mechanisms are workshops and seminars, participative initiatives such as tree planting or different biodiversity inventories, programmes to support public initiatives in their local communities (e.g. like development of urban gardens or improvement of degraded spaces), and initiatives to foster knowledge on biodiversity and green infrastructure. The municipality is coordinating a citizen science participation network⁸.

The roots of tomorrow: 250 000 trees and citizens: The strategy also implied a project called “Roots of Tomorrow”, which was completed in 2020 (Climate-ADAPT, 2018a). The project was initiated by the municipal Centre of Environmental Studies as a continuation of the Green Belt project (which started in the 90s). The project aimed to get citizens involved in ecological restoration through planting of trees in the surrounding areas of the city – areas that for a long time was assumed as “nobody’s-land” and a suitable area for dumping of waste. The Green Belt project had for long time been constrained of budget cuts in a poor economic climate. To overcome this challenge, the city administration established “The roots of tomorrow” campaign as a public-private initiative, engaging businesses and other institutions to



Figure 5. Citizens involved in tree planting as part of the Green Belt project. Source: blogs.vitoria-gasteiz.org

⁸ Ataria Citizen Science https://www.vitoria-gasteiz.org/wb021/was/contenidoAction.do?idioma=en&uid=u25e08f9d_14a56aaea69_7f88

contribute both in terms of finance and tree-planting. This campaign has also successfully engaged the public, and almost 50 different community groups, 3000 students and thousands of other citizens have participated in planting activities. At the end of the project, 250 000 trees and shrubs, one for each citizen, had been planted making up the Green Belt.

According to Climate-ADAPT (2018a) the renovation of the Gasteiz Avenue and the installation of the green façade on the Europa Conference Centre cost 10 million Euros, four years of implementing the Green Belt project reached 2 million Euros, and the investments in the pilot projects of the Lakua district cost 415 000 Euros.

The Green Urban Infrastructure Strategy keeps running as long as the council allocate budget to accomplish new projects and interventions.

Success and limiting factors

Broad involvement of citizens and different stakeholders during the development phase of the strategy as well as during implementation is considered as a success factor as broad involvement helped create a consensus on the needs and benefits of the Green Urban Infrastructure Strategy (Climate-ADAPT, 2018a). To what extent this reflects the public opinion does not appear from the source material.

The pilot projects enable the exploration and assessment of different measures, actions, and performances, thus enabling export of most suitable approaches to other parts of the city (Climate-ADAPT, 2018a).

The focus of the strategy on multiple objectives and outcomes as co-benefits beyond climate change adaptation made the strategy respond to several urban challenges related to e.g., mobility, traffic, water management and quality of public spaces. The strategy stresses the importance of integration in urban planning, making the different plans harmonize with each other. However, an increasing population and the general city development challenge the connectivity of the green infrastructure at various places, and some of the pilot projects take place in areas classified as future plots for municipal installations in the city's urban development plan (Environmental Studies Center, 2014).

The Green Urban Infrastructure Strategy lays upon the General plan for urban planning, a strategy that shares objectives with other municipal strategies and plans, especially the Biodiversity Conservation Strategy. The Plan to Combat and Adapt to Climate Change also directly relate to this strategy. In addition, it has synergies with Plan for Sustainable Mobility and Public Space, and the municipal Health Plan (Climate-ADAPT, 2018a).

Outcome and lessons learnt

Both implemented and planned interventions contribute to the reduction of heat stress and the heat island effect, help regulating the local climate, and improve the inundation capacity and resilience to flooding. The improved climate change mitigation capacity following increased greenery should not either be underestimated. Concrete measures like the green façade of the Europa Conference Centre will improve the temperature regulation in its interior and nearer surroundings, as well as lowering energy consumption in the building. Furthermore, one can expect increased use of green spaces among the citizens.

The strategy is ambitious in protecting ecosystems and their consequently ecosystem services that residents benefit from. It takes a comprehensive approach to strengthen biodiversity, and in particular of native species, the backbone of resilient ecosystems. Ecological connectivity is therefore a core priority in their work on green infrastructure. In general, when building up green infrastructure, species selected should be adapted to both the local climate and the expected future climatic conditions. Native species are often considered a preferred option, whereas alien species may impair biodiversity.

Furthermore, green infrastructure represents multifunctionality, hence having the potential to support various policies, both regional and sector vice such as urban planning, climate change, agriculture, housing, etc. Not least, urban green infrastructure is a promising tool to create healthy environments and improve health and well-being among a city's residents. The integration of the strategy and its green infrastructure projects in the territory planning processes, is an effective way of making such projects feasible and coherent with other interests.

Further readings

There are a wide range of programs, projects and initiatives related to The Urban Green Infrastructure Strategy going on coordinated by the Environmental Studies Centre of Vitoria-Gasteiz municipality (Environmental Studies Center, 2021). Worth noting is the city's engagement with wetland restoration projects, such as the restoration of the Salburua wetlands that were drained for agricultural use in the mid-19th century. Drains were removed and dikes were constructed to let the area be flooded, and actions were taken to reintroduce biodiversity and create certain biotopes. Because of its ecological attributes, Salburua is today a RAMSAR wetland, and one of the most valuable ones of the Basque Country. These wetlands are providing ecosystem services like preventing floods, improving the water quality of the underlying aquifer, increasing biodiversity, and the area is offering possibilities for public use and environmental education.

3.3 Example: From vulnerability assessment to implementation of adaptation measures in Trnava (Slovakia)

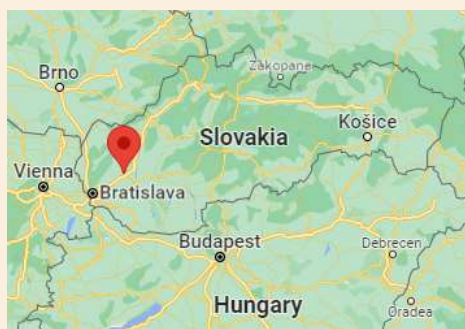
Place name: Trnava, Slovakia

Type of location: City, 65 000 inhabitants

Vulnerabilities: Heat, drought

Measures: Development of a local climate change adaptation plan, building adaptive capacity in city administration.

Co-benefits: CCM, biodiversity, health & well-being



Sources: Energiaklub and Carpathian Foundation (2017)⁹, Climate-ADAPT (2018b)¹⁰

Summary

In absence of strategies and plans for adaptation to climate change on the national level, the city of Trnava decided to develop a local adaptation plan. A close collaboration between city authorities and The Carpathian Development Institute became crucial in this process. The Carpathian Development Institute conducted a comprehensive vulnerability assessment of the city and its residents to heat and provided guidance to the city leadership in the process of developing the adaptation plan. Some pilot adaptation projects were completed during the project period, and the further implementation of the plan is ongoing. This process has revealed how complex, cross-sectorial, and all-encompassing climate change adaptation is.

⁹ Adaptation best practices from the Visegrad countries 2017.
https://adaptace.ci2.co.cz/sites/default/files/souboryredakce/energiaklub_adaptiation_best_practices_final.pdf

¹⁰ Case study in ClimateADAPT <https://climate-adapt.eea.europa.eu/metadata/case-studies/social-vulnerability-to-heatwaves-2013-from-assessment-to-implementation-of-adaptation-measures-in-košice-and-trnava-slovakia>

Challenges

With climate change, high temperatures and increase in frequency of heatwaves during summer pose increasing risk to citizens of Slovakian cities. Climatological analysis of Trnava City reveals decreasing amount of precipitation whilst temperatures increase during all seasons (Energiaklub and Carpathian Foundation, 2017). From the period 1961-1990 the annual number of summer days with minimum 25 degrees are expected to rise from 58 to 100 and number of tropical days with minimum 30 degrees from 12 to 36. These trends in combination will cause decreased soil moisture and extended drought periods. The City of Trnava is characterized by high proportion of paved surfaces which exacerbate heat stress during warm periods, leaving the citizens of Trnava City extremely vulnerable to heatwaves and the urban heat island effect.

Objectives

In 2012, representatives of Trnava City were aware the rising risk to urban heat although having indefinite idea about the consequences at local level. As part of exploring this they participated in the international conference “Climate Change and Local Development – Challenge for Local Governments” (Energiaklub and Carpathian Foundation, 2017). Here they got knowledge and input on how to address climate change locally through green and blue infrastructure, management of energy and water, and tools to mainstream climate change into the city’s governing processes of local development. The conference inspired the representatives to start the work on systematic tackling of climate change impacts, particularly more extreme heat, in Trnava City. A collaboration between local authorities and The Carpathian Development Institute, which provided methodology and expert leadership, became essential for the accomplishment of this objective.

Solutions and implementation

The Carpathian Development Institute (CDI) led a joint project financed by Swiss Financial Mechanism called “Cities resilient to Climate Change Impacts – inspired by city of Trnava” (Energiaklub and Carpathian Foundation, 2017). In collaboration with city authorities, CDI conducted a comprehensive assessment of vulnerability to high

temperatures throughout the City of Trnava. The assessment included spatial mapping of temperature by both continuous temperature measurement and measurement of selected spots. The measurements showed that the whole city was exposed to heat, but also emphasized significant differences in temperature at various places and elements in the city, for example in the parks and on paved parking lots. Further, factors relevant for assessment of sensitivity and adaptive capacity were identified and analysed;

Sensitivity factors examined: Thermal insulation of buildings, extent of unshielded paved surfaces, surface roughness preventing air-circulation, green areas with 60% or more shielding provided by treetops, and density of the most vulnerable residents - those younger than 4 and elder than 75.

Adaptive capacity factors examined: Accessibility of green areas with at least 60% shielding by treetops, level of knowledge and behavioural patterns of residents, early warning systems on heatwaves, information and educational activities for citizens, air condition in public transport and shielding of stops, healthcare emergency services.

The combination of all factors included in the vulnerability assessment produced an overall vulnerability map divided by 300m x 300m grid cells showing the most vulnerable areas within the city (Energiaklub and Carpathian Foundation, 2017).

Based on the vulnerability assessment, The Adaptation Plan was elaborated by the city authorities with guidance of CDI (Energiaklub and Carpathian Foundation, 2017). In addition, a local expert group was established to contribute to the process. This team was made up of planners who can link adaptation to the local development context, landscape architects specialized in green and blue infrastructure, demographic experts, and physicians capable of assessing climate change impacts on human health. The public was involved through a survey, mapping their awareness and behavioural patterns.

The Adaptation Plan¹¹ aims to reduce the cities vulnerability to heatwaves and urban heat island effect by a set of programs (each including numerous specific adaptation measures):

- Shielding and cooling of public spaces
- Education on good behaviour during heat waves
- Extension and improvement of refreshing places
- Good decision making (building adaptive capacity of public administration)
- Stimulation of citizens to realize adaptation measures
- Improvement of buildings at risk (e.g. by green roofs, better insulations etc.).

During the project time a few pilot adaptation measures were carried out from planning to implementation (Energiaklub and Carpathian Foundation, 2017). An example is the conversion of a neglected open space neighbouring blocks of flats, a kindergarten, and a care home for elderly into an inviting green space offering comfort during heatwaves as well as a place for socialising for the local community. Asphalt and compacted ground were replaced with plants and trees, which will achieve 60% crown coverage when trees mature, a fountain, new benches, and a sustainable urban drainage system to improve water infiltration and retention. This pilot greening project was carried out by the local authority after a round of consultation with residents nearby.



Figure 6. The pilot project of greening an open space in Trnava, before and after revitalisation. Source: The Carpathian Development Institute

At city scale, a second example focused on encouragement of citizen engagement in climate

¹¹ The plan to adapt the city of Trnava to heat waves (available in Slovak)
https://www.trnava.sk/userfiles/download/attachment/Strategia_adaptacie_Trnava%20schv%C3%A1len%C3%A1.pdf

change adaptation by setting up a municipal budget (minimum 10 000 euro a year) to financially support activities proposed by residents and local organisations (Energiaklub and Carpathian Foundation, 2017). The adaptation grant applications must follow a detailed set of criteria that ensures that measures are coherent with the city adaptation plan. Mainly awareness-raising activities have so far been supported.

The vulnerability assessment and the development of the adaptation plan were carried out between 2013-2015 (Energiaklub and Carpathian Foundation, 2017). To secure the further implementation of the plan, a “Partnership for Adaptation” was established, consisting of representatives from the city administration, local businesses, local state administration and local NGOs. The representatives’ task is to promote the objectives of the adaptation plan within their own institution and environment.

The process of implementing the adaptation plan is ongoing. The plan is a vivid document which should be regularly evaluated and updated, remaining valid for up to 10 years.

The project and the development of the plan was funded via the Swiss Financial Mechanism, including 20000 Euro for tree seedlings (Climate-ADAPT, 2018b)

Success and limiting factors

There was strong commitment from the city leadership throughout the project time, even though there was a change of mayor midway through the project (Energiaklub and Carpathian Foundation, 2017). The project was well organized in such a way that defined programs contained specific measures to tackle urban heat, and all relevant participants of the city administration were given the opportunity to contribute in a proper manner during the project period. To mainstream climate change into city planning, principles for adaptation have been incorporated into the city regulation acts.

The establishment of a grant scheme for citizens' initiatives must be regarded as an important potential for implementing adaptation measures and, not least, spreading awareness about adaptation to climate change impacts.

Slovakia did not have a national adaptation action plan (National Adaptation Strategy developed in 2018, the National Adaptation Plan is under development), meaning the initiative in Trnava was carried out in the absence of national regulations (Climate-ADAPT, 2018b). Thus, there is little support from the national level on local authorities' work on climate change adaptation.

At the city level, climate change adaptation is a new and multi-sectoral topic (Energiaklub and Carpathian Foundation, 2017). Beside that there are struggles to coordinate activities among different government agencies, some sectoral experts are not yet familiarized with all links, correlations and causalities related to climate change impacts and adaptation. An additional challenge is that local authority officials are overwhelmed by their day-to-day activities, and climate change adaptation may be seen as another task on top of already full working days.

Successful implementation of The Adaptation Plan remains dependent on external funding (Energiaklub and Carpathian Foundation, 2017).

Outcome and lessons learnt

The complexity of the process has made it clear how all-encompassing climate change adaptation is, demanding collaborative action among governing agencies and consideration of infinite societal, ecological, and economic links simultaneously (Energiaklub and Carpathian Foundation, 2017). It takes time for city administrations and authorities to become familiar with climate change adaptation. The process of mainstreaming climate change adaptation into the day-to-day tasks of a city must allow for trial and error to learn and find optimal ways of organizing and collaborate on this topic.

However, the adaptation plan will serve as a crucial tool in the work of adapting to heat waves and mitigating the urban heat island effect in years to come. Making it a vivid document facilitate learning and improvement of both its interventions and processes towards its objectives. Among other, as described in the source material it may seem like there are potential for improvements of public involvement, e.g., by boosting the grant program and local initiatives regarding climate change adaptation.

Further readings

Except from the source material, no further readings of relevance and available in English have been found.

3.4 Cross-case learning points and discussion

The overall approach to deal with urban heat that is chosen in this document is nature-based solutions, often referred to as green and blue infrastructure or ecosystem-based adaptation options. The strategy of Vitoria-Gasteiz is primarily focusing on biodiversity and nature conservation, where contributions to reduce the urban heat island effect is regarded an important co-benefit. The example of Trnava pose a more direct approach to deal with heat stress and mitigating the urban heat island effect.

Green and blue infrastructure in urban environments comes with multiple co-benefits, like increased biodiversity, reduced vulnerability to heatwaves and floods, climate change mitigation and improved air quality, and improved environmental qualities such as provision of recreational areas, aesthetics and increased residential well-being. This multifunctionality is well communicated in both examples presented in this chapter.

However, managing urban landscapes are complex processes, and what is less discussed are the potential conflicts inherent in the development and implementation of green infrastructure (Kabisch et al., 2016). There may be conflicting objectives regarding e.g., transport infrastructure, housing, businesses, and industry. Also, implementation of such interventions often require collaboration across sectors, institutions, and communities (Lin et al., 2021). Therefore, to successfully build up green and blue infrastructure, an integrated approach is needed to coordinate management, city planning, and urban design, and to carefully consider vulnerabilities to climate change and other local challenges. To some extent, these tensions are apparent in the case of Trnava, wherein improving collaboration and building adaptive capacity in the city administration is considered important to enable successful implementation of the adaptation plan.

Another difficulty related to ecosystem-based adaptation solutions is that it is difficult to assess their performance and benefits produced (Kabisch et al., 2016). Comparable standards and methodologies applied to engineering approaches are lacking, something which is pointed to as a major barrier to such solutions (Seddon et al., 2020). The method used in the case of Trnava by thoroughly assess and map vulnerability to heat is though producing a basis for being able to compare before and after implementation of measures, and consequently being able to confirm changes regarding vulnerabilities and risks. Also the performance of the green façade described in the Vitoria-Gasteiz case can be assessed and confirmed in numbers. Another way of assessments is investigation of public experiences on weather measures have led to improved urban environments and well-being during warm periods.

Exposure and vulnerability to urban heat vary among different groups of society and different parts of the city, making urban heat management and adaptation a social policy field (Harlan et al., 2007). Decreasing vulnerability to heat among the most vulnerable groups is a main objective of the adaptation plan for Trnava, wherein programmes beyond ecosystem services (such as improvement of residential buildings and behavioural education) are included. The Vitoria-Gasteiz' Green Urban Infrastructure Strategy does not reflect the city's complete efforts to adopt to climate change and urban heat. However, its scope of increasing the amount of green spaces throughout the whole city may be regarded as socially just as "everyone" can benefit from proximity to green areas. To what extent the green infrastructure in this case increase shielding is unknown.

It should be noted that to successfully reduce vulnerability to heat, green infrastructure may not be the only solution. Improvements of residential buildings, information on good behaviour during heat, provision of cool indoor public places, access to health services and clean water may be as equal important. Not least, careful city development and design can improve air circulation and reflect heat, thus mitigating the urban heat island effect.

4 Drought and water supply

4.1 Problem description

With climate change, southern Europe is expected to become warmer and dryer, leading to more frequent and severe drought events and challenge water supply. Non-climatic drivers such as urbanization, population increase, tourism, agriculture, industry, and land use changes will further challenge the sustainability of water resources by increasing demand or decreasing water supply. For municipal water services higher average temperatures and dryer conditions may, among other, decrease natural storage of water and its availability, increase soil compaction and water run-off, increase pollutant concentrations in groundwater and other reservoirs, and increase risks from algal bloom and cyanotoxins in water sources.

Adapting the management of water resources to climate change can improve the availability of water and ensure access to clean drinking water. This surely has an equity dimension as the poorest are the most vulnerable to drought and water shortages. At one hand, there will be necessary to prepare tools and solutions to occasions of water shortage and crisis. On the other hand, there is a need for long-term planning to ensure future water access for all. Such strategies may include increase of water reservoirs, ecosystem management to improve aquifer refill, or cooperation with neighbouring administrative entities for improved water management and water availability.

However, improved management of water resources, in the sense of increasing efficiency of its use, have great potential. Rather than trying to increase water supply, efforts should be taken to reduce water demand. Targeting pricing of water services may serve as a tool to promote water conservation. Moreover, in order to become more efficient, water management must prioritize measures to reduce water losses and to spread information on water-efficiency.

4.2 Example: Wroclaw harvesting rainwater (Poland)

Place name: Wroclaw, Poland

Type of location: City, 640 000 inhabitants

Vulnerabilities: Heat, drought, flood

Measures: Subsidy program for installation of rainwater harvesting and retention systems

Co-benefits: Biodiversity, cost-savings, health & well-being



Sources: Covenant of Mayors Europe (2020)¹², ICLEI Europe (2019)¹³, Interreg Central Europe (2020)¹⁴

Summary

Drinking water is a limited resource in Poland and the supply is likely to become more unstable with climate change. As part of their Adaptation 2030 plan, the City of Wroclaw is providing grants to citizens to install rainwater harvesting systems. Such systems contribute to reduced consumption of tap water, mitigate drought and water scarcity, and may even reduce risk of flash floods and reduce pressure on sewage systems. The grant scheme allows citizens to participate and benefit from the city's local adaptation plan.

¹² "Catching the rain" for climate adaptation https://www.conventiondesmaires.eu/index.php?option=com_attachments&task=download&id=921

¹³ Sustainable rainwater management <https://iclei-europe.org/member-in-the-spotlight/wroclaw/>

¹⁴ The "Catch the rain" subsidy program https://rainman-toolbox.eu/wp-content/uploads/2020/06/81_RR_PL-LowerSilesia_Wroclaw-subsidy-program-Catch-the-Rain.pdf

Challenges

Wroclaw is located in the southwest of Poland in the valley of the Odra River. The city, characterized by large amounts of impermeable surfaces and increasing urbanisation outside the inner city, is at risk of river floods, as well as urban floods caused by heavy rains which exceeds the capacity of the rainwater drainage system (ICLEI Europe, 2019). The city also experiences increasingly periods of heatwaves and drought during summer, exacerbated by the urban heat island effect (Wroclaw municipality, 2020). With climate change, more severe situations of both water scarcity and heavy rains are likely to happen more frequently.

Objectives

As a consequence of several periods of drought and heavy rain events causing urban floods, the strategic document Urban Plan for Adaptation to Climate Change¹⁵ for Wrocław City and a Good Practice Catalogue¹⁶ were prepared to mitigate the risks amplified by climate change (Covenant of Mayors Europe, 2020). Since 2017, Wrocław city has implemented measures for sustainable rainwater management to prevent both flash floods and drought.

After adopting a resolution on water resources protection, the Office of Water and Energy of the Municipal Office proposed a program called “Catch the Rain” in 2019 (Covenant of Mayors Europe, 2020). The objective of the program was to raise awareness around water consumption, reduce the use of drinkable water (for e.g. washing, watering plants/gardens, flushing the toilet etc.) and reduce burden of the overloaded municipal sewage system by supporting residents for more efficient rainwater management in their households.

¹⁵ Urban Plan for Adaptation to Climate Change (available in Polish)
<https://www.wroclaw.pl/zielony-wroclaw/miejski-plan-adaptacji-do-zmian-klimatu>

¹⁶ Catalogue of Good Practices I (available in Polish)
<https://www.wroclaw.pl/srodowisko/files/dokumenty/8811/Katalog%20Dobrych%20Praktyk%20-%20drogi.pdf>

Solutions and implementation

The “Catch the Rain” program was launched by the city council as a pilot project in August 2019 (Covenant of Mayors Europe, 2020). The program offered grants to citizens to sustainably manage rainwater on their own premises. Residents could receive up to 80% funding to install a rainwater retention solution. Possible installations include underground and free-standing rainwater storage tanks, rain gardens and absorbing wells. The costs of purchasing, constructing, and assembling elements needed for the retention and use of rainwater was included, but limited to 1130 Euro per application.

The pilot edition received great interest, and just few days after the release, the council decided to more than double the pot for funding (Covenant of Mayors Europe, 2020). During this first edition in August and September 2019, 62500 Euro was allocated to the programme, about 140 applications were submitted and 90 contracts were concluded for implementation of measures. Rainwater storage tanks adjacent to rain gutters was the absolute most popular option.

Because of the great interest, the city council decided to run a second edition of the “Catch the Rain” program the next year, this time with 125000 Euro allocated to the program. All available grants were allocated in five weeks.

Alongside the program, the city council and the Wroclaw university of Environmental and Life Sciences created a guide for residents on how to independently install systems for rainwater harvesting¹⁷ (ICLEI Europe, 2019).

As a mean to improve management of rainwater in Wroclaw, the city also invited children and residents to learn how to build a rain garden and on-site management of rainwater (ICLEI Europe, 2019). The workshops raised awareness of the value of rainwater, which goes to waste if just let down the drain. About 400 residents participated in these workshops in May and June 2019. Also, schools are involved in

¹⁷ Catalogue of Good Practices II (available in Polish) <https://www.wroclaw.pl/zielony-wroclaw/zlap-deszcz-2021>

the task of improved rainwater management. Through a project called “I like the rain”, 2500 children will experience and learn about the benefits of rain gardens at school.

The “Catch the Rain” programme is one of several adaptive actions implemented by the city to contribute to the Urban Plan for Adaptation to Climate Change in Wroclaw.



Figure 7. Bid catching rainwater. Source: Wroclaw.pl

Success and limiting factors

Through the “Catch the Rain” program, the Wroclaw city increase local water retention in resident’s private areas in different parts of the city. Number of applications exceeded the funding possibilities. Increased retention capacity throughout the city could have been greater if more funding were allocated to the program (Interreg Central Europe, 2020).

The immediate positive response to the programme suggests that many citizens are already aware of the need to manage rainwater efficiently (Covenant of Mayors Europe, 2020). Rain harvesting systems are not widespread in Poland. Pot-water is relatively cheap and system construction costs relatively high (Sakson, 2018). The grant program encouraged and enabled citizens to act and install rainwater retention systems that would not have been realised otherwise due to lack of funding (Covenant of Mayors Europe, 2020).

Although the program received great interest, the municipality identifies dissemination of the program and its positive effects and encouragement of the public as main challenges (Covenant of Mayors Europe, 2020).

Outcome and lessons learnt

The first edition of the program has been analysed in terms of effectiveness to harvest rain. The total capacity of the implemented measures of the first edition in 2019 was calculated to 142 m³ litres of water collected during each steady rainfall lasting 15 minutes or longer (Covenant of Mayors Europe, 2020).

Rainwater harvesting has a great potential for saving drinking water and to mitigate drought and water shortage. Stored rainwater can play a crucial role during dry periods. Also, in case of heavy rain, systems to collect rainwater contributes to prevent flooding and damage to city environments and infrastructure. By relieving drainage systems and sewage, maintenance cost decrease. Local businesses may also benefit from collection of rainwater. Furthermore, local microclimate and biodiversity benefit from preservation of the natural water cycle. Rain gardens and increased amount of green area in the city improve well-being of residents.

The “Catch the Rain” program is a way to let citizens get involved and benefit from the city’s adaptation plan. The program raises awareness among participants of the impacts and opportunities of local climate adaptation, and not least how these actions can improve quality of life. The city of Wroclaw will repeat the program in the next few years to allow more residents to install water retention systems (Interreg Central Europe, 2020).

Further readings

Except from the source material, no further readings of relevance and available in English have been found.

4.3 Example: Establishing a water saving culture in Zaragoza (Spain)

Place name: Zaragoza, Spain

Type of location: City, 680 000 inhabitants

Vulnerabilities: Drought

Measures: Public-private collaboration, adapted water tariff structure, and awareness campaigns to reduce water consumption

Co-benefits: CCM, reduced energy consumption



Sources: Climate-ADAPT (2016)¹⁸, Kayaga et al. (2008)¹⁹, SWITCH (2021)²⁰

Summary

The densely populated Zaragoza city is situated in a dry and warm climate, and climate change will further challenge water availability. Multiple experiences of drought and water scarcity led to establishment of The Zaragoza Water Saving City program in 1997. Alongside investments for limiting leakages and a reformed water tariff's structure, a collaborative partnership model enabled a comprehensive awareness campaign which resulted in a 30% reduction of water consumption in the city in 15 years (2010). Long-term and targeted work for curbing water demand and improved water management has led to a water saving culture in Zaragoza. Despite population growth and increased demand for water, the city continues to save water.

¹⁸ Case study in ClimateADAPT <https://climate-adapt.eea.europa.eu/metadata/case-studies/zaragoza-combining-awareness-raising-and-financial-measures-to-enhance-water-efficiency>

¹⁹ Kayaga, Sam, L. Saintavit, Ian K. Smout, and V. Bueno. 2019. "Partnerships for Enhancing the Water-saving Culture in Zaragoza, Spain". <https://hdl.handle.net/2134/6668>

²⁰ Water demand management in Zaragoza http://switchurbanwater.lboro.ac.uk/outputs/pdfs/W3-1_CZAR_RPT_Water_Demand_Management_in_Zaragoza.pdf

Challenges

Zaragoza with its 706 000 inhabitants is located in a semi-arid region in the north of Spain (Climate-ADAPT, 2016). Average annual precipitation is only 314 mm, most of which falls during winter. Water scarcity is a serious challenge for the municipality, which have been proved through several severe situations of drought throughout the last decades causing water restrictions and public anger. With climate change, the summers are expected to become even drier, thus exacerbating the problem of water scarcity.

Objectives

In 1995, Spain experienced a long-lasting and wide-scale drought with water shortages affecting nearly 11 million people (Kayaga et al., 2008). In addition to several drought experiences the last decades, this surely put light on the need for addressing local water management to handle similar situations in the future. Zaragoza municipality gets its water from the river Ebro. Ideas about how improving municipal water management had been focused on increased supply by e.g. building more dams, reservoirs and regional water transshipments – measures of high costs and environmental damages. In 1997 the city of Zaragoza decided to transform its water management from wasting of a limited resource to saving water by increasing efficiency in its use – a cheaper, faster, and less contentious approach.

Solutions and implementation

The solutions were multiple and required collaboration between a range of participating stakeholders (City Council, NGOs, businesses, citizen groups and residents). Through the Municipal Strategic Plan 1996-2010 the municipality set out an ambitious objective to reduce total city water consumption from 85 to 65 Mm³ (Climate-ADAPT, 2016). In this work the City Council established a municipal Water Commission (with representatives of different municipal departments, citizens groups and other stakeholders) to coordinate activities and the implementation of a range of long-term water saving initiatives; (1) The Zaragoza Water Saving City program; (2) a complete reform of the water billing system and (3) investments to reduce water leaks from the city's distribution network.

The Zaragoza Water Saving City programme was initiated by the NGO Fundación Ecológica y Desarrollo (FED) with support from the municipality (Climate-ADAPT, 2016). Other funding parties included The European Union LIFE programme, City Council of Zaragoza, the regional government, a bank and four local businesses. The program included a widespread awareness-raising campaign called “Small steps, big solutions” to reduce water consumption of households, public buildings and commercial activity through simple water saving technology and behavioural change. Based on the principle of shared responsibility, the intervention was designed to create a collective challenge which would bring about participation of all stakeholders in the city and build on the synergy of these partnerships.

Key elements of the awareness-raising campaign;

- Advertising campaigns through various medias ensuring all residents were aware of the Water Saving City program
- Citizen education on how to make changes at home by adopting water efficient practices and technologies
- Engagement with businesses selling domestic water products. The regional government offered discounts of 20-25% to those purchasing water efficient products
- Educational schemes within schools to actively engage the younger generation in efficient water management
- A “50 Good Practices” guide was developed for businesses to identify effective methods of improving water efficiency

In 2002 the City Council of Zaragoza offered a 10% bill discount to households that reduces their water consumption with a at least 40%, then 10% consumption reduction in subsequent years (Climate-ADAPT, 2016). The reformed water tariff structure aimed for a more equitable and demand-responsive structure;

- Equitable charging, affordable access to basic water services for all, including the availability of subsidies for vulnerable households such as pensioners, unemployed, large families)

- Water bill discounts as incentive for the consumer to use water efficiently. Since 2002 the City Council of Zaragoza offered a 10% bill discount to households that reduce their consumption with at least 10% annually
- Penalising excessive consumption with higher prices

This system has been kept and prices are adjusted on a regular basis.

A great effort has been made to deal with leakages from the city's aging network of water supply pipelines (Climate-ADAPT, 2016). This work implies among other considerable investments in controlling water losses and rehabilitation of the pipeline network, monitoring of water use, sectionalisation of the network into different supply zones and improvements of leaking storage tanks of apartment buildings²¹. 65 km of the pipeline network was renovated between 2010 and 2019. Due to the economic crisis dominating the last decade, the renewal and growth rate of the water supply network decreased significantly compared to the previous period.

The population of Zaragoza increased by 12% between 1997 and 2008. In the same period daily water use in the city decreased from 85 Mm³ to 62 Mm³ (Climate-ADAPT, 2016).

A municipal law for water efficiency: in 2011, the municipality of Zaragoza adopted the "Municipal By Law for Eco-Efficiency and Quality of Comprehensive water Management" (SWITCH, 2021). In general, this law sums up the regulations of the city for management of the water cycle, water quality, water efficiency, as well as the right of citizens to be informed. This law includes key aspects such as stop the use of drinking water for particular uses, track the consumption of big consumers, reduce the use of water in gardens and park by e.g. planting of arid climate plant species and the use of more efficient irrigation systems, and reuse of water from e.g. swimming pools. This law helps Zaragoza city to improve its urban water management.

The Zaragoza Water Saving City programme is still on going.

²¹ Systematization of the water supply system of Zaragoza
http://switchurbanwater.lboro.ac.uk/outputs/pdfs/W3-1_CZAR_RPT_Systematization_of_the_water_supply_system_of_Zaragoza.pdf

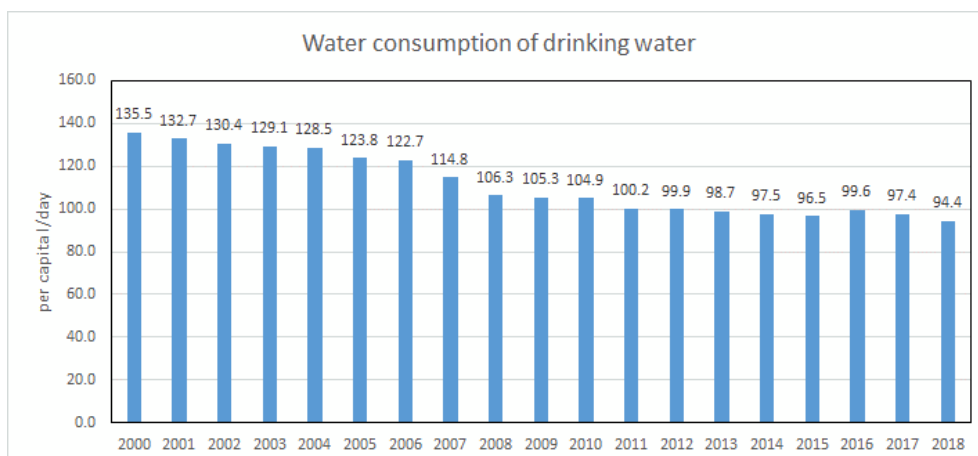


Figure 8. From 2000-2012 water use per capita in households decreased from 135 litres/day to a level below 100 litres/day. Source: City of Zaragoza

Success and limiting factors

The setting up of Zaragoza Water Commission with representatives from the city council and different stakeholder groups, including residents, enabled effective coordination of consultation, implementation, and evaluation of the different activities and collaboration towards common goals. A supportive city council contributed with economic funding and allowed policy commitments to be made (Climate-ADAPT, 2016).

The awareness-campaigns targeted specific sectors and user groups with information and activities that was perceived directly relevant for their business or lifestyle (Climate-ADAPT, 2016). Also, the campaigns were directed towards all groups of society, making high-use groups and authorities responsible for water equally committed to improve their use of water as the general public. Businesses and residents were more inclined to contribute to the water saving project when provided with more efficient and reliable water and wastewater services.

The reformed tariff system was perhaps not so important for changing behaviour in domestic water use. Rather, the revenue gains made it possible to make improvements to the water supply network system (Climate-ADAPT, 2016). Economic crisis since 2008 has resulted in a stabilization of the situation, but larger investments, in particular to the water infrastructure network, has slowed down.

Outcome and lessons learnt

The Water Saving City project has resulted in reduced water consumption and related energy consumption. Perhaps more important is the establishment of a water saving culture among citizens and businesses in Zaragoza and improved robustness to drought. The project has paved the way for new initiatives and projects on water quality, purification and reuse of wastewater, and protection of ecosystems and ecosystem services linked to water. An ongoing campaign “We Take Care of Every Drop” aims to raise awareness on the relationships between water consumption and climate change mitigation (Climate-ADAPT, 2016).

Partnerships and involvement of the different partners and stakeholders from the very beginning is important to ensure a collaborative spirit and fulfilment of project objectives (Kayaga et al., 2008). Although municipal authorities must provide a facilitating role, this example shows that dedicated and well-organised NGOs can successfully coordinate public actions.

Projects like this are cross-sectorial and require the participation of many stakeholders. A phasing approach with specific time-bound targets for the various implementations is more likely to sustain the motivation of the participating actors (Kayaga et al., 2008).

The formidable effort for improved water management in Zaragoza has received great attention, e.g. by UN-HABITAT selecting the project as one of hundred most successful interventions for sustainable urban management (Kayaga et al., 2008). The methods used in this project pose an example to follow for other cities for more efficient urban water management.

Further readings

The article by Shirley-Smith et al. (2008) presents a structured overview of the different challenges and their solutions, water savings made by different actors, businesses and institutions. It outlines the roles of the different stakeholders, in particular of the NGO, throughout the different phases of the program to improve efficiency of the water management in Zaragoza municipality. The article also

discusses the sustainability of political, economic, social, technological, and environmental aspects, and stresses the importance of harmonizing the energies, finances, and commitments of the stakeholders in order to achieve significant progress.

4.4 Cross-case learning points and discussion

Both examples presented here are parts of the city's respective strategic documents regarding climate change adaptation and water management and does not present all efforts taken by city authorities to deal with drought and water shortage. The case of Wroclaw harvesting rain poses an example of a concrete, rather small scale, contribution to climate change adaptation and reduction of the risk of both flooding and water shortage. The water saving city project in Zaragoza represents a more diverse and comprehensive strategy towards drought resilience and climate change adaptation. These are not conflicting, and there may be lessons and inspirations to elaborate on in other cities at risk of drought and water shortage.

A main take-home message may be the focus of increasing efficiency in the use of existing water supplies that can diminish water demand, and which comes with co-benefits as reduced CO₂ emissions (mitigation) as well as minimized environmental impacts and costs related to developing new supplies. This is clearly seen in the case of Zaragoza's Water Saving City program with its multiple measures to reduce water use per capita, including efforts to decrease water leakage from the distribution network. The case of Wroclaw represents another approach to enhanced efficiency of water management although at a smaller scale, namely rain harvesting solutions to save pot-water.

A reflection point is that of equity and socially sound interventions. The Wroclaw harvesting rain example may be criticized for offering solutions with its benefits only to a small proportion of society, and in particular to those privileged with a private garden or territory suitable to harvest rain. But every little helps, and a third edition of the programme in 2021 actually broadened the scope to include also housing cooperatives and communities in the subsidy program to build rain harvesting infrastructure (Wroclaw municipality, 2021). This allows more people to benefit from

the program and does further increase efficiency of water use citywide. The measures described in the case of Zaragoza were to a larger degree targeting all residents, including high-users and industries. The project also prioritized improvements of water services, strengthening the public acceptance as city authorities largely took the role of being responsible of the problem.

In general, municipal drought and water conservation plans may become tools for climate change adaptation if considerations on climate change scenarios and extreme events are included (European Environment Agency, 2015). Such plans should include guidelines and requirements regarding governing water conservation and drought contingency for public water suppliers. Moreover, they should include provisions concerning restrictions on water use, rationing schemes, special water tariffs etc. Ideally, the plan should contain quantitative and measurable targets of water conservation and set of measures to achieve these targets, prioritised according to their performance and implementation costs. Such plans should be in accordance with relevant legal aspects and other related strategic documents, such as river basin management plans. Not least, such plans should be developed through inclusive and collaborative processes involving relevant stakeholders to generate collaborative and socially acceptable solutions.

As presented in this document, the example from Zaragoza largely reflects these recommendations. By understanding how much water is available in a region, where it's coming from and who uses it, one will be able to build effective local strategies to adapt to climate change. Furthermore, this case shows the great potential of inclusive and collaborative processes of developing strategies and managing water resources. By allowing a wide range of stakeholders to take ownership to such projects, interventions may become more likely to succeed. Such all-encompassing processes thus require political and organisational will and capacity to allocate both finances and human resources to such efforts.

5 Flood, landslides and erosion

5.1 Problem description

Past trends show declining river floods in southern Europe due to decreasing precipitation and increased temperatures. However, the future climate will be characterized by extremes. Once-in-a-century river floods will occur more frequently in most part of Europe. Moreover, more intense local precipitation events trigger pluvial and flash floods and are likely to become more frequent. In coastal zones, sea-level rise will intensify floods. Climate change alter seasonal precipitation patterns and timing of flooding events. Also, activities related to socio-economic development, land use management and urbanisation processes often take place nearby rivers and water bodies, further contributing to increased risk and negative impacts of flooding events.

River floods are one of the most damaging extreme climate events in Europe, affecting all sectors, creating large costs, and affecting poor people the most due to poor housing often in flood prone areas. In almost all European countries, climate change will increase the population affected and economic damages from floods.

Landslides and erosion are climate events that are closely related to floods, because all these hazards can be triggered by heavy rain. The term landslide covers both rockfall, debris slide/flow, and snow avalanche. Debris slide/flow is a fast sliding mass flow of soil on steep slopes, with varying water content. In recent years erosion of river shores has become a more pronounced challenge in connection with river floods where rapid runoff leads to high velocity on the water masses.

For adaptation to rising flood risk to be effective, a diversified approach of interventions is required. Depending on place-specific contexts, this may include structural flood protection measures, nature-based solutions, risk-informed land planning, early warning systems, social protection measures and risk financing instruments. Nature-based solutions, such as expanding and protecting wetlands and natural flood plains, has recently gained popularity among governments to reduce

risk of flooding. In addition, such solutions can deliver co-benefits like carbon storage, ecosystem conservation, and effect tourism and local employment positively. Moreover, their implementation often requires broad stakeholder involvement which help rise awareness and build consensus.

5.2 Example: Adapting a spatial planning tool to climate change in Isola Vicentina, Italy

Place name: Isola Vicentina, Italy

Type of location: Town, 10 000 inhabitants

Vulnerabilities: Flood, erosion

Measures: Adapting planning, forest and wetland restauration, retention basins, SUDS

Co-benefits: CCM, biodiversity, improved land use management



Sources: Climate-ADAPT (2017)²², Covenant of Mayors (2017)²³

Summary

Isola Vicentina municipality is vulnerable to flooding and erosion, which is likely to exacerbate with climate change. Shortly after joining the Covenant of Mayors the municipality started the elaboration process of its Municipal Water Management Plan to incorporate climate change adaptation in its policies. The new plan includes a

²² Case study in Climate-ADAPT <https://climate-adapt.eea.europa.eu/metadata/case-studies/mainstreaming-adaptation-in-water-management-for-flood-protection-in-isola-vicentina>

²³ Twinning visit report Isola Vicentina https://www.konventderbuergermeister.eu/IMG/pdf/Isola_Vicentina_Twinning_report_2016_FINAL.pdf

variety of measures to improve water management following the principles of prevention, protection, and preparedness, and include a pilot project to demonstrate the capacity of woodland preservation to prevent flooding and landslides. The elaborated plan takes the potential increasing risk of flooding seriously, preparing to handle 300-years floods.

Challenges

The Italian municipality Isola Vicentina is prone to flooding stemming from the two main rivers running through the municipality (Climate-ADAPT, 2017). Extensive and damaging river floods are less frequent in the municipal area, the last one occurred in 2010 with more damage to the downstream municipalities. On the contrary, pluvial flooding cause damage in both rural and urban areas of the municipality almost every year. With climate change precipitation patterns change and more events of intense precipitation are expected, thus making more frequent events of both pluvial and river floods likely.

Objectives

Isola Vicentina municipality joined the initiative Covenant of Mayors for Climate and Energy in 2014. In order to adapt to future increased flooding risk generated by climate change the municipal government of Isola Vicentina decided to transform the Municipal Water Management Plan (MWMP) into an ambitious local flood adaptation plan which couples prevention, protection and preparedness strategies to cope with floods with a return period up to 300 years (Climate-ADAPT, 2017). The MWMP were originally a coordination tool between the municipality and land reclamation authorities with objectives of a shared analysis of the local drainage system, distribution of administrative and maintenance responsibilities and to identify and solve the main criticalities in the local drainage system. The objective of the climate change adapted MWMP is to solve current and future local hydraulic problems in a holistic way; by decreasing vulnerability of urban environments, infrastructure, and people, promoting sustainable land use practices, and transferring gained climate adaptation knowledge into other sectorial spatial planning tools.

Solutions and implementation

The elaboration process of the MWMP²⁴ started in October 2015 and was concluded in June 2016. Over two 3-years steps the planned measures will be implemented from 2017 to 2022.

In the process of integrating climate change adaptation into the water management plan the Mayor of Isola Vicentina engaged the Planning Climate Change research group at the IUAV University of Venice and Green-Dev Studio, a local technical consultancy firm (Climate-ADAPT, 2017). With scientific support from the research group the consultancy firm analysed every drainage basin, river, and stream in the municipality, evaluated their maximum conveying capacity and flood inundation extent and created flood scenarios with different return periods spanning from 5 to 300-years.

Further, flood hazard data was collected from official maps and plans (e.g. Hydrogeological Plan and the Eastern Alps' Flood Risk Management Plan). Information on historical events generated by the local drainage system was collected by local authorities (e.g. land reclamation authority, municipal authorities and civil protection organisations). Citizens' experiences and local knowledge were surveyed through public workshops. Citizens and targeted key stakeholder groups such as farmers, businesses and landowners of flood-prone areas were invited to join four public workshops to envisage locally appropriate measures for flood risk reduction and to gather feedback on proposed actions. Around 200 people participated in the workshops. The results were compared and integrated with the various flood estimations prepared by the researcher and consultancy group, identifying more than 20 areas suffering poor drainage and high risk of flooding.

The MWMP elaboration was inspired by the EU's Flood Directive (2007/60/EC) which suggests flood risk management strategies following three main focus areas;

²⁴ Municipal Water Management Plan (available in Italian)

http://www.comune.isolavicentina.vi.it/alfstreaming-servlet/streamer/resourceId/fb709549-5bc2-4c3e-83a3-b2dd361d3cfd/PCdA_Relazione_Idrologica_Idraulica.pdf

prevention, protection and preparedness. The MWMP includes measures following these three typologies (Climate-ADAPT, 2017).

Prevention measures: Avoiding new developments in flood-prone areas, Sustainable Urban Drainage Systems (SUDS) to reduce soil-sealing and surface runoff, and structurally adapting urban fabrics.

According to a theoretical scenario prepared during the elaboration process of the MWMP a today unbuilt area showed a potential decrease in the flood extent of about 40% if reforested. Therefore, a ten-hectare pilot area was chosen to simulate the potential of woodland preservation for improved resilience to flooding and landslides.

Protection measures: Reducing the likelihood and/or the impact of floods in specific locations by restoring flood plains and wetlands, enhancing the conveyance capacity of the drainage network, and building flood defences.

The MWMP includes about 50 protection measures which mainly include creation of new ditches and retention areas, widening the existing urban drainage network and cleaning up of rivers and streams. Thanks to a regional funding, a water retention area located in the south of the municipality on the Orolo River is already being implemented. By reducing and temporarily storing a portion of the flood-wave, the retention basin mainly aims to protect downstream municipalities.

Preparedness measures: Providing guidelines and good behavioural practices to citizens on how to act in case of flooding event.

Based on existing documents produced by the Italian civil protection service, citizens of Isola Vicentina have received guidelines on what to do before, during and after a flood in their territory. The workshops were also used to spread flood risk awareness and to train people on how to respond in case of emergency and extreme weather conditions. Moreover, the municipality has developed a WebGis application where citizens can learn about the environmental and economic added value of the measures presented in the plan (Covenant of Mayors, 2017).

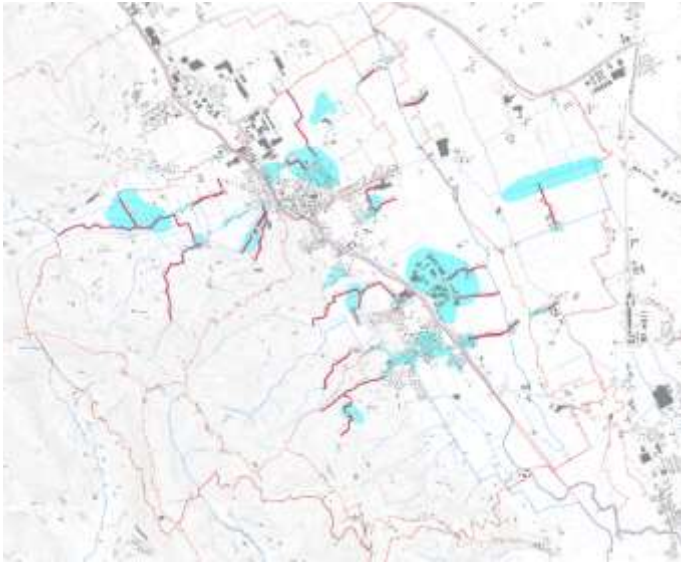


Figure 9. The map shows historically proven flood-prone rivers and areas recognized by the citizens during the public meetings. Source: Green-Dev datasets – Isola Vicentina MWMP



Figure 10. Planned risk reduction measures in a flood-prone area. Source: Green-Dev Studio

According to Climate-ADAPT (2017), the elaboration of the MWMP cost 25000 Euro. The structural protection measures for 1/100years floods will, according to the plan, cost up to 4 million Euro. Major interventions to areas and catchments beyond the municipality will require the economic support of the regional land reclamation authority and the regional government.

Success and limiting factors

Determination and dedication of the municipal government of Isola Vicentina was a key factor enabling a successful elaboration process of the MWMP, together with scientific support of the IUAV University and field work done by the technical consultants. Citizens' local knowledge and experiences helped the identification of most critical areas. Because of a recent flood event (2010) which caused significant damage to the region, the topic was assumed relevant, and the participating citizens were highly motivated (Climate-ADAPT, 2017).

The MWMP is valid within the municipality's boundaries and lack coordination with neighbouring municipalities (Climate-ADAPT, 2017). Hydraulic criticalities and challenges upstream of Isola Vicentina may impact the hydrological system locally and cannot be solved by the plan. On the other hand, municipalities downstream may benefit from measures taken in Isola Vicentina.

It was difficult to agree upon the exact responsibilities of every stakeholder of the various drainage system components, which e.g. impact farmers' agricultural practices and rural drainage, homeowners' maintenance of private ditches and water companies' management of urban storm water (Climate-ADAPT, 2017).

Outcome and lessons learnt

As member of the Covenant of Mayors for Climate and Energy, Isola Vicentina has been a mentor-municipality for an Italian and a Portuguese municipality in climate change adaptation. The experiences of Isola Vicentina have been important for the learning municipalities' processes of planning and implementation of their own strategies to cope with similar challenges concerning climate change (Covenant of Mayors, 2017).

Throughout the elaboration process involved participants have gained better understanding of the need to preserve wooded and green areas in the reduction of flood and erosion risks. More agricultural land is considered to be converted into wooded areas alongside river streams (Climate-ADAPT, 2017).

The already implemented and planned measures of this plan will improve water retention and strengthen resilience to flooding, improve resistance to soil erosion, increase carbon capture, and strengthen local resilience through raised awareness and increased local capacity to respond to flooding.

The plan also implies several co-benefits to other fields. It suggests improvements to land use management and maintenance of rural and green areas, improved stability of urban infrastructure, and more attractive green spaces for citizens to enjoy (Covenant of Mayors, 2016).

Further readings

Except from the source material, no further readings of relevance and available in English have been found.

5.3 Example: Landslide risk mapping and climate adaptation planning in Bergen (Norway)

Place name: Bergen, Norway

Type of location: Town,
284 000 inhabitants

Vulnerabilities: Landslide,
urban flood

Measures: Hazard zone
mapping, risk and
vulnerability assessment,
water framework plans.

Co-benefits: Social security,
improved land use
management



Sources: Groven (2013); nve.no

Summary

This case focuses on how experiences from dramatic landslide and flooding events in Bergen in 2005 led to the implementation of new planning tools and raised awareness of climate change vulnerability. Bergen municipality introduced hazards zone mapping, risk and vulnerability assessments, as well as water framework planning partly as a response to extreme weather events. By doing so, the city of Bergen became a pioneer who also influenced national policy within natural damage prevention.

Challenges

Bergen is located in an area with a lot of steep terrain, which makes parts of the municipality prone to landslides. For the most part, this is about the danger of rockfall, but some areas are also exposed to debris slide or debris flow (due to the mild winter climate, snow avalanche is not a problem in Bergen). The danger of

such events is greatest in connection with heavy rainfall. With its location on the west coast of Norway, Bergen is the rainiest city in Europe. In recent times, extreme rainfall episodes have triggered landslides that have claimed lives and caused great material damage.



Figure 11 The debris slide in Hatlestad terrasse, Bergen, 14 September 2005 claimed 3 lives. Photo: Bergens Tidende.

On the night of Wednesday 14 September 2005 at 01.30 a landslide occurred in Hatlestad terrasse in Fana, Bergen. Waterlogged soil collapsed down a 30 meter high slope and hit five apartments (Figure 11). A soup of soil and water penetrated on the ground floor of the row house and buried ten people. Three of these died and one was seriously injured due to lack of oxygen.

The soil in Bergen was already saturated with water after several weeks with a lot of rain when the remains of the tropical hurricane Maria came across the Atlantic with large amounts of moist air. On the same day as the deadly landslide, it was recorded 156.5 mm of rain, the largest daily value ever measured in Bergen. The same night that the landslide occurred in Hatlestad terrasse, there was a flood in the Nesttun watercourse, just a few kilometers away. One of the reasons for this was that the water flow capacity had been reduced over a long period of time through constrictions, among other things because the Nesttun Center had been built over the

river itself. Flooding water flowed under the mall, so this was close to collapsing. Just two months after these incidents, a new landslide occurred in Åsane north of Bergen city, which took two lives.

The events of the autumn of 2005 made a deep impression, not only on the inhabitants in Bergen, but on the whole nation. The crisis management system was put on a test, and the media attention around the fatal landslide accidents was colossal. It soon became clear that these experiences would have consequences for future natural hazards prevention work in Bergen (Groven, 2013).

Objectives

Shortly after the landslide and flood accidents in 2005, the politicians of Bergen decided to intensify the prevention of natural disasters. Two decisions became particularly important in putting natural hazards on the political agenda: Firstly, already at the end of 2005 it was decided to speed up a risk and vulnerability assessment process that started in 2004, and to widen the scope of the assessment. The following focus areas were defined: Landslides, precipitation, wind, sea level rise (including wave height) and flood. Secondly, in June 2007, two planning instruments were incorporated into the new version of the municipal plan, namely new provisions and guidelines on risk and vulnerability assessment (RVA) and water, sewage and stormwater management.

Solutions and implementation

Among the five natural hazards themes which became the subject of RVA in 2006, the mapping of landslide danger zones was the most comprehensive, and the vulnerability topic that received the most attention. The first phase was a rough mapping of all built-up area in the municipality, where steep slopes combined with houses and other infrastructure were marked as potential danger areas. In the next phase, this was followed up with a detailed mapping of vulnerable localities.

Danger zone mapping of an entire municipality had not been carried out previously in Norway, and this marked a shift in the natural damage prevention

work at national level. The Norwegian Water Resources and Energy Directorate (NVE) is the national authority responsible for reducing the risk of damages associated with landslides and flooding. After NVE was given the national responsibility for the prevention of landslide danger in 2009, a two-stage mapping was introduced in landslide-prone areas. It consists of (1) machine-generated landslide susceptibility maps, and (2) landslide hazard maps based on field inspections. Similar susceptibility and hazard maps are also produced for other natural hazards, such as snow avalanche, clay slide, and flooding. The maps distinguish between danger zones with a return period of 100, 500 and 1000 years, corresponding to safety classes set in national regulations on technical requirements for

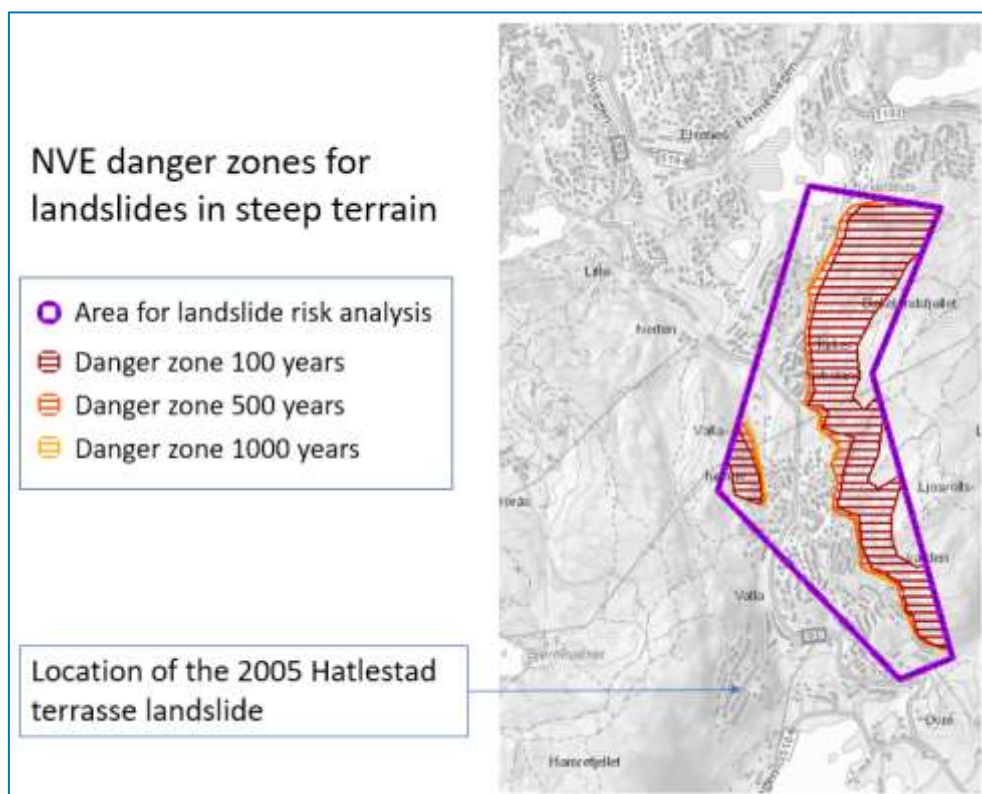


Figure 12 Web based map showing danger zones for landslide in steep terrain south of Bergen City. The location of the 2005 landslide accident in Hatlestad terrasse is indicated. Source: temakart.nve.no.

construction works. Hazard maps have become important planning tools in all Norwegian municipalities.

Success and limiting factors

In 2007, Bergen Municipality introduced a self-imposed requirement that all land-use planning and building applications in areas exposed to natural hazards, for example in steep terrain or near the sea, should trigger a requirement for RVA. A principle was also introduced that all new zoning plans must include a framework plan for water and sewage. The purpose of this is to ensure that as much of the precipitation as possible is drained through natural infiltration into the ground and via open waterways. This happened two years before the Planning and Building Act received similar requirements for RVA and so-called consideration zones in municipal plans. These efforts were put in context with climate change, and climate adaptation was raised on the political and administrative agenda in 2008, when a separate climate department was established close to the political and administrative leadership of Bergen municipality. Important prerequisites for this to happen were the combination of enthusiastic professionals who worked strategically over years to create a paradigm shift, especially within the water management sector, and key political and administrative actors who took advantage of a window of opportunity that opened up after the dramatic events of 2005.

Outcome and lessons learnt

The comprehensive measures Bergen municipality implemented after the landslide and flood events in 2005, placed the municipality as one of the pioneers in civil preparedness and natural damage prevention in Norway, and by 2008 this effort was amalgated with the emerging climate adaptation strategy of the city. The experiences from Bergen also had an impact on the formulation of national guidelines and practices within natural damage prevention work.

Further readings

English information on hazard maps issued by the Norwegian Water Resources and Energy Directorate can be found at NVE's web pages.²⁵

²⁵ <https://www.nve.no/map-services/>

5.4 Example: Improving preparedness to floods with a forecasting and monitoring system in Sundsvall (Sweden)

Place name: Sundsvall, Sweden

Type of location: City, 60 000 inhabitants

Vulnerabilities: Flood, erosion

Measures: Forecasting and monitoring system, improved flood contingency

Co-benefits: Cost-savings, enhanced security



Sources: SMHI (2017)²⁶, Sundsvall Municipality (2011)

Summary

In 2001, Sundsvall municipality experienced a large flood in the river running through the city, as well as in tributaries, causing damage to houses and infrastructure. The risk of flooding is expected to increase with climate change and sea-level rise unless the municipality adapt. To respond to these challenges, a forecasting and monitoring system was established to be better prepared for new flooding events.

Challenges

Sundsvall is located by the Baltic Sea in central Sweden, with the river Selångersån running through the city. The climate is expected to become both wetter and warmer, with more heavy rain and increased precipitation during autumn and winter, while spring and summer generally get dryer (SMHI, 2017). The risk of flooding, particularly

²⁶ Case study in SMHI (only available in Swedish) <https://www.smhi.se/klimat/klimatanpassa-samhallet/exempel-pa-klimatanpassning/minskad-oversvamningsrisk-i-sundsvall-fordjupning-1.127029?l=null>

during the wet months, increase with climate change. In a long-term perspective, this is further amplified by sea-level rise.

In 2001, the city experienced a great flood. During a few days in late August, early September, Sundsvall received 43% of the annually expected precipitation. The river Selångersån and its tributaries flooded, eroded large amounts of sediments and vegetation, and caused significant damage to infrastructure and houses. The flood was exacerbated by high tides. Also, a dam of a lake south of the city was close to burst, which would have caused tremendous damages to the city and its inhabitants.

This event sparked immediate upgrading of the dam, and a project to adapt Sundsvall city to climate change and reduce the risk of flooding²⁷.

Objectives

A representative of the city planning office in Sundsvall municipality pointed out that the big challenge in dealing with this flood was that it was not anticipated, and that municipal staff had to react very suddenly (SMHI, 2017). This experience made it clear that there was a need for forecasting of critical water levels in the Selångersån river to carry out preventive measures and allocate resources effectively. To improve the ability to prevent damage from future flooding events, the Sundsvall municipality decided to hire a consultant to make a hydraulic modelling of the river, and to establish a forecasting and monitoring system of the water levels.

Solutions and implementation

Shortly after the flood, emergency measures to reinforce the dam that nearly burst were implemented by the regional rescue service (SMHI, 2017). It was strengthened with 6 tons concrete, and sluices were removed permanently making it an overflow dam. Restoration of the river course and measures to prevent erosion downstream was also undertaken. A burst of this dam would create large damage to residents, critical infrastructure, and supply of drinking water.

²⁷ Final report of the project to adapt Sundsvall municipality to climate change (available in Swedish) <https://sundsvall.se/wp-content/uploads/2016/09/00-Slutrappport-Klimats%C3%A4rking-p%C3%A5g%C3%A5r-Klimatanpassa-Sundsvall.pdf>



Figure 13. The river Selångersån wick runs through the city, and the dammed lake Sidsjön. Source: Sundsvall municipality



Figure 14. The rescue service is making temporary embankments to prevent damage to the public sports hall during the flood in 2001. Source: Sundsvall municipality

Forecasting and monitoring system: The project of establishing a forecast and monitoring system of the water levels in Selångersån river was part of a larger project to adapt Sundsvall to climate change, lasting from 2009-2011 (Sundsvall Municipality, 2011). The larger project investigated numerous potential climate change impacts on e.g., water flows, stormwater, drinking water, health issues, risks of natural disasters, and different adaptation options. Also, the project explored new ways of organising

the work on climate change adaptation in the municipality and altered the guidelines for planning.

To enable preventive work to reduce negatively impacts of flooding, a consultant was engaged to create a hydraulic model of the Selångersån river (SMHI, 2017). Based on the average water flow from the reference period 1961-2008, the model operates with three different warning classes, following return-periods of 2-10years, 10-50years, and 50years and beyond. The model includes data on water flow, weather forecasts, tides, and bottom and terrain data. It is proven that when floods coincide with high tides, the floods become more extensive. Sensors placed in different parts of the water stream support the hydraulic model and form a quality assurance of the modelled values. This system allows for forecasting of water levels up to ten days, which are presented on the municipal website. The website is monitored by the city planning office, and the regional rescue service and the municipal contingency unit have access to it.

Preventive measures: At high water levels, the regional rescue service put out protective dikes (aluminium and plastic barriers) and are prepared with mobile water pumps. On regular basis they also remove material that is stuck along the rivers' edges.

A conclusion of the project to adapt Sundsvall to climate change is that climate change adaptation must be mainstreamed into all planning processes in all sectors (Sundsvall Municipality, 2011). The system described here, and future management of floods are, among other, related to strategic documents such as the Regional Plan for Climate Change Adaptation and Strategy for Surface Runoff in Sundsvall Municipality.

The larger project to adapt Sundsvall to climate change was jointly financed by the municipality, EU, and local energy and water companies, at a total cost of about 800 000 Euro (SMHI, 2017). By comparison, the creation of the hydraulic model (that are used to forecast flooding) and the establishment of the monitoring system cost about 34 000 Euro.

Success and limiting factors

The monitoring and forecasting system help avoid damage and large restoration costs in case of flooding. If this system had been in place before the flood in 2001, the protective walls at the sports hall would most likely have been built before the water entered its basement. There would though exist a number of preventive and protective measures that need to be implemented, such as improved and permanent protection of the sports hall (Sundsvall Municipality, 2011).

As the damage costs of flood-related problems often fall on various organizations and administrations in society, the concerned actors accepted to contribute financially to the project of establishing a forecasting and monitoring system (SMHI, 2017).

Although sea-level rise is expected to be outweighed by land uplift up to 2050, sea-level rise has still been accounted for in the efforts to adapt Sundsvall to climate change (SMHI, 2017).

The first edition of the monitoring and forecasting system used more sensors measuring various sections of the river, which allowed for the identification of critical areas (SMHI, 2017). The sensors depend on electricity, and combined with major maintenance work, this model was considered too costly. Now the system only reports non-sectioned flows.

Outcome and lessons learnt

When flooding events are forecasted, greater security is created as there is time to implement measures to prevent damage and accidents, such as put in place temporary flood protection, secure objects, ensure open and efficient waterways and evacuate people. Not least, it is more cost-efficient to prevent damage than to repair after the damages have occurred (SMHI, 2017).

For the forecast system to be robust, the website must be monitored continuously (SMHI, 2017). To reduce the risk of missing any critical forecasts, the monitoring responsibility should be shared between the administrations involved. Because the system no longer warns of critical levels in the river's different sections, those who

monitor the website must be educated on understanding the river's response to the current flow forecasts and making risk assessments.

However, for adaptation to increased risk of flooding to be effective, forecasting and monitoring systems as described in this case should be accompanied with prevention and protection measures. Several measures are highlighted, though more efforts to increase and improve e.g., retention capacity along the river would help control flooding.

Further readings

No further readings of relevance and available in English have been found.

5.5 Cross-case learning points and discussion

The case of Isola Vicentina treats a whole water management plan aimed to deal with flood risk, where the case of Sundsvall presents a concrete action to forecast critical water levels in the main river running through the city. Especially the latter case description does not reflect all efforts locally to deal with flood risk and climate change adaptation of urban water management.

As presented in the problem description, managing flood risk is a context specific and complex issue, requiring different types of measures for adaptation to be effective and to avoid maladaptation. Some nature-based solutions are highlighted in this chapter, such as flood control zones and woodland restoration in Isola Vicentina. Although such solutions include multiple benefits, flood control interventions generally remain largely dependent on “gray” (structural/physical) infrastructure interventions (Jongman, 2018). Scaling up nature-based solutions may require improved understanding of feasible protection levels, available funding mechanisms for such solutions, and appropriate maintenance and monitoring systems (UN-Water, 2018). The combination of both green and gray infrastructure measures may in many cases be the optimal approach, providing the benefits of nature-based solutions while ensuring the security provided by infrastructure. When developing flood management schemes, the range of available solutions should be analysed carefully

to combine structural, natural and policy instruments in the most effective way given the local conditions (Jongman, 2018).

Both cases include mapping and assessments of flood risk. When assessing river characteristics, it is important to bear in mind that a river comprises not only a main course but also a vast number of tributaries, which is clearly reflected in the case of Isola Vicentina. Modelling different flooding scenarios is a good departure to identify solutions and measures to deal with floods. In addition, supplying such models with local experiences of previous flooding events may improve the understanding of local river characteristics. Use of local knowledge may be an effective way to find local coherent solutions. Not least, such bottom-up approaches to deal with local challenges may support collaboration between different local stakeholders and create consensus about solutions and implementations.

Natural landscapes and ecosystems that are vulnerable to climate change and/or physical interventions may become even more vulnerable when structural flood protections (such as dikes or walls) are built. This may often not be conflictual in urban environments with less biodiversity and natural landscapes, although what's present may be conceived valuable. On the other side, in sub-urbs and areas surrounding the city, considerations of possible impacts on ecosystems from physical barriers between water courses and land should be taken. Nature-based solutions, such as conservation of natural flood plains, preservation and restauration of wetlands and forests, is a more biodiversity friendly way of reducing risk of flooding.

The Bergen case differs from the other two, both in that it is mainly about landslide hazard, and in that it focuses on how experiences with extreme weather events have accelerated the introduction of new planning tools. Emphasis is placed on the importance of institutional changes to facilitate long-term planning for enhanced civil protection. Also in Bergen, stormwater management is an important element in the damage prevention work.

The case examples do not describe in detail efforts taken to reduce the risk of erosion related to river floods, although measures are planned or implemented to improve the robustness of riversides and urban fabrics. Measures to improve water flow and control flooding may often hinder erosion. However, adaptation measures to e.g.,

handle a 100-years flood may perhaps not withstand a 300-years flood, which in turn may erode freely beyond the protection measure first implemented. Hence, detailed assessments of erosion risk in various climate change scenarios should be conducted in planning processes and in work to strengthen flood resilience.

6 Urban flood

6.1 Problem description

Stormwater (also called *surface water*) is precipitation and melting water that is not infiltrated into the ground. Instead the water runs off at the surface on its way to the nearest rivercourse, lake or to the sea. In natural areas that are not developed, the amount of stormwater is low, because the rain either trickles into the soil and becomes ground water, it is absorbed by the vegetation (especially in wetlands), it evaporates into the air, or it is quickly led away through a web of finely branched streams. By urbanisation the natural water balance is heavily changed as much of the vegetation is replaced by sealed surfaces, and because natural waterways are channeled or closed. In periods with heavy rain or snow melting, this leads to a rapid rise in runoff, and large quantities of water need to be treated in order to prevent damage.

Stormwater problems are expected to increase in the future as more humidity in the atmosphere will lead to more intense precipitation. In addition urbanisation leads both to city growth and more dense cities, which contribute to more surface water. For more than a century, urban stormwater management in European cities has been focused on draining off excess water through underground drains, mostly mixed with sewage. Although modern cities need effective sewer and stormwater drainage pipes, we have become too eager to remove water from the urban landscape.

Larger and more intense stormwater run-off poses a risk of flood damage and erosion. Rapid runoff gives high flood peaks shortly after rainfall, which increases the risk that the capacity of the drainage network can be blown. This is particularly problematic in areas where wastewater and surface water run in the same pipe, what we call a combined system. When such combined drains are unable to remove the extra rainwater, untreated, diluted sewage will be discharged into watercourses through overflows, where it can damage the life of the river and be a nuisance. Many

homeowners also experience that water from overloaded sewer networks turns and flows into the basement through drains and toilets, so-called backflow.



Figure 15 Urban flood in Oslo, Norway, June 2014. Photo: Oslo Municipality.

When much of the surface water is carried away, the level of the groundwater becomes lower, and this can lead to drying out of vegetation, scarcity of water, and to settlement damage to buildings. Another problem is that surface water can carry environmental toxins, e.g. road pollution, and contribute to the pollution of the ecosystem and groundwater.

Due to urbanization, many of the natural waterways have been closed to accommodate buildings and transport infrastructure. When rivers and streams are piped, vulnerability to urban flooding increases. In addition, fewer natural waterways provide less biological diversity both in and around the watercourse. This means that the city loses many qualities related to recreation, health and biodiversity.

By managing the stormwater locally, preferably in open solutions, cities can reduce damage caused by urban floods, improve water quality in watercourses and groundwater, and contribute to healthier and more attractive neighborhoods. To realize this, a long-term strategy and cooperation between many actors is needed.

6.2 Example: Strategic planning and practical measures for stormwater management in Oslo

Place name: Oslo, Norway

Type of location: City,
697 000 inhabitants

Vulnerabilities: Stormwater
flooding

Measures: Strategic planning
for climate adapted
stormwater management;
Rain gardens; Green roofs.

Co-benefits: Improved well-
being, air quality and
biodiversity



Sources: Strategy, action plan, and fact sheets on stormwater management (Braskerud, 2016; Braskerud and Paus, 2016).²⁸ All sources in Norwegian.

Summary

In February 2014 Oslo City Council adopted a stormwater strategy that set the course for a climate adapted and sustainable stormwater management in the future (Oslo kommune, 2014). By giving water space in the cityscape, the goal of the strategy was to reduce the risk of flooding when it rains, to facilitate a vibrant city where water provides added value in urban development, and to help ensure that clean surface water is led to the city's watercourses.

²⁸ <https://www.oslo.kommune.no/vann-og-avlop/arbeider-pa-vann-og-avlopsnett/overvannshandtering/>

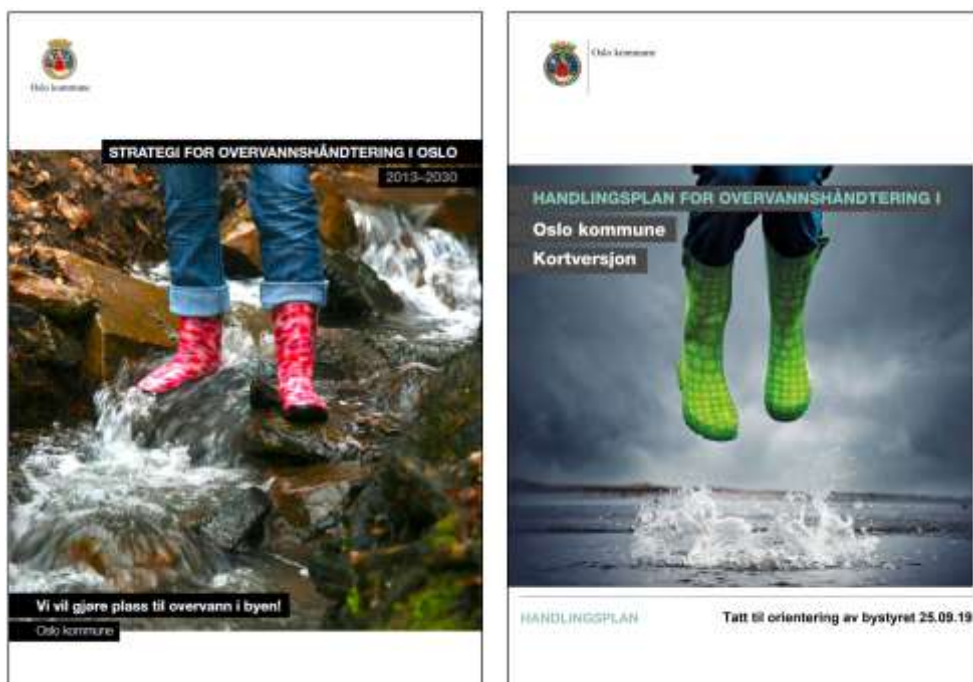


Figure 16 The two main documents on stormwater management adopted by the City Council of Oslo: The stormwater management strategy from 2014 to the left, and the associated action plan from 2019 to the right.

Five years later, an action plan for stormwater management was drawn up, with measures for the period 2019-2024 (Oslo kommune, 2019). The aim of the action plan is to facilitate a structured, goal-oriented and comprehensive work to achieve the goals in the stormwater strategy. A starting point for the plan is that municipal agencies should cooperate more closely on stormwater issues, that the municipality should involve other important actors, and that good solutions should be found and implemented in the right places. The action plan assumes that the municipality will lead by example and acquire new knowledge through its own construction projects.

This chapter also gives practical advices on how to plan and construct two types of nature-based solutions for stormwater management, namely rain gardens and green roofs.

Challenges

In recent years the city of Oslo has experienced more frequent episodes of heavy rainfall. On 26 June 2014, the Norwegian Meteorological Institute registered a precipitation record at Blindern in Oslo. 44.5 mm of precipitation in 1 hour and 72.8

mm in one day created major floods in parts of the city. As the floods only occurred in smaller parts of the city, the extent of the damage was limited. In September 2015, there was a lot of precipitation over a longer period, which led to high water flow in the city watercourses. Closed stretches became bottlenecks that led to major floods and damage over larger areas. Both incidents are examples of precipitation episodes that are expected to occur more frequently, and which were exacerbated by a large proportion of sealed surfaces and closed watercourse sections.

The stormwater management strategy adopted by Oslo municipality (2014) highlights the main challenges that must be solved: The public drainpipes built in earlier times were meant to take care of both sewage and rainwater. More heavy rain combined with a denser city with a large proportion of sealed surfaces, leads to urban floods and more frequent cases of sewage overflow into the waterways and the sea.

Objectives

The objectives of the 2014 stormwater management strategy states that Oslo should have a stormwater management that by use of open, multifunctional and local solutions:

- Meets climate challenges and minimizes damage and inconvenience to people, buildings, property and infrastructure
- Protects the environment and ensures good ecological and chemical condition in the water bodies
- Uses stormwater as a resource in the urban landscape.

The stormwater strategy further emphasizes that a prerequisite for success is that stormwater management is *incorporated early in the planning process*, in the same way as the establishment of roads and other infrastructure. Although the local water authorities have a sector responsibility for coordinating stormwater management, all municipal agencies, private developers and landowners have a shared responsibility to contribute to the work and cost sharing.

The 2019 action plan for stormwater management in Oslo identifies five themes that the municipality will prioritize until 2024:

- Gain more knowledge
- Prevent damage
- Develop model projects
- Collaborate more closely
- Inform and guide better

Solutions and implementation

The action plan is built around a *three-step strategy* for handling different amounts of stormwater: Light rain should be infiltrated in the ground or captured by vegetation (step 1), heavy rain should be retained and delayed by open, multifunctional bluegreen structures (step 2), while safe runoff towards

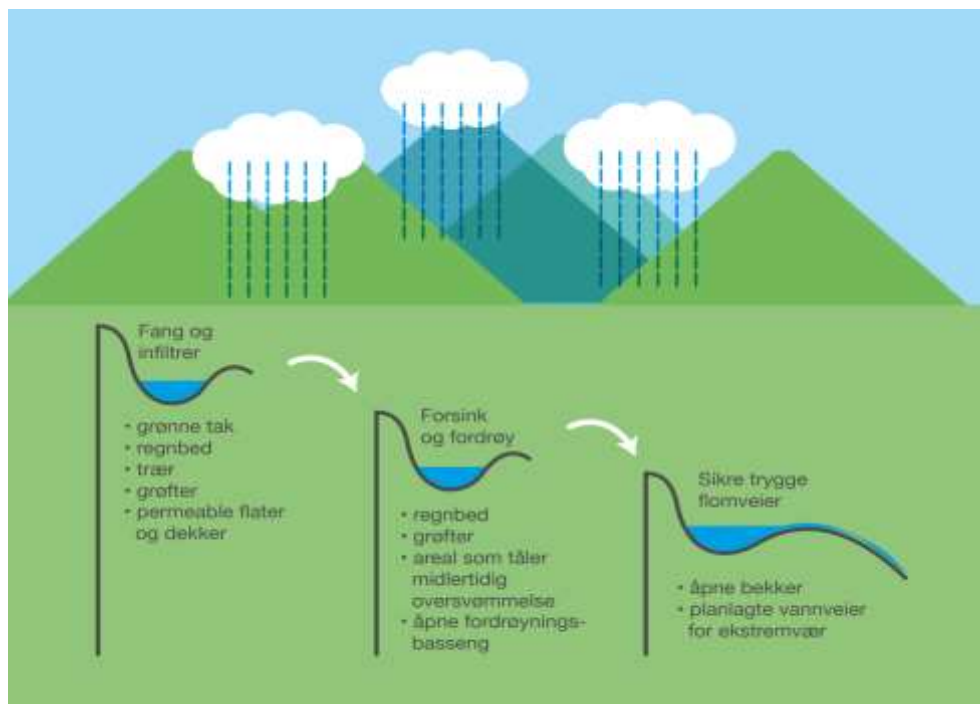


Figure 17 The three-step strategy for stormwater management: *Step 1 Capture and infiltrate; Step 2 Delay and retain; Step 3 Ensure safe flood routes. Typical measures shown with bulletpoints are (1) green roofs, rain gardens, trees, ditches, permeable surfaces and covers; (2) rain gardens, ditches, area that can withstand temporary flooding, open retention basins; (3) open waterways, planned floodways for extreme weather events.*

a recipient through natural floodways should be secured in periods when the capacity of the stormwater system is exceeded (step 3).

The two mentioned steering documents list up a variety of solutions that could be implemented under different conditions and in various parts of the city in order to help meet the goals for Oslo's stormwater management. Recommendations on the practical design of these measures are given in a number of *fact sheets* available on the municipality's website. In the following, we will present a selection of examples of measures that the local water authorities recommend, both for municipal and private development projects, as well as inspiration for private property owners.

Rain gardens

Rain gardens or *bioretention structures* are small, artificial wetlands made for collecting and retaining rain and melting water. Bioretention may serve several purposes, such as preventing urban flood by reducing runoff volumes and peak flows (and thereby the load on the drainage network downstream), and purifying stormwater by filtering contaminants, such as suspended solids, nutrients, hydrocarbons, and heavy metals (Davis et al., 2009). The infiltration efficiency of a rain garden is better under long lasting, moderate rains, compared to more intense precipitation. Oslo Municipality's factsheet on rain gardens (Braskerud & Paus, 2016) suggest the following process of establishing a raingarden:

1. Map waterways to find a suitable location. Ensure sufficient distance to buildings (prevent infiltrating water from entering nearby basements).
2. Determine the size of the catchment area, average runoff coefficient and the design precipitation event (quantity and duration) according to goals in the three-step strategy.
3. Determine the maximum water level, assume saturated hydraulic conductivity and calculate surface area. A rain garden handles limited amounts of water, so excess water should be managed properly.



Figure 18 Rain garden established on earlier sealed surface. Photo: Tharan Fergus, Oslo Municipality.

4. Assess whether the infiltration capacity of local soil is sufficient. If not, new filter and drainage should be used. Clay soils must be completely or partially replaced and drained.
5. Use filtering mass with good infiltration capacity to efficiently handle surface water throughout the year. Sandy soil with garden compost and some good local topsoil is suitable as a filter medium for plant growth. Consider sloping drainage and drainage pipes in contact with rainbed surface.
6. Give the rain garden a shape where the water is led over the entire surface. It will provide all the vegetation with water, and utilize the water purifying capacity of the rain garden.
7. Use vegetation adapted to the local climate, and avoid alien species.

8. Water, fertilize and remove weeds until desired vegetation has been established.
9. Maintain the rain garden as needed.

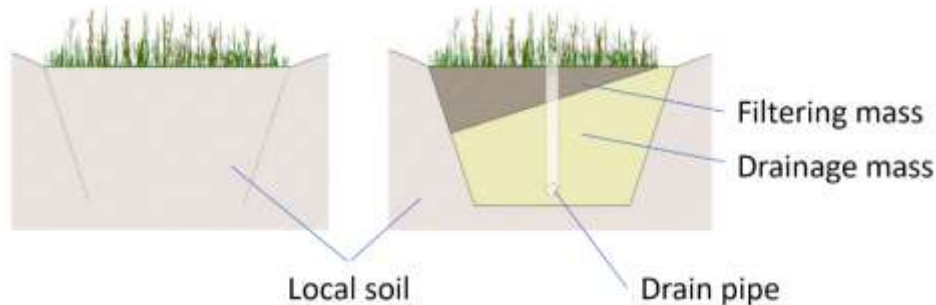


Figure 19 Principle drawing of rain gardens tested in Oslo. When local soil has good infiltration capacity (sandy, well drained soil), there is no need for drainage mass and drain pipes. However, use of filtering mass will be an advantage for the purification of contaminated water, and as a growth medium for rain garden vegetation. Source: Braskerud and Paus (2016).

There are notable co-benefits attached to rain gardens. In addition to their ability to purify polluted stormwater, they increase the biodiversity in the city, and may mobilize the inhabitants in solution-oriented behaviour. Possible trade-offs or conflicts may occur, especially if the rain garden is poorly planned, constructed and maintained. Poor drainage of excess water can lead to local flooding problems. Stagnant water can cause odor and insect nuisance, but this can be avoided with proper design.

Green roofs

Green roofs can be divided into different categories dependent on the choice of vegetation and soil thickness. *Intensive green roofs* (roof gardens) are expensive, they demand much maintenance work, and can only be placed on new buildings that are adapted to the high weight, which usually is between 240-900 kg/m² (roof gardens with trees are the heaviest green roofs).

This text applies to *extensive green roofs*, which are constructed with a soil layer not thicker than 10 cm, which gives a weight load of 40-130 kg/m² in water-saturated condition. Extensive green roofs are most often covered with sedum species. These

are succulent (drought tolerant) plants that tolerate nutrient-poor soil. Green roofs with sedum require little maintenance, inspections 1-3 times a year are enough.



Figure 20 In Norway most green roofs are covered with Sedum species. Photo: Oslo Municipality.

Green roofs can in principle be installed at all roof angles, but the cost increases significantly when the roof angle exceeds 30 degrees.

Braskerud (2016) contains the following checklist that should be reviewed before designing and building green roofs:

1. What functions should the roof have? The retention of precipitation increases with the thickness of the growth medium (substrate). The same goes for biological diversity, but also the requirement for care.
2. Be aware and specify what kind of roof you want and what kind of quality it should have, both with regard to the visual expression, the vegetation and the structure of the roof.
3. What is the compass point of the roof? The exposure in relation to the sun is important for the humidity conditions and which species thrive.

4. What is the roof angle of the building? The flatter the roof, the easier the care, but the roof must have drainage and an outlet, because plants drown if they are left under water. Roof angles below 30 degrees are preferred.
5. Can the roof withstand the weight of the green roof (including snow load)?
Can reinforcements be made easily?
6. Make sure the roof is tight before laying a green roof. It should be reinforced with a protective root barrier, or have roofing that can withstand roots.

Testing of green roofs in Oslo shows that the water retention effect is more than 50% for most rains that last up to 30 minutes. Retention is also high at a duration of 1 hour. In general, small rains were kept back by the test roofs, while larger precipitation events were reduced. The most important retention effect of green roofs is the reduction of the run-off intensity from the roof. It is the flood peak that has the greatest damage potential, because the capacity of the drain pipes can be exceeded during torrential rain and the water is forced to the surface, or into basements. The flood peak can have a very short duration, so if a measure can delay precipitation, much will be achieved (Braskerud, 2016).

Green roofs have several benefits in addition to urban flood mitigation. They have the ability to cool buildings on hot days, and can therefore be part of an adaptation strategy to mitigate urban heat. Vegetation-covered roofs provide better noise insulation from above. Green roofs also have significantly longer lifespan than regular roofs, provided good moisture sealing. The vegetation catches airborne dust, which gives improved air quality. Green roofs also contribute to a greener urban environment and increased biodiversity.

Disadvantages are high construction costs, there is need for inspection and maintenance (as for all gardens), and in case of leakage it is more demanding to find the damage.

Success factors and constraints

The Oslo case is divided into two parts, in that it focuses on both overall strategy documents and concrete measures within local stormwater management. In the following, we will treat the two parts separately.

Three major constraints can be identified within this policy field: *Firstly*, water management is characterized by the fact that it is locked into patterns laid through more than a hundred years of infrastructure construction based on principles that aim to remove water from the urban precipitation fields as quickly as possible. Because most of the city has been completed, it is expensive and time-consuming to change structures that contribute to climate vulnerability.

Secondly, introducing a new way of treating stormwater also requires a change on the mental level. One must replace ways of thinking and approaches to problem solving in the stormwater management field. Paradigm shifts do not happen in a few years, it can take decades to perform such a transition.

A third constraint is that public administration is divided into sectors, with the various agencies acting as independent "silos". To achieve good management of surface water, cross-sectoral efforts are required, where you cooperate throughout the process, from planning, to construction and operational phase.

The most important success factor for restructuring the water management in Oslo has been to anchor the transition with the municipal management, and lay down clear premises for a new policy in the most powerful steering documents. Once a common understanding of the goals has been established, it has been easier to put in place regulations and incentives that bring development in the desired direction. Good demonstration projects have been important in mobilizing enthusiasm and spreading ideas. Building networks with private developers, contractors and consulting companies has also been crucial.

Outcome and lessons learnt

In this section we will focus on the experiences on the practical "down to earth" level. When new techniques for local stormwater management have been sourced from other countries, they need testing and adaptation for them to work under local conditions. For Norway, it is a particular challenge that the climatic

conditions are so different from countries on the European continent or the USA, where many of the impulses for technology change have come from. An example of this is when snow and frost in winter cause runoff from surface water systems to stop, even during short periods of mild weather. It has been important to find plants that can withstand the climate and function as intended in multifunctional nature-based solutions.

When local water authorities are to set requirements for developers regarding local management of rainwater, it is important to be able to document the retention effect of various measures. Without scientifically based knowledge about the effect of the measures that are put in place, it becomes difficult to make the right choices. For this reason, it has been challenging to get developers to take the risk of using some blue-green solutions.

For the Water and Sewerage Authority in Oslo, it has therefore been a priority to stimulate testing, and to share documented experiences through various channels. The fact sheets on which parts of this chapter are based are examples of such communication.

Further reading

A substantial English literature on green roofs is available (e.g. McIntyre & Snodgrass, 2010).

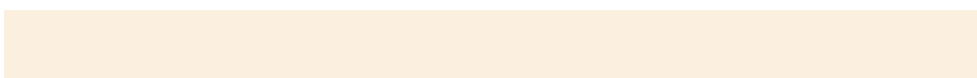
7 Vector borne diseases

7.1 Problem description

Vector-borne diseases are infections that are transmitted by infected arthropod species, such as mosquitoes and ticks. Arthropod species are cold-blooded and therefore especially sensitive to climatic conditions. Milder winters, raising temperatures and increased rainfall as consequence of climate change may improve the living conditions of arthropod species and are likely to drive the emergence and re-emergence of many vector-borne diseases in Europe (Calzolari, 2016). Higher temperatures allow a faster replication of the pathogen in the insect, but also affect its reproduction, activity, and survival. However, climate is only one out of many factors affecting vector distribution, such as the introduction of pathogens, land use, habitat destruction, use of pesticides, and host density (Semenza & Menne, 2009).

To what extent people will be at risk in areas where vector-borne diseases are present rely partly upon how we design, build, and manage our surrounding environments. Just as important are access to and the quality of health services. Ineffective health governance structures and underfunded health systems are likely to be a major barrier to successful control and mitigation of vector-borne diseases (Bardosh et al., 2017).

In this report we will not go in detail on the different types of vectors nor diseases, though mosquitoes are the main focus. However, it is important to note that different vector-borne diseases will respond differently to a changing climate as well as land use change and global change. To deepen the impression, a broad description of the climate sensitivity of Malaria and West Nile virus is included:



Malaria in Europe

Anopheline mosquitoes can transmit imported plasmodium parasite and cause malaria. With several factors related to socioeconomic development, malaria has been eradicated from Europe. Temperature appears to have a nonlinear influence on malaria development and is vector specific. This means that when other conditions are optimal, even modest warming may increase transmission of malaria. Otherwise, modest warming at relatively high temperatures may decrease transmission. The risk of malaria and other “tropical” diseases to emerge or re-emerge in southern Europe is considered low and rather an expansion of risk due to climate change. However, surveillance should be a priority, and in case of economic downturns, deteriorated living standards and faltering health services, more episodes of local transmission of malaria are likely.

Source: IPCC AR5 (Smith & Sauerborn, 2014)

West Nile virus

West Nile Virus, causing West Nile Fever, is often spread in complex interaction between birds and Culex mosquitoes. An increasing number of WNV autochthonous cases has been reported in Europe. High temperatures and humidity show a positive correlation with the aggressiveness of the vector mosquitoes. Optimal climatic conditions for the West Nile virus are mild winters, heatwaves early in the season, dry spring and summers, and wet autumns. Reproduction of Culex mosquitoes in urban environments are high during dry periods and may lead to multiplication of virus as vectors and avian hosts concentrate around water sources.

Source: Paz (2015) and ECDC (2021)

7.2 Example: The Mosquito Management Plan of City of South Perth, Australia

Place name: City of South Perth, Australia

Type of location: City, 45 000 inhabitants

Vulnerabilities: Mosquito nuisance, mosquito-borne diseases

Measures: Mosquito management plan

Co-benefits: Improved well-being



Sources: City of South Perth (2020)²⁹

Summary

The City of South Perth's government received massive public complaints for poor mosquito management in the city. This resulted in an elaboration process of the local mosquito management plan, taking a comprehensive approach to improve the management program and to ensure an ongoing process of continuous learning and improvement of its operations and management. From being a rather low priority, the city's mosquito management plan is now a vivid document building on public and stakeholder involvement and principles such as transparency and accountability.

Challenges

The City of South Perth is a peninsular city surrounded by river water. There are several tidal flood plains and wetlands where mosquitoes breed close to residential

²⁹ City of South Perth Mosquito Management Plan 2020-2021

https://southperth.wa.gov.au/docs/default-source/1-residents/services/mosquitoes/mmp-20-21-final.pdf?sfvrsn=78c3dabd_4

areas, causing mosquito nuisance in different parts of the city. The Waterford district is particularly affected, making this area a primary target of the plan. This area includes about 20 hectares of saltmarshes. Hot and warm summers with low rainfall and large tide difference create optimal environments for mosquito breeding on this wetland. There are also freshwater breeding species in the area. El Niño years exacerbates the mosquito nuisance in the city. Climate predictions for the City of South Perth shows an increase in average temperatures and decreased average rainfall. This combined with sea level rise mean that mosquito nuisance and potential disease transmissions will continue to be a challenge for city leadership. Mosquito types transmitting diseases like Ross River virus and Barmah Forest virus are present in the City of South Perth, though they rarely cause disease outbreaks.

Prior to 2010 the city held a two and a half side Mosquito Management Plan covering the aims, control, monitoring and application of treatments. The mosquito season 2009/2010 was considered among the city's residents being of the worst, and people were unhappy with the City's effort in addressing the problem. Also, the media exposed the topic in negative terms. The public opposition culminated in a public meeting between residents and city authorities, which resulted in the establishment of Waterford Action Group that would support the city in addressing the mosquito problem. The city leadership decided to develop a comprehensive Mosquito Management Plan, including investments in this field and the engagement of a consultant to give advice on the robustness of the plan.

Objectives

Mosquito management is a priority in Australia and is becoming more and more effective. However, mosquitoes are important parts of ecosystems, and due to environmental factors, there will always be times when mosquito numbers exceed levels that residents will consider desirable. Therefore, the City of South Perth's Mosquito Management Plan does not aim to entirely solve the problems of discomfort caused by mosquitoes. Rather, the plan is a vivid document that aims for continuous learning and improvement based on practice evaluation and experiences to reduce mosquito nuisance to the city's residents. Through community consultation, following principles were articulated and adopted to the developing process of the Plan:

Accountability, transparency, residents' involvement, and professional input.

Solutions and implementation

The City of South Perth's Mosquito Management Plan were established in 2010, and serves as a guiding operational program which is evaluated and updated annually with the objectives of

- Guiding the City on the control of seasonal mosquitoes; Monitor and treat larval and adult mosquito activity, and investigate more effective methods of control in mosquito prone areas
- Conducting educational and communication programmes to residents on how to manage mosquito infestations
- Improving the effectiveness of the operations of the plan by consulting various stakeholders, feedback from residents gathered by the Waterford Action Group and by using statistical data on resident complaints and mosquito trappings

In addition, the Mosquito Management Plan aims for creating an expectation with residents that the city will make actions to ensure an acceptable outdoor environment during the mosquito season. Environmental protection is also of high priority alongside mosquito management. Further, the plan facilitate collaboration with state agencies such as the Department of Biodiversity and the Department of Health and other relevant organisations on mosquito management in a fragile environment close to residential and urban sites.

The plan presented here is the one of the season 2020/2021. Officers of the City has prepared the plan by using information available from different state and commonwealth agencies, Mosquito consulting services, community representatives of the city and data gathered by the city since the first edition of the Mosquito Management plan in 2010.

The Plan is in accordance with the city's Strategic Community Plan 2020 – 2030, and in accordance with relevant statutory, such as the *Health Act 1911* with respect to nuisances, and the *Environmental Protection Act 1986*.

Mosquito Management Program

The program takes an integrated approach to mosquito management. This is a mosquito control strategy in where environmentally sensitive methods to control mosquito populations are considered first, and where a variety of management measures are co-working focusing on prevention and reduction of mosquito nuisance and the risk of mosquito borne diseases. Cultural controls and mosquito surveillance are also important elements of such an approach.

Mosquito monitoring: Mosquito monitoring is simply about determining of mosquito numbers and the locations of breeding sites. All known breeding sites will be monitored during the mosquito season and is timed strategically following tides and weather conditions. When numbers of larval exceeds defined thresholds, different treatment options will be considered. Adult mosquitoes are also monitored during the season by trapping in certain areas. Trapping is a good indicator showing increase or reduction of mosquito populations, and to monitor the different mosquito species in different parts of the city. The determination of the different species allow targeted direction of treatments were needed. The city publishes the trapping results at their website.

Chemical control: The larvicides used are bacterial controls (like *Bacillus Thuringiensis* var *Israelensis*) and insect hormone controls (methoprene). These are target specific larvicides which not impact beneficial insects such as pollinators and predators. Larvicides are the preferred treatment as it is better to prevent a problem than trying to control a problem when it occurs. Moreover, it is easier to control mosquitoes at the larval stage than when adults. In the wetland area treatments are often conducted by helicopter. Treatments by drones are under investigation, potentially providing more targeted treatment.

Adulticiding is considered in cases of great mosquito nuisance and mosquito numbers exceeding defined thresholds. Fogging or residual barrier treatments is like large scale insect spraying which negatively impact or kill other and beneficial insect species and predators. Only approved Pyrethrin chemicals are allowed with minor impact on birds, mammals and humans when applied within the label requirements. Adulticiding is strictly regulated following environmental considerations and

weather conditions. Residual insecticide barrier treatment allows for more selective and targeted treatment of less sensitive area such as along pathways and vegetation in urban environments harbouring mosquitoes, although also killing non-targeted species.

All pesticides in use have been approved by Australian Pesticide and Veterinary Medicines Authority.

Cultural control: An important element of the program is to increase awareness of the mosquito problem among citizens and provide educational tools on how to protect yourself from bites and how to minimize mosquitoes around residential dwelling sites. Cultural control includes communication and promotion of protection measures to residents, such as

- Avoiding outdoor exposure to mosquitoes around dusk
- Installation of insect screens in homes
- Using repellents
- Wearing loose and light-coloured clothing outdoors
- Emptying water from all sorts of containers around homes frequently to stop mosquitoes from breeding

Moreover, other health authorities and local governments with similar challenges and programs exchange best practices and learn from each other.

Supporting biological control: Mosquitoes are important bricks in the ecosystem of any wetland. The city is implementing different nature restoration projects to increase biodiversity and improve water quality of various wetlands in the city. Maintaining healthy wetlands sustain natural enemies of mosquitoes, such as native fish and bats. One example is actions to increase the number of micro-bats, which may eat up to 1000 adult mosquitoes per night.

Land use: The plan includes a discussion on the relation between urban development and mosquito nuisance. To minimize contact and impact with residents and mosquitoes, residential developments should not be located in proximity to mosquito breeding sites. The plan state that this ideal criteria is often

not met in practice as there are various public agencies involved in residential land use approval and these considerations are set aside. This is a long-term problem created by the local councils, who also will be responsible of addressing these issues in the future.

Success and limiting factors

At the end of each mosquito season, the Mosquito Management Plan is reviewed following best practice principles to continually improve the mosquito control program. The performance of the plan's objectives is measured and reported, which in turn are used to make improvements to the plan for the next mosquito season. The resident's representative group and other stakeholders are included throughout the reviewing process. In this way a continuous learning process is secured and the effort to continuously improve the program maintained.

The plan does not explain the migration patterns of adult mosquitoes in the affected areas. Doing so could be an effective method for responding to spikes in mosquito activity and breeding sites around the city and in inaccessible wetland area.

Saltmarsh mosquitoes are of core attention in this plan, though there are a range of other mosquito types in the study area. The local government and other mosquito managers could broaden the surveillance and management of freshwater and container-breeding mosquito species in the City of South Perth.

There are clearly concerns about the use of pesticides, and in particular adulticiding, which largely impacts other organisms and, in many cases, fragile ecosystems.

Outcome and lessons learnt

The city has responded to its citizens' complaints about unsatisfying mosquito management and does now make a great effort to deal with mosquito nuisance and to ensure that the whole management process is accountable, transparent, and auditable within a cycle of continuous improvement. The general feedback from the public is that the mosquito problem has abated with the elaborated and improved management program. This may imply a certain success of the plan, its operations,

and its acceptance among residents, although weather conditions may have been less favourable to mosquito breeding.

The plan raises the need of different local government agencies to improve cross-sectoral collaboration on this issue to ensure that future city development is not exacerbating the problem of mosquito nuisance and risk of mosquito borne diseases to the city's residents.

Structurally engagement with these challenges within city leadership and administration, and in collaboration with relevant stakeholder groups and citizens, must be understood as a way of building resilience and adaptive capacity locally to deal with mosquito nuisance and prevent disease outbreaks. Adapted to local conditions, the City of South Perth's work on improved mosquito management may be a good example to follow.

Further readings

Australia has great experience with mosquito control and avoidance of various mosquito-borne diseases, caused by e.g., transmission of Ross River virus or West Nile virus (Potter et al., 2019). Campaigns to raise awareness and change behaviours has for a long time been dominated by the passive distribution of information through websites and brochures and limited to community-based actions to prevent container-breeding vector species by removing stagnant waters in the neighbourhoods and reducing the incidence of mosquito-borne diseases using insecticides. More recently, health authorities in Australia have turned to a more integrated approach to mosquito management, emphasising the role of education. Alongside the traditional methods of mosquito control, several campaigns also include a variety of educational approaches, targeting of certain groups, and distribution of protective materials to reduce the incidence of preventable diseases. Potter et al. (2019) describes the methods and stakeholders' roles in such a campaign that involves several local governments and health units in the Western Australia and discusses its strengths and weaknesses.

7.3 Case learning points and discussion

In this chapter we have presented the main features of a management plan to deal with mosquito nuisance and disease control at municipal/city level. The plan may serve as an example to elaborate on, or wherein measures and actions may be transferrable to other cities. Such plans may also have applicability to management of other vector-borne diseases and relevance to control of other vectors than mosquitoes.

Vector control is a complex issue, often requiring a set of different approaches and measures, as well as involvement of different stakeholders and governing agencies. At a local level, controlling mosquito breeding in urban environments is different than controlling mosquito cohorts in wetlands outside the city. Managing nuisance species is often a responsibility of local governments, whereas disease transmitting species are dealt with by state and public health units (European Centre for Disease Prevention and Control 2012). This emphasizes the importance of supporting plan and strategy documents with actions and addressing the different agencies' responsibility concerning the various implementation tasks.

Although efforts are taken to ensure high quality and biodiversity in ecosystems which support natural predators, the use of pesticides to control vector-borne diseases is and will most likely continue to pose an inevitable solution. This is clearly problematic, as pesticides affect surrounding organisms negatively. When treatment is considered a necessity, one should strive for as purposeful and gentle use of pesticides as possible. This requires strict management, regulations, and statutory regarding use of pesticides. To minimize impact, knowledge about ecosystems and the potential extent of damage to environments, water quality, animals and humans is needed among those responsible for carrying out treatment. If possible, controlling mosquitoes at the larval stage is preferred, as adulticiding affects far more area and organisms.

The plan presented in this chapter mainly focus on mosquito control in wetlands surrounding the city. It does also include numerous measures to control mosquito breeding and cohorts in the city, such as educational schemes. The plan does not focus

on how landscape architecture and urban design prevent or contribute to rising risk of mosquito nuisance or vector-borne diseases.

Increasing green and blue infrastructure in the urban environment is often considered being critical for climate change adaptation and mitigation, sustainability, and improved human health, as also highlighted in the various examples presented in this document. It is possible, however, that efforts of bringing more nature (increasing biodiversity and water bodies) into the city may also promote increased introduction and survival of vector or host organisms for infectious pathogens resulting in spread of different diseases (Löhmus & Balbus, 2015).

Increased awareness of the potential mosquito nuisance and risk of diseases of urban green and blue infrastructure should not be an argument to stop such projects. Mosquitoes rely on standing water to complete their life cycle. In some cases, draining or filling of water ponds may be a solution without compromising the environment or other goods. In general, proper design, vegetation control and manipulation of water levels can create less favourable conditions for the larval as exposure to wave activity and water circulation make obtaining of food difficult. Incorporation of public health awareness and considerations of the potential risk of increased mosquito breeding into urban planning can strengthen fulfilment of green and blue infrastructure objectives (Löhmus & Balbus, 2015).

8 Problems and prospects of coping with climate change

The preceding chapters show examples of how cities in several countries, and under different conditions, have adapted to climate change. Hopefully these examples will provide Bulgarian cities with ideas, approaches and technical solutions that can be useful in adaptation efforts that lie ahead. As mentioned in chapter 1, climate adaptation is not an easy task to tackle; there are many considerations to take. One of the biggest challenges we face when implementing adaptation measures in our local communities, is to find ways to negotiate and balance the many *goal conflicts* which characterize the climate and environmental policy field. In the following, we present a simple framework for assessing climate risk. This takes departure in the IPCC concept of climate risk as a function of hazards, vulnerability and exposure. We use the example of *urban heat* to illustrate how this framework can be used to better inform adaptation policy decisions. Further, we will discuss the importance of avoiding that the two dimensions of climate policy, climate mitigation and climate adaptation, oppose each other. We will also deal with the potential conflicts between climate policy and biodiversity conservation.

8.1 A framework for climate risk assessment

Based on the IPCC concept of climate risk in social-ecological system, we will introduce a framework for decomposing climate risk as a function of hazards, vulnerability and exposure. We will use the case of urban heat to illustrate how the framework could be applied. The figures below present 3 steps in the process of splitting up the components that make up the climate risk, and identify options for addressing the different dimensions. These are:

- Identifying factors that determine climate risks
- Determine the level of climate risks
- Identify policy measures for climate risk reduction.

The model could be useful when discussing climate adaptation options with stakeholders and policymakers. The first step described below is typically suitable for consultations with users and residents, while the second step can be successfully completed by employees of the municipal administration. To carry out the third step, we would recommend involving politicians.

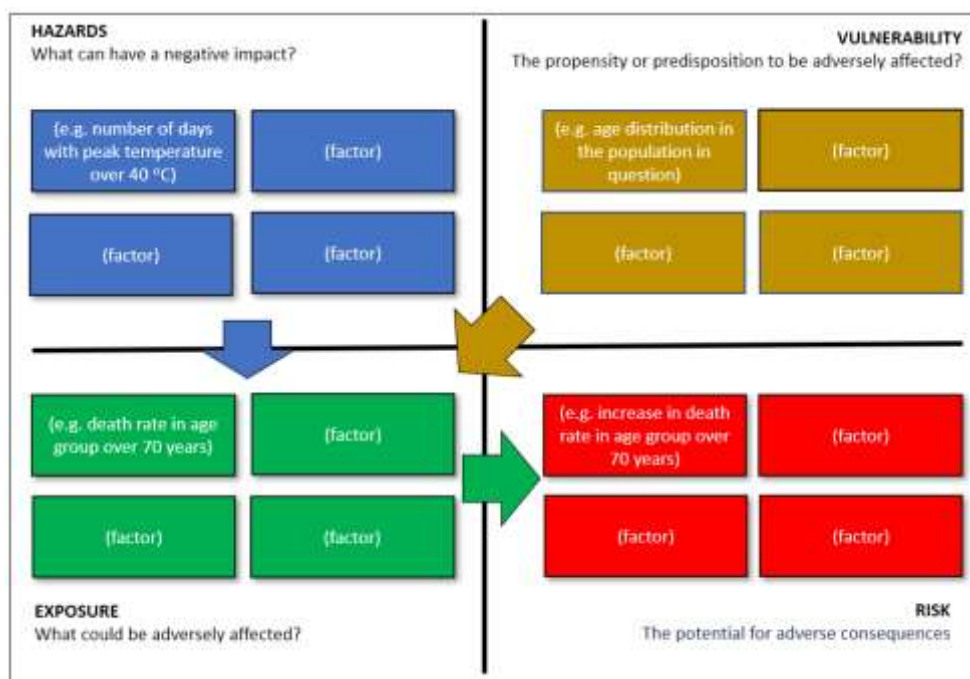


Figure 21 Step 1: Identify factors that determine climate risks.

The first step in the process is to identify the factors that determine climate risks. It is not evident which of the four boxes one should start to fill in, in some cases it would be logical to start with identifying the hazards. In the case of urban heat, the hazard could be expressed as number of days with maximum temperature above 40°C. One could also start with identifying the *exposure*, by asking “what could be adversely affected?” The ultimate exposure would be death toll due to excessive heat, and could be expressed as mortality in a population or a segment of the population. *Vulnerability* is the most open of the four categories. Here we can identify a large number of factors that predispose the society to be affected by the hazard. It could be physical features, such as properties of buildings, or the amount of vegetation in the urban environment. Socio-economic and demographic factors, such as poverty and age distribution, also affect how vulnerable the population is to heat. In this model, the *risk* is an expression

for the potential for adverse consequences, such as heat wave induced mortality increase, and is the combined result of hazards, vulnerability and exposure.

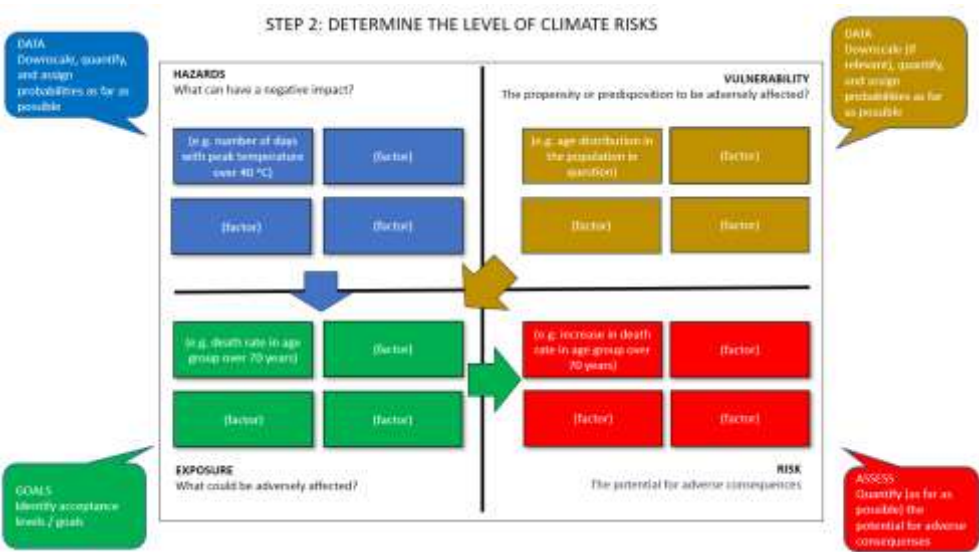


Figure 22 Step 2: Determine the level of climate risks.

In the second step, the task is to determine the level of climate risks. This is done by quantifying and downscaling the factors that were identified in the previous step. Such knowledge acquisition is time-consuming, but the better data one has, the more precise the basis for policy decisions.

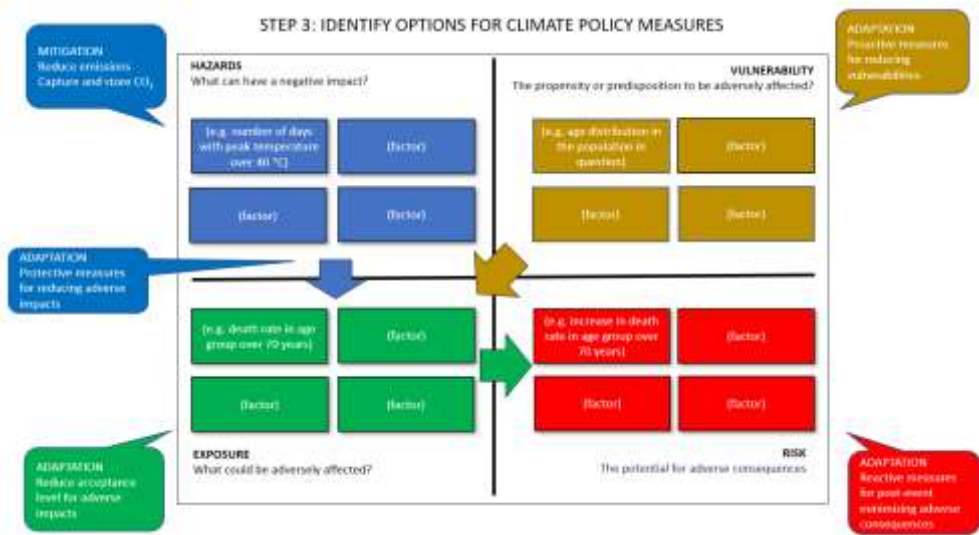


Figure 23 Step 3: Identify options for climate policy measures.

In the third step of the climate risk assessment, where we identify options for climate policy measures, the *hazards* could be addressed by mitigation (i.e. reduced emissions and/or carbon sequestration) or protective adaptation measures for reducing adverse impacts. In the case of urban heat, this could be by installing air conditioning in existing houses.

In order to reduce the *vulnerability* to urban heat, proactive measures could be to plant more trees in the city or establish green roofs and walls. Also policy for improving the social and economic status among vulnerable groups, could be proactive adaptation measures.

One way of addressing the *exposure* could be to adjust the acceptance level for adverse impacts. We do not advocate accepting increased mortality; a more realistic and morally acceptable alternative would be to abandon neighbourhoods where the death rate during heatwaves are persistently high.

Reactive adaptation measures that aim to reduce the *risk* directly, could be to strengthen the civil protection system, such as improving warning systems or better monitoring of the health status of the elderly and other vulnerable groups. Common to such measures is that they attack the problem after it has occurred (post event).

8.2 Climate change and biodiversity loss must be treated jointly

In 1992 the Earth Summit in Rio de Janeiro adopted two international conventions that separately addressed two emerging global crises: United Nations Framework Convention on Climate Change (UNFCCC) established the framework for later international treaties on climate change. The Convention on Biological Diversity (CBD), also adopted in Rio 30 years ago, drew attention to the decline of biodiversity and the need for protecting ecosystems worldwide. While entering the international agenda at about the same time, the two policy fields have developed at different rates, and climate negotiations have been more influential than the corresponding processes in the field of biodiversity protection. This imbalance can also be seen in the scientific community, where IPBES, the intergovernmental organisation that deals

with the science/policy interface on biodiversity and ecosystem services, was established 25 years later than its climate science counterpart IPCC.

Over the last decade it has become increasingly clear that the two crises of climate change and biodiversity loss are closely interconnected, and that both pose threats to economic development and human wellbeing. In 2021 the two intergovernmental panels IPBES and IPCC for the first time issued a common report that examined the fundamental intertwining of biodiversity and climate, and made a case for why climate policy and biodiversity policy must be considered jointly to meet the challenge of achieving a good quality of life for all (IPBES & IPCC, 2021).

8.3 Nature-based solutions as a way to avoid conflicts and achieve synergies

Many of the synergies that have been documented across these policy fields, can be linked to the use of nature-based solutions such as use of vegetation in cities to mitigate urban heat, improve air quality, prevent urban flood and provide carbon sequestration (Grafakos et al., 2020; Landauer et al., 2015).

There exists a wide range of different technological solutions to address all sorts of climate challenges and to help cities create more resilient systems. Various examples have been presented in this report, e.g., permeable surfaces to mitigate both urban heat and stormwater runoff, smart urban drainage systems (SUDS), water meters to improve efficiency in water use, and dikes. Although technological solutions are continuously developed and improved, and their effectiveness is well studied and documented, they are inaccessible to many cities due to lack of resources to implement and maintain them. In many cases, there are need for social and governmental interventions to overcome barriers to implementation of technological solutions.

Although nature-based solutions seem to be a viable solution to many climate and biodiversity challenges, one should be aware that such solutions will be affected by changes in temperature and precipitation, thus being sensitive to the climate challenges they are meant to address. For example, increased shading and evaporative cooling by trees canopy to deal with urban heat may decline with drought

events and reduced water availability. For urban vegetation to be resilient and capable to deliver desired benefits, such solutions should be planned concerning future climate change scenarios. Native species are often more likely to succeed at the given place, without requiring too much care. On the other hand, the introduction of alien species may lead to undesired outcomes as they may displace local species and reduce biodiversity. Nevertheless, nature-based solutions will in any case require a certain degree of careful management and maintenance to continue delivering the desired eco-system services.

8.4 Combating air pollution and climate emissions - a vital synergy

Cities' efforts to mitigate climate change must go hand-in-hand with efforts to reduce air pollution. Without mitigation, air pollution will be worse with climate change. Many of the air pollutants that harm the climate also negatively impact our health. This means that action to reduce emissions will not only deliver long-term global climate impacts, but also near-term local health benefits.

Cities should target short-lived pollutants³⁰, e.g., black carbon (soot), methane, tropospheric ozone, and hydrofluorocarbons. These are the main contributors to air pollution and health issues, and reduction of these will be crucial in order to avoid global temperature rise above 1,5 degree and beyond. However, reduction of carbon dioxide should also be of high priority, as it remains in the atmosphere for around 200 years and constitutes the largest source to global warming.

Both air pollution and climate emissions share solutions, and cities can target these pollutants in multiple ways: Support a shift from private vehicles to public transport, cycling and walking to reduce emissions, as well as electrification of vehicles, and in particular of public transport. Support a transition to cleaner cookstoves in private homes. Shifting energy production from fossils to renewables. Improve the management of municipal sewage and solid waste. And by improving

³⁰ Climate and Clean Air Coalition (2018) IPCC 1.5°C report: reducing short-lived climate pollutants necessary to achieve 1.5°C goal

energy efficiency of buildings, by retrofitting existing ones and ensure high standards for new ones.

Nature-based solutions to adapt to climate change will have synergies with actions to reduce climate emissions by carbon sequestration. Furthermore, increased biodiversity, ecosystem connectivity and vital natural systems capable to deliver ecosystem-services will help cleansing water systems and contribute to air purification.

8.5 The Sustainable development goals as a possible framework

To reconcile the consideration of both climate policy, biodiversity protection and a good quality of life for all, which IPBES and IPCC (2021) advocate, is a question of balancing competing interests in society in a long-term perspective. This is also the main idea of the Sustainable Development Goals (SDGs) that were introduced in the resolution Agenda 2030 adopted by the UN General Assembly in 2015. There are 17 SDGs and nothing less than 169 targets (sub-goals). These form an indivisible whole, which means that sustainable development cannot be achieved unless all elements of the SDGs are taken into account.

Even though all 17 SDGs are indispensable in the strive for sustainable development, it has been argued that the goals can be arranged in a hierarchy which indicates how some aspects of sustainability are more basic than others. This approach has been expressed in the figure below, the so-called 'wedding cake diagram'.

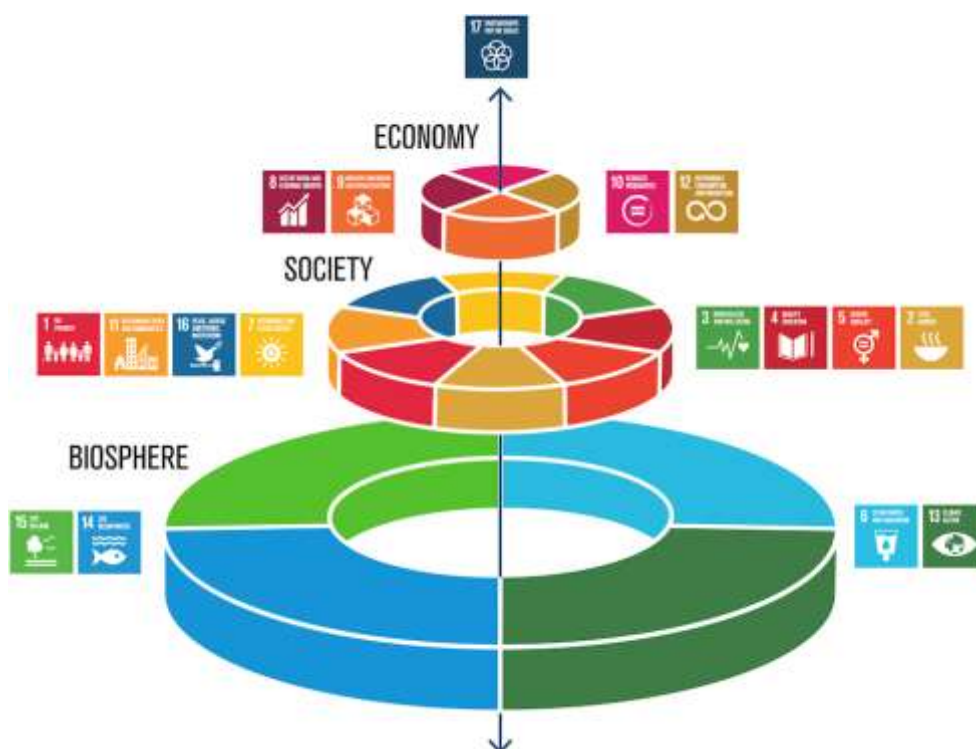


Figure 24. The «wedding cake diagram» displaying the SDGs across three dimensions of sustainability.

The figure rests on the view that the biosphere, which provides us with vital ecosystem services (food, drinking water, and other natural resources) is a prerequisite for society and human well-being. A well-functioning society is in turn a prerequisite for a vital economy. Each of the realms – biosphere, society and economy – can be connected to a set of sustainability goals. Such a framework of understanding the conditions of sustainable development could be a useful guide for local decision-makers when conflicting interests are to be balanced through climate adaptation measures.

8.6 Coverage of the selected climate topics

In the following we will discuss to which extent this report succeeds in covering the choice of vulnerability themes that has been emphasized by the project partner cities. In other words: Have we picked the right examples?

It has proved to be hard to find suitable examples on managing water scarcity and drought, vector-borne diseases, river floods in urban environments, and particularly

examples of adaptation measures that aim to prevent erosion and landslides. At the other hand, cases on blue-green structures as stormwater management measures and mitigation of urban heat are abundant. In general, many adaptation projects are characterized by being large-scale, prestigious and expensive. Such examples have been judged less relevant in terms of the Bulgarian cities' expectations to the project outcome. Even though we have avoided the most expensive adaptation projects as cases in this report, several of the examples we have referred to, stem from rather comprehensive projects.

It is also of interest to evaluate whether this collection of adaptation cases represents a good coverage of topics, and a sufficiently broad approach to climate adaptation. Most of the example reviews focus on managing one or a few risks, and thus provide an indication of what climate adaptation to different risks may look like. Some of the examples are far broader than others, cover several risk topics, and also focus on building "institutional resilience", or good governance of climate change adaptation, such as mainstreaming adaptation into city administration. In sum, we would argue that the report provides a relatively broad approach to climate adaptation.

Once more we would like to emphasize the importance of considering several risks and sustainability themes while planning and performing adaptation measures. This in order to avoid conflicts and maladaptation. Several of the shown examples do not prove to cover this perspective in a good manner.

Furthermore, the report paints a good picture of blue-green structures and nature-based solutions. These have great potential to serve their purpose, but can often be even more effective in combination with other adaptation approaches, such as attitude and behaviour changes, and technical solutions. Technical solutions are often expensive, but more basic and affordable solutions do appear in the case descriptions. Several of the examples also include a mix of nature-based, technical and social adaptation measures.

One particular challenge we have come across when putting this report together, is that large parts of the best-case literature is biased in the sense that it conveys an image that is characterized by the perspectives of initiators and financiers. Hence, it can be difficult to find independent assessments that reveal lines of conflict, barriers,

challenges, trade-offs, etc. during the process, or specific organization of the project, description of different actors' roles, methods for inclusion, methods for assessing the effect of individual measures.

Long-term effects of the described measures can be difficult to grasp. This could be explained by lack of long-term focus by the project owners or evaluators, or simply because the implementation took place quite recently, so that long-term effects are still unknown. Information on operating expenses and maintenance costs are hard to find in the available best-practice literature.

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