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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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Content

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 written by Western Norway Research Institute, as a sub-contractor to KS.

We wish 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 the best of luck and hope that this report can be a source of inspiration.

Sogndal (Norway), 25 November 2021

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Summary

Sustainable development has, both as a theory and a political concept, for a long time 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 must deal with all of 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 to minimize conflicts between these objectives. This report focuses primarily on the urgent need to adapt our cities and communities to the adverse effects of climate change, through the presentation of European cities' good practices on climate adaptation, but also stresses 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 cool 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 infrastructure may be challenged by conflicting objectives in urban planning. Collaboration and integration across sectors, institutions, and local communities help overcome 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 equally 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, diminishing 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 can save pot water, improve the micro-climate, and mitigate urban flooding. Increasing water efficiency also reduce CO_2 emissions, and minimize environmental impacts and costs 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 are likely to occur more frequently, which together with more heavy precipitation increases the risk of landslides and erosion. Nature-based solutions – such as flood plains, wetland and woodland restoration – include multiple benefits, although a combination of green and grey measures is often required to ensure a certain safety level. Modelling different flooding scenarios is a good point of departure for identifying solutions related to floods and preventing landslides and erosion. Supplementing such models with local insight into previous or historical flooding events may improve the total 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. Possible impacts on ecosystems from installing physical barriers along riverbanks and shorelines, should be considered.

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 because of climate change. The cities of the world are facing a transition from closed and grey 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 technological experimentation, 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 lie at the core of climate change adaptation, may lead to more favourable living conditions for e.g. mosquitoes, ticks and rats that potentially transmit diseases, but should not be taken as a reason to avoid 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 requires 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 is expected to rise above 70% by 2070. In Bulgaria, cities are already home to more than 70% of the country's population, and by 2050 the urban population will most likely exceed 80%. Despite clearly being 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 current and future risks related to the impacts of climate change.

1.2 How to use the report

This report includes examples of climate adaptation measures carried out in cities across Europe and in other parts of the world. These cases are intended to serve as a source of inspiration and should not be seen as recipes for adapting 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 a matter of concrete physical interventions as a matter of changing one's mindset, day-to-day actions, and traditions. Climate change adaptation is to a great extent culturally conditioned and requires local solutions. A specific approach to reducing water consumption in Burgas will not necessarily be effective in 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 might be applicable to 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, the individual cases described in the report may include measures, processes, methods, or mindsets that can be considered relevant, and that may be built on and adapted to the local context. Furthermore, this report presents only a 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 it is possible to read these reports and web pages using 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) were both pointed out as challenging (5 out of 8). Risks such as 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 coincide 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 consequently, criticism, shortcomings, and inherent conflicts related to the developing and implementation processes are not included. Consequently, some case descriptions (such as the examples from Vitoria-Gasteiz and Zaragoza) are more complete 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 has in many cases been a barrier to supplementary source material.

Table 2 presents a general, rough 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 case headings 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.

	Type of climate risk				
Type of case	**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 the work on climate change adaptation locally	Trnava	Zaragoza	Oslo	Bergen	
Adaptation and mitigation	Vitoria-Gasteiz Trnava	Zaragoza	Oslo	Isola Vicentina	

Case selection

During the kick-off meeting of this project, the representatives of the Bulgarian cities were asked to express their expectations regarding this report, mainly to provide 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? Weather 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 concerning a climate risk, or because they provide 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 relations 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 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 allowing 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 must be treated carefully 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 of Bulgaria. Projections suggests a decrease in precipitation of 15% by 2050, and up to 40% by 2080.

Based on updated AR6 projections, the 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.

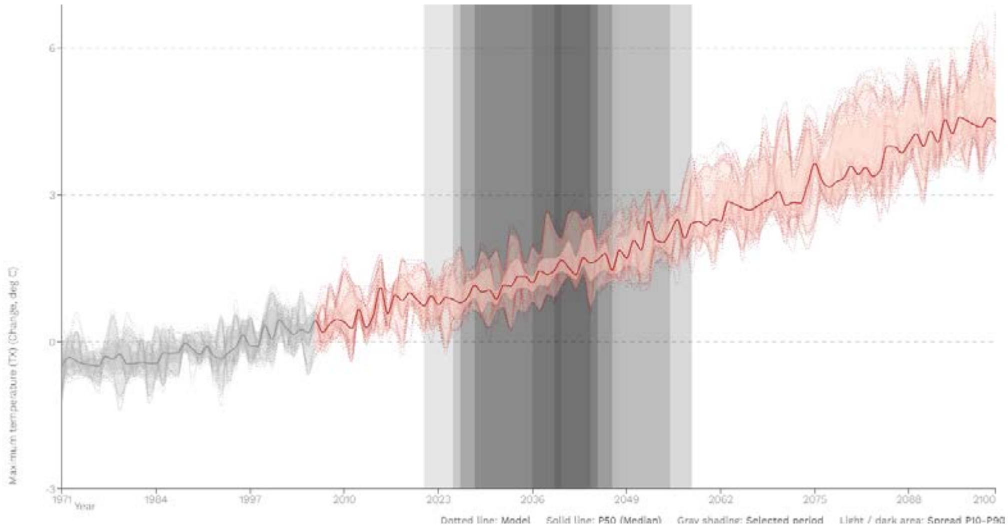

Figure 1. Change in maximum temperature (˚C) in the Mediterranian Europe in a 2 ˚C warming scenario (RCP8.5) throughout this century, based on 46 models (CORDEX Europe). Source: IPCC Interactive Atlas (https://interactive-atlas.ipcc.ch/)

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** as well as great damage in urban environments, whereas people 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 beyond the scope of this report.

2.2 Dimensions of sustainable development

Mitigation[1] and adaptation[2] 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 crises. 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: 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 is not going to become a reality.

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[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.

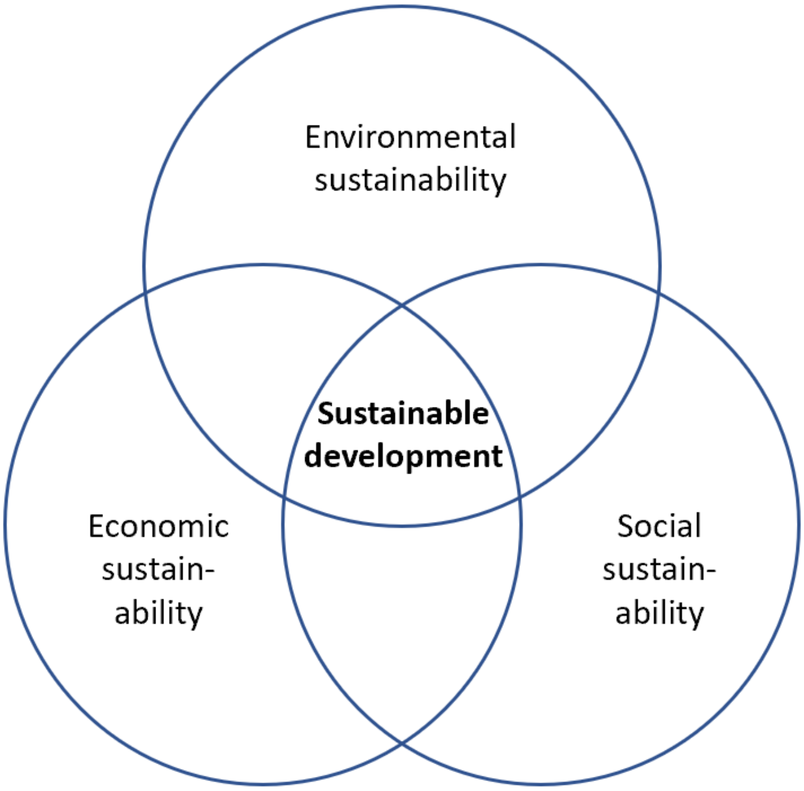

Figure 2. The three dimensions of sustainable development.

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 academic 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 use 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 CO_2 emissions from producing electricity to run the air conditioning units (counteracts climate mitigation). This is also called maladaptation. Conflicting processes that go the other way round, i.e. malmitigation, 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), a mitigation measure aimed at reducing transport volumes is also commonly associated with conflicts, in the sense that urban green areas are developed and sealed, causing a decline in biodiversity and human wellbeing. While it is important to avoid goal conflicts in the fields of climate and environment, it is equally important to strive for synergies between climate adaptation, climate mitigation, and biodiversity conservation. The potential for achieving such synergies will be discussed in greater detail in chapter 8.

3 Urban heat

3.1 Problem description

Rising temperatures due to climate change poses a 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 environments absorbs heat due to its high proportion of dark, impermeable surfaces, such as 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. Therefore, there is an urgent need to cool down cities and densely populated areas.

Measures to reduce urban heat, such as green and blue infrastructure[3] 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 by 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 a long-standing tradition of 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 the general wellbeing 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 patterns and an increase in the risk of flooding (Climate-ADAPT, 2018a). By 2100, maximum temperatures are expected to rise with about 3 degrees during summer, and longer and more severe heatwaves will occur more frequently. An expected increase of 30% in events involving extreme precipitation will further increase the risk of flooding.

To meet these changes there is a need to both improve the quality of, and increase the number of, green spaces throughout the city that can contribute to the reduction of the heat island effect and other heatwave impacts, as well as preventing flooding and increasing 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 natural 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 which 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 restauration, 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 vegetation belts along water streams. The interventions are diverse and span 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 which requires less maintenance and costs. Furthermore, the strategy emphasizes citizens' engagement and initiatives of local transformation activities.

Figure 3. The green infrastructure network. Source: vitoria-gasteiz.org

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, constitute the city's most emblematic interventions (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, cycling and walking lanes, as well as attractive meeting places. It has restored the river corridor along the avenue and increased the amount of vegetation, contributing to the ecological connectivity throughout the city. Great improvements of urban water management have also been carried out, e.g. through the separation of the sewage network to prevent mixing with rainwater, installation of a sustainable urban drainage system for infiltration and purification of stormwaters, and the installation of irrigation systems using rainwater to irrigate vegetation, parks, and community gardens nearby. The avenue has been 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 was finished in 2015 (Vitoria-Gasteiz City Council, 2021). Throughout the construction phase, the utilisation of materials has stressed sustainability, thus life cycle, reuse, and recycling considerations, and the materials selected are characterized by low environmental impact and high thermal inertia. Several measures have been taken to increase the energy efficiency of the building, including the installation of a green façade. The façade with a total surface area of about 1500 m^2 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 were selected to reduce maintenance costs and management. The façade is irrigated by a rainwater collection system on the roof.

The green façade has tripled the insulation level of the building. It further improves the air quality around the building, reduces air pollution, and contributes to carbon sequestration. Green facades create spaces for urban biodiversity and improves the aesthetics and environmental quality of public spaces. Not least, the evapotranspiration of the plants reduces the urban heat island effect[6].

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

Pilot projects of greening the neighbourhoods

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 improved air quality,

[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

improved water management systems that reduce the risk of flooding, improved regulation of the local climate, and mitigation of the heat island effect.

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. There are also numerous vacant spaces owned by the municipality were planned facilities and developments have not taken place, resulting in dirtiness and a neglected appearance. Using the framework provided by the Urban Green Infrastructure strategy, various naturalization interventions have been planned for 50 spaces, including transitory uses of vacant plots, to improve the 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 are now providing shade and evapotranspiration, freshen up the local atmosphere and improve infiltration of rainwater, thus relieving the sewage system.

Another example is the transformation of a 9000 m^2 vacant plot in the Sierra de Andia Street, with 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 area[7].

[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

A participative approach

Communication and public participation are considered critical for the urban green infrastructure strategy to succeed (Environmental Studies Center, 2014). A participative approach was chosen, inviting social groups such as neighbourhood associations, citizens groups, the University, teaching centres, and other groups 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 provide financial support, as well as conducting their own greenery projects on their properties. By involving the public, the likeliness of the green infrastructure to respond to existing objectives and sensibilities is considered high. Some examples of participation mechanisms are workshops and seminars, participative initiatives such as tree planting days or different biodiversity inventories, programmes to support public initiatives in their local communities (e.g. 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 network[8].

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

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

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[8] Ataria Citizen Science https://www.vitoria-gasteiz.org/wb021/was/contenidoAction.do?idioma=en&uid=u25e08f9d_14a56aaea69__7f88

started in the 1990s). The project aimed to get citizens involved in ecological restoration through planting trees in the areas surrounding the city – areas that for years were considered “no man’s-land” and a suitable area for dumping waste. The Green Belt project had for a long time been constrained by 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 contribute both in terms of funding 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 allocates a 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).

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

The focus of the strategy on multiple objectives, outcomes, and 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 overall 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 relates 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 regulate the local climate, and improve the inundation capacity and resilience to flooding. The improved climate change mitigation capacity following increased greenery should not be underestimated either. 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 strengthening biodiversity, and in particular 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-specific, 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 spatial planning processes, is an effective way of making such projects feasible and coherent with other interests.

Further readings

There are a wide range of ongoing programs, projects, and initiatives related to The Urban Green Infrastructure Strategy 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 such as flood prevention, improved water quality of the underlying aquifer, and increased biodiversity. Moreover, the area is now offering possibilities for public use and environmental education.

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

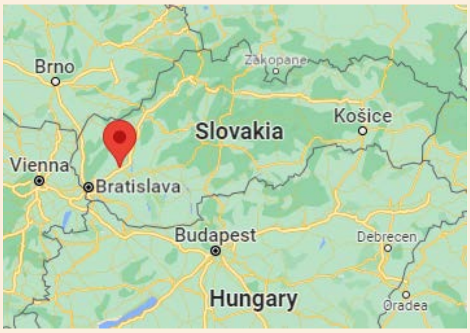
Place name: Trnava, Slovakia

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 Carphatian 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.

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[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-kosice-and-trnava-slovakia

Challenges

With climate change, high temperatures and an increase in the frequency of heatwaves during summer pose increasing risk to citizens of Slovakian cities. A climatological analysis of Trnava reveals a decreasing amount of precipitation whilst temperatures increase during all seasons (Energiaklub and Carphatian Foundation, 2017). Relative to the period 1961-1990, the annual number of summer days with minimum 25 degrees is expected to rise from 58 to 100 and the number of tropical days with a minimum of 30 degrees will rise from 12 to 36. These trends in combination will cause decreased soil moisture and extended drought periods. Trnava is characterized by a high proportion of paved surfaces which exacerbate heat stress during warm periods, leaving the citizens of Trnava 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 ideas about the consequences at the local level. As part of exploring this they attended the international conference "Climate Change and Local Development – Challenge for Local Governments" (Energiaklub and Carphatian Foundation, 2017). Here they acquired 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. 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 the city of Trnava" (Energiaklub and Carphatian Foundation, 2017). In collaboration with city authorities, CDI conducted a comprehensive assessment of vulnerability to high temperatures throughout the city. 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 the 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 Carphatian Foundation, 2017).

Based on the vulnerability assessment, The Adaptation Plan was elaborated by the city authorities with guidance of CDI (Energiaklub and Carphatian 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 Plan[11] aims to reduce the city's 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 Carphatian 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

[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

At city scale, a second example focused on encouragement of citizen engagement in climate 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 Carphatian Foundation, 2017). The adaptation grant applications must follow a detailed set of criteria that ensures that measures are coherent with the city adaptation plan. So far, mainly awareness-raising activities have been granted support.

The vulnerability assessment and the development of the adaptation plan were carried out between 2013 and 2015 (Energiaklub and Carphatian 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 Carphatian 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 Carphatian Foundation, 2017). Moreover, there are struggles to coordinate activities among different government agencies, and 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-today 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 Carphatian 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 Carphatian 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-today 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 to facilitate learning and improvement of both its interventions and processes towards its objectives. Among more, as described in the source material, it may seem to be a 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 that are of relevance and available in English have been found.

3.4 Cross-case learning points and discussion

The overall approach to dealing 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 to focus primarily on biodiversity and nature conservation, where contributions to reduce the urban heat island effect are regarded an important co-benefit. The example of Trnava poses a more direct approach to dealing 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 is a complex process, 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 requires 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 applied in the case of Trnava, thorough assessment and mapping of vulnerability to heat, is however producing a basis for being able to compare the situation before and after the 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 form of assessments is investigation of public opinion on whether measures have led to improved urban environments and well-being during heat periods.

Exposure and vulnerability to urban heat vary among different groups in society and across 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 space 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 increases 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 equally 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. On the one hand, it 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, holds 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, to increase efficiency, water management must prioritize measures to reduce water loss and 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 the 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.

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[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 exceed the capacity of the rainwater drainage system (ICLEI Europe, 2019). The city also experiences increase in 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 take place 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 Change[15] for Wrocław City and a Good Practice Catalogue[16] were prepared to mitigate the risks amplified by climate change (Covenant of Mayors Europe, 2020). Since 2017, Wroclaw 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 the burden on the overloaded municipal sewage system by supporting residents in achieving more efficient rainwater management in their households.

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[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 evoked great interest, and just few days after the release, the council decided to more than double the funding (Covenant of Mayors Europe, 2020). During this first edition in August and September 2019, a total amount of 62 500 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 by far the 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 125 000 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 issued a guide for residents on how to independently install systems for rainwater harvesting[17] (ICLEI Europe, 2019).

As a means to improve the 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 you just let it go down the drain. About 400 residents participated in these workshops in May

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

and June 2019. Also, schools are involved in 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 City of Wroclaw sought to increase local water retention on resident's private properties in different parts of the city. The number of applications exceeded the programme's funding possibilities. Increased retention capacity throughout the city could have been greater if more funding was allocated to the program (Interreg Central Europe, 2020).

The immediate and 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 a 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 programme has been analysed in terms of its effectiveness in harvesting rainwater. The total capacity of the implemented measures of the first edition in 2019 was calculated to 142 m^3 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 mitigating drought and water shortage. Stored rainwater can play a crucial part during dry spells. Also, in the case of heavy rain, systems to collect rainwater contribute 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 an increase in green areas in the city both contribute to improving the 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 people's 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 that are available in English have been identified.

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 the establishment of The Zaragoza 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. Sainctavit, 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

Saving City programme 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 over 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.

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, as seen in several severe situations of drought throughout the last decades, causing water restrictions and public anger. With climate change, 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 shed light on the need for addressing local water management to avoid or tackle similar situations in the future. Zaragoza Municipality collects 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 transhipments – 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 usage – a cheaper, faster, and less contentious approach.

Solutions and implementation

The solutions were multiple and required collaboration between a range of stakeholders (City Council, NGOs, businesses, citizen groups and residents). Through the Municipal Strategic Plan 1996-2010 the municipality decided on 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 programme; (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 Desarollo (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 programme 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 in the media to ensure that all residents were aware of the Water Saving City programme
- 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 for improving water efficiency.

In 2002 the City Council of Zaragoza offered a 10% bill discount to households that reduced their water consumption by at least 40%, followed by a 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, and large families)
- Water bill discounts as an 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 by at least 10% annually
- Penalising excessive consumption through higher prices.

This system has been continued 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 buildings[21]. 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.

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[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

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 stopping the use of drinking water for particular uses, tracking the consumption of big consumers, reducing the use of water in gardens and parks 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 ongoing.

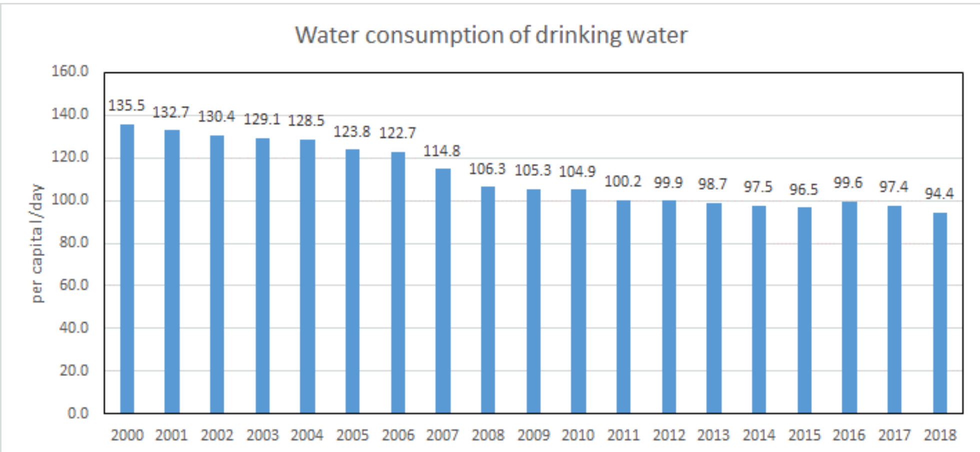

Figure 8. From 2000-2012 water use per capita in households decreased from 135 litres/day to a level below 100 litres/day. Source: City of Zaragoza

Success and limiting factors

The establishment 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-raising campaigns targeted specific sectors and user groups with information and activities that was perceived as directly relevant for their business or lifestyle (Climate-ADAPT, 2016). Also, the campaigns were directed towards all groups in society, ensuring that high-use groups and authorities in charge of water were as committed to improving 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). Since 2008, the economic crisis has resulted in a stabilization of the situation, but larger investments, in particular in the water infrastructure network, have slowed down.

Outcome and lessons learnt

The Water Saving City project has achieved reductions in both water consumption and related energy consumption. Perhaps more important is the emergence 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 related to water. An ongoing campaign called “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 out of the 100 most successful interventions for sustainable urban management (Kayaga et al., 2008). The project serves as an example to follow for other cities seeking to achieve 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 saving efforts by different stakeholders, businesses, and institutions. It outlines the roles of the different stakeholders and in particular the role of NGOs, throughout the different phases of the program to improve the efficiency of the Municipality of Zaragoza's water management. 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 do not represent the complete efforts of the city authorities in dealing 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 on increasing efficiency in the use of existing water supplies that can diminish water demand, and which comes with co-benefits such as reduced CO_2 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 programme 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 for harvesting rain. But every little helps, and a third edition of the programme in 2021 actually broadened the scope to also include 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 further increases the 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 for 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 is 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 of such projects, interventions may be 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 rising temperatures. However, the future climate will be characterized by extremes. Once-in-a-century river floods will occur more frequently in most parts of Europe. Moreover, more intense local precipitation events which trigger pluvial and flash floods, are likely to become more frequent. In coastal zones, sea-level rise will intensify floods. Climate change alters seasonal precipitation patterns and affects the timing of flooding events. Also, activities related to socio-economic development, land use management, and urbanisation processes often take place near 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 as they affect all sectors at a high cost, and afflict poor people the most due to poor housing, often in flood prone areas. In almost all European countries, climate change will increase the share of populations affected and the 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 the risk of flooding. In addition, such solutions can deliver co-benefits like carbon storage, ecosystem conservation, and may have a positive effect on tourism and local employment. Moreover, their implementation often requires broad stakeholder involvement which help raise 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]

[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

Summary

Isola Vicentina Municipality is vulnerable to flooding and erosion, which is likely to be exacerbated by 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 variety of measures to improve water management following the principles of prevention, protection, and preparedness, and includes 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-year floods.

Challenges

The Italian municipality Isola Vicentina is prone to flooding because of 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 increasing the likelihood of more frequent occurrence of both pluvial and river floods.

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 was originally a coordination tool used by the municipality and land reclamation authorities with the objective of developing 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 comprehensive manner, 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 MWMP[24] began in October 2015 and was concluded in June 2016. Over two 3-year 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 were 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. the 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

[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

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: 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 currently undeveloped 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 a flooding event.

Based on existing documents produced by the Italian civil protection service, citizens of Isola Vicentina have received guidelines on what do to before, during, and after a flooding event in their territory. The workshops were also used to spread flood risk awareness and to train people on how to respond in case of an 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).

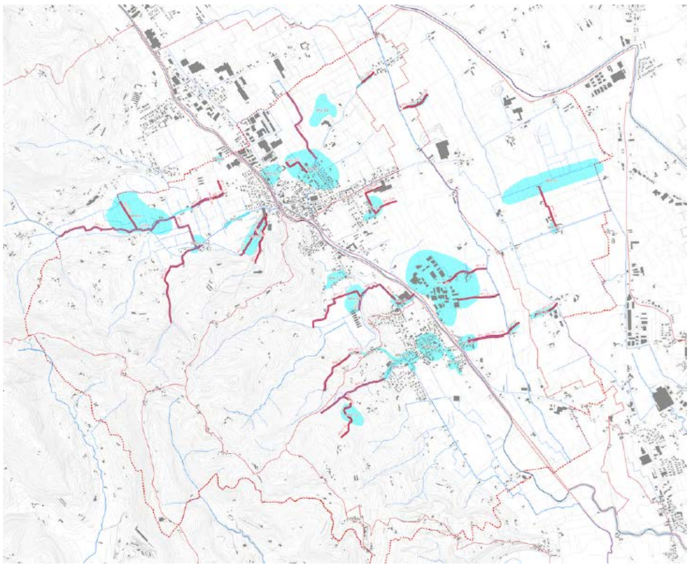

Figure 9. The map shows historically proven flood-prone rivers and areas recognized by the citizens during the public meetings. Source: Green-Dev datasets – Isola Vicentina MWMP

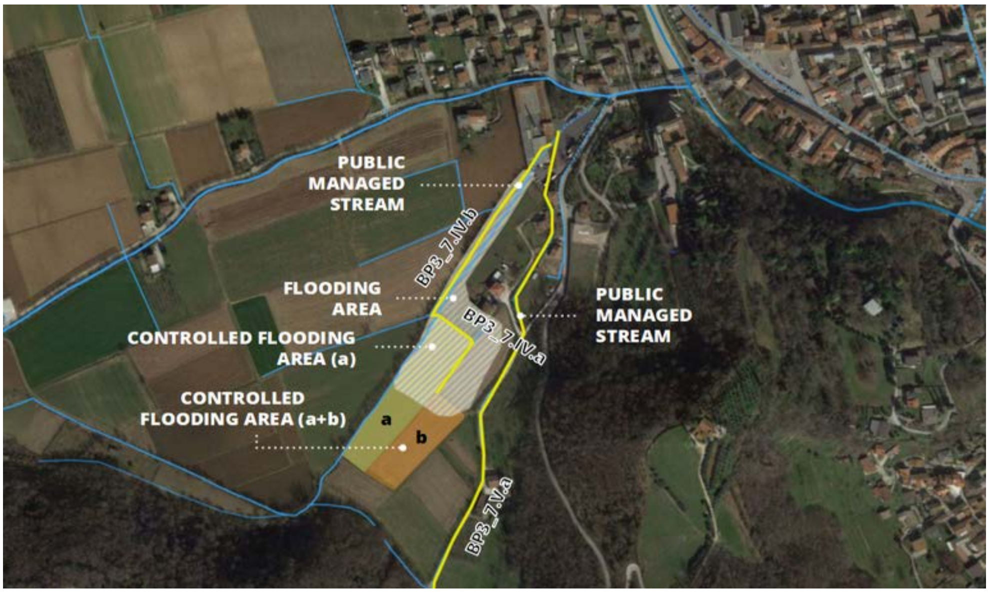

Figure 10. Planned risk reduction measures in a flood-prone area. Source: Green-Dev Studio

According to Climate-ADAPT (2017), the elaboration of the MWMP cost 25 000 Euro. The structural protection measures for 1/100 year 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 flooding event (2010) which caused significant damage to the region, the topic was considered relevant, and the participating citizens were highly motivated (Climate-ADAPT, 2017).

The MWMP is valid within the municipality's boundaries and lacks 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 a 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 the realm of 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 that are available in English have been identified.

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 which also influenced national policy within natural damage prevention.

Challenges

Bergen's topography is partly characterized by steep terrain, which makes certain 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.m. a landslide hit attached houses in the residential area Hatlestad terrasse in Fana, Bergen. Waterlogged soil collapsed down a slope of 30 metres, hitting five apartments (Figure 11). A soup of mud and water penetrated the ground floor of the attached houses, burying ten people. Three of these died and one was seriously injured due to a lack of oxygen.

The soil in Bergen was already saturated with water after several weeks of rain when the remnants of the tropical hurricane Maria crossed the Atlantic, bringing vast amounts of moist air. On the same day as the lethal landslide, a total of 156.5 mm of rain was recorded, the largest daily value ever measured in Bergen. On the night of the landslide in Hatlestad terrasse, a flood developed 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 Centre, a shopping mall, had been built on top of the river. Flooding water flowed underneath the mall, causing a near- collapse. Just two months after these incidents, a new landslide occurred in Åsane, a community north of Bergen city, taking 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 to the test, and the the fatal landslide was subject to colossal attention from the media. 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 effort to prevent 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 hazard themes which became the subject of RVAs in 2006, the mapping of landslide danger zones was the most comprehensive, and also evoked the most attention among the vulnerability topics. 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 the national level. The Norwegian Water Resources and Energy Directorate (NVE) is the national authority in charge of reducing the risk of damages associated with landslides and flooding. After NVE was given the national responsibility for the prevention of landslide risks 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 construction work. Hazard maps have later become important planning tools in all Norwegian municipalities.

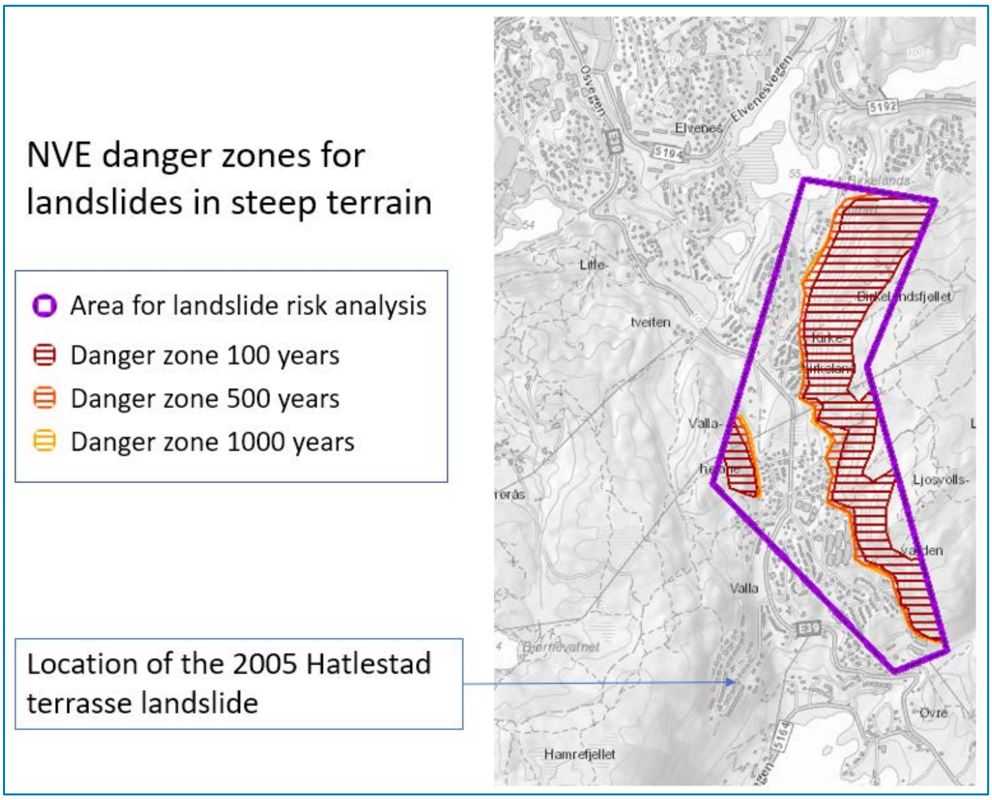

Figure 12. Web-based map displaying danger zones for landslides in steep terrain south of Bergen City. The location of the 2005 landslide accident in Hatlestad terrasse is indicated. Source: temakart.nve.no

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, would automatically trigger a requirement for an RVA. A new principle was also introduced, stating that all new zoning plans must include a framework plan for water and sewage, the purpose of which 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 includes a 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 flooding 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 amalgamated with the city's emerging climate adaptation strategy. 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 buildings and infrastructure. The risk of flooding is expected to increase with climate change and sea-level rise unless the municipality takes measures to adapt. To respond to these challenges, a forecasting and monitoring system was established to be better prepared for future flooding events.

Challenges

Sundsvall is located by the Baltic Sea in central Sweden, with the river Selångersån running through the city. The local climate is expected to become

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[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

both wetter and warmer, with more heavy rain and increased precipitation during autumn and winter, while spring and summer will generally get drier (SMHI, 2017). The risk of flooding, particularly during the wet months, increases 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 and 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 bursting, which would have caused tremendous damage to the city and its inhabitants.

This event sparked an immediate upgrading of the dam and gave rise to a project to adapt Sundsvall city to climate change and reduce the risk of flooding[27].

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.

[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-Slutrapport-Klimats%C3%A4kring-p%C3%A5g%C3%A5r-Klimatanpassa-Sundsvall.pdf

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 of 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.

Figure 13. The river Selångersån wich 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 forecasting 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 negative impact 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 tree different warning classes, following return-periods of 2-10 years, 10-50 years, and 50 years 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 a 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 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 the 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, however, be a number of preventive and protective measures that needed 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 an invitation to co-fund the establishment of 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 achieved, as there is time to implement measures to prevent damage and accidents, such as putting in place temporary flood protection, securing objects, ensuring open and efficient waterways, and evacuating people. Not least, it is more cost-efficient to prevent damage than to repair after the damages have occurred (SMHI, 2017).

For the forecasting 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 by 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 that are available in English have been found.

5.5 Cross-case learning points and discussion

The case of Isola Vicentina encompasses a whole water management plan aimed to deal with flood risk, whereas 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 the totality of local efforts 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 avoiding maladaptation. Some nature-based solutions are highlighted in this chapter, such as flood control zones and woodland restauration in Isola Vicentina. Although such solutions include multiple benefits, flood control interventions generally remain largely dependent on "grey" (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 grey 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 point of departure for identifying 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 as valuable. On the other side, in suburbs 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 restoration of wetlands and forests, is a more biodiversity-friendly way of reducing risk of flooding.

The Bergen case differs from the other two, both because it mainly pertains to landslide hazard, and because 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 prevent erosion. However, adaptation measures to e.g., handle a 100-year flood may perhaps not withstand a 300-year flood, which may in turn erode freely beyond the protection measure first implemented. Hence, detailed assessments of erosion risk in various climate change scenarios should be conducted as a part of planning processes and in work to strengthen flood resilience.

6 Urban flood

6.1 Problem description

Stormwater (also called *surface water*) includes 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 river course, lake, or into the sea. In natural areas that are not developed, the amount of stormwater is small, as the rain either trickles into the soil and becomes ground water, is absorbed by the vegetation (especially in wetlands), evaporates into the air, or is quickly led away through a web of finely branched streams. Through urbanisation, the natural water balance is disturbed, 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 denser cities, which contributes 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 groundwater level becomes lower, which may lead to vegetation drying up, water scarcity, and settlement damage in buildings. Another problem is that surface water can carry environmental toxins, e.g. from road pollution, and in turn causeecosystem and groundwater pollution.

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 neighbourhoods. To achieve these qualities, a long-term strategy and cooperation between many stakeholders is required.

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 during heavy rain, to facilitate a vibrant city where water provides added value in urban development, and to help ensure that clean surface water is led into the city's watercourses.

[28] https://www.oslo.kommune.no/vann-og-avlop/arbeider-pa-vann-og-avlopsnettet/overvannshandtering/

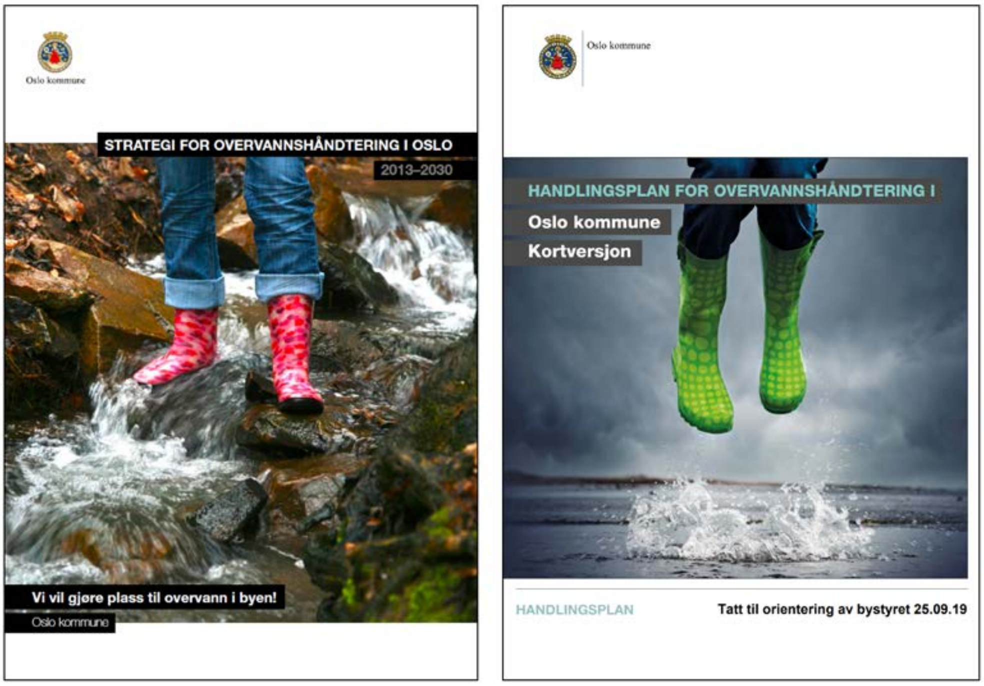

Figure 16. The two main documents on stormwater management adopted by the City Council of Oslo: The stormwater management strategy from 2014 to the left, and the associated action plan from 2019 to the right.

Five years later, an action plan for stormwater management was drawn up, with measures for the period 2019-2024 (Oslo kommune, 2019). The purpose of the action plan is to facilitate a structured, goal-oriented, and comprehensive effort to achieve the goals described 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 key players, and that good solutions should be identified and implemented in the right locations. 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 advice 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 the course of one hour and a total of 72.8 mm in a single day caused major flooding in parts of the city. As the floods only occurred in smaller segments of the city, the extent of the damage was limited. In September 2015, Oslo also saw a lot of precipitation over a longer period, leading 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 hold a sector responsibility for coordinating stormwater management, all municipal agencies, private developers and landowners are obliged 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:

- Build knowledge
- Prevent damage
- Develop model projects
- Collaborate more closely
- Provide better information and guidance

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

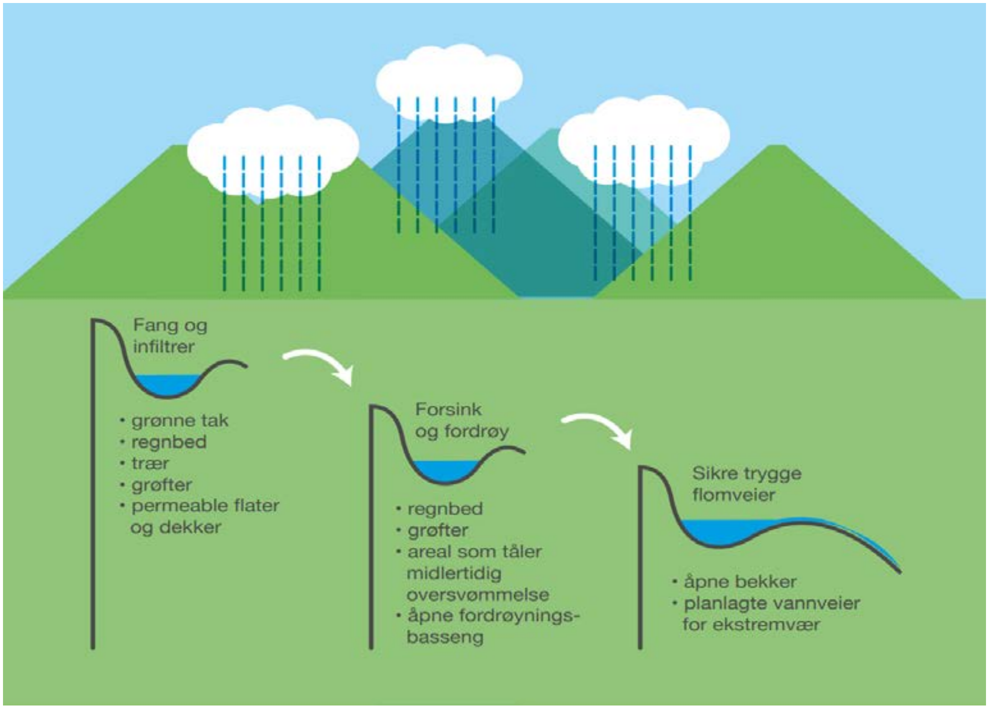

Figure 17. The three-step strategy for stormwater management: Step 1 Capture and infiltrate; Step 2 Delay and retain; Step 3 Ensure safe flood routes. Typical measures shown whith bulletpoints are (1) green roofs, rain gardens, trees, ditches, permeable surfaces and covers; (2) rain gardens, ditches,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

open, multi-functional blue and green structures (step 2), while safe runoff towards 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 a variety of solutions that could be implemented under different conditions and in various parts of the city 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 constructed to collect and retain rain and melting water. Bioretention may serve several purposes, such as preventing urban flooding by reducing runoff volumes and peak flows (and thereby the load on the drainage network downstream), and purifing 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 Municiaplity'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. Provide water and fertilizers and remove weeds until desired vegetation has been established.
9. Maintain the rain garden as needed.

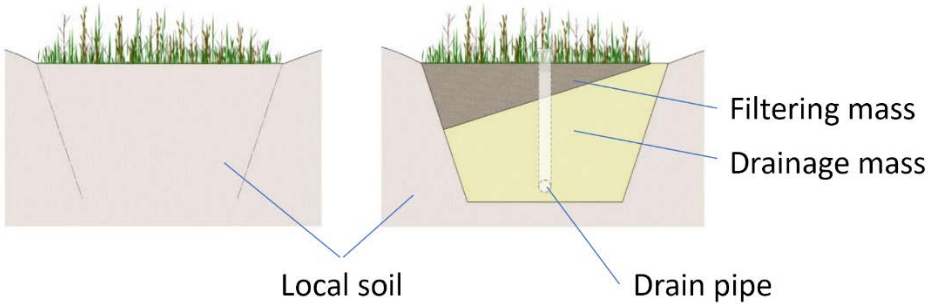

Figure 19. Principle drawing of rain gardens tested in Oslo. When local soil has good infiltration capacity (sandy, well-drained soil), there is no need for drainage mass and drainage pipes. However, the use of filtering mass will be an advantage for the purification of contaminated water, and as a growth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

Rain gardens are associated with notable co-benefits. In addition to their ability to purify polluted stormwater, they increase the biodiversity in the city, and may engage 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 odour 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, demand a high degree of maintenance and can only be placed on new buildings that are constructed to bear considerable weight, usually between 240 and 900 kg/m^2 (roof gardens with trees constitute the heaviest category).

In the following, we describe *extensive green roofs*, which are constructed with a soil layer no thicker than 10 cm, which gives a weight load of 40-130 kg/m^2 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 and it is sufficient to conduct 1-3 annual inspections.

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 regards 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 of less than 30 degrees are preferred.
5. Can the roof withstand the weight of the green roof (including snow load)? Can reinforcements easily be made?
6. Make sure the roof is impermeable before laying a green roof. The surface should be reinforced with a protective root barrier unless the roofing 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, run-off from small rainfall events were kept back by the test roofs, while run-off from 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 drainage 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 is able to delay the run-off, much will be achieved (Braskerud, 2016).

Green roofs have several benefits in addition to urban flood mitigation. They 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 a significantly longer lifespan than regular roofs, provided good moisture sealing. The vegetation catches airborne dust, which improves air quality. Green roofs also contribute to a greener urban environment and increased biodiversity.

Disadvantages include high construction costs, as there is need for inspection and maintenance (as for all gardens), an in case of leakage it is more demanding to locate the source of the problem.

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 during the 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 at the practical "down to earth" level. When new techniques for local stormwater management have been sourced from other countries, testing and adaptation is required for them to work under local conditions. For Norway, it is a particular challenge that climatic conditions differ greatly from countries on the European continent or the USA, from where many of the impulses for technological change have come. 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 dissemination.

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, rising temperatures and increased rainfall as a consequence of climate change may improve the living conditions of arthropod species and is 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 were vector-borne diseases are present relies 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 into great 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 mean that when other conditions are optimal, even modest warming may increase the transmission of malaria. Otherwise, modest warming at relatively high temperatures may decrease transmission. The risk that malaria and other “tropical” diseases could emerge or re-emerge in southern Europe is considered low and rather an expansion of risk due to climate change. However, monitoring should be a priority, and in case of economic downturns, deteriorating 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 include mild winters, heatwaves early in the season, dry springs and summers, and wet autumns. Reproduction of Culex mosquitoes in urban environments are high during dry periods and may lead to the multiplication of viruses 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.

[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

Challenges

The City of South Perth is a peninsular city surrounded by river water. There are several tidal flood plains and wetlands were mosquitoes breed close to residential areas, causing mosquito nuisance in different parts of the city. The Waterford district is particularly afflicted, 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 tidal 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. Combined with sea level rise, this means that mosquito nuisance and potential disease transmissions will continue to pose challenges for the city's 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 2.5-page Mosquito Management Plan covering the aims, control, monitoring, and application of treatments. According to common belief, the mosquito season 2009/2010 was the worst in a long time, and people were unhappy with the city's effort to address 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 constitute an important part of several ecosystems, and due to environmental factors, there will always be times when mosquito numbers exceed levels acceptable to city residents. Therefore, the City of South Perth's Mosquito Management Plan does not aim to entirely remove the problems and 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 the mosquito nuisance for the city's residents. Through community consultation, following principles where 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 was 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 investigating 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 to create an expectation with residents that the city will take action to ensure an acceptable outdoor environment during the mosquito season. Environmental protection is also of high priority alongside mosquito management. Further, the plan facilitates 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 for the season 2020/2021. Officers of the City have 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 programme 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 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 larvae exceed 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 of increase or reduction in mosquito populations, and for monitoring the various 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 on 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 impacts or kills 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 areas 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 states that this criterion 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 will also be responsible for 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, and the assessment is in turn used to make improvements to the plan for the next mosquito season. The residents' 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 afflicted 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 areas.

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 now makes 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 for 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.

Structural 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 Perths' 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 have 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 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 be applicable to the management of other vector-borne diseases and have relevance for control of vectors other 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 be an inevitable solution. This is clearly problematic, as pesticides affect other 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 focuses on mosquito control in wetlands surrounding the city. It also includes 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 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 various diseases (Lõhmus & 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 still water to complete their life cycle. In some cases, draining or filling water ponds may be a solution without compromising the environment. In general, proper design, vegetation control and manipulation of water levels can create less favourable conditions for the larvae as exposure to wave activity and water circulation make it difficult to obtain food. 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 (Lõhmus & 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:

- identify 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.

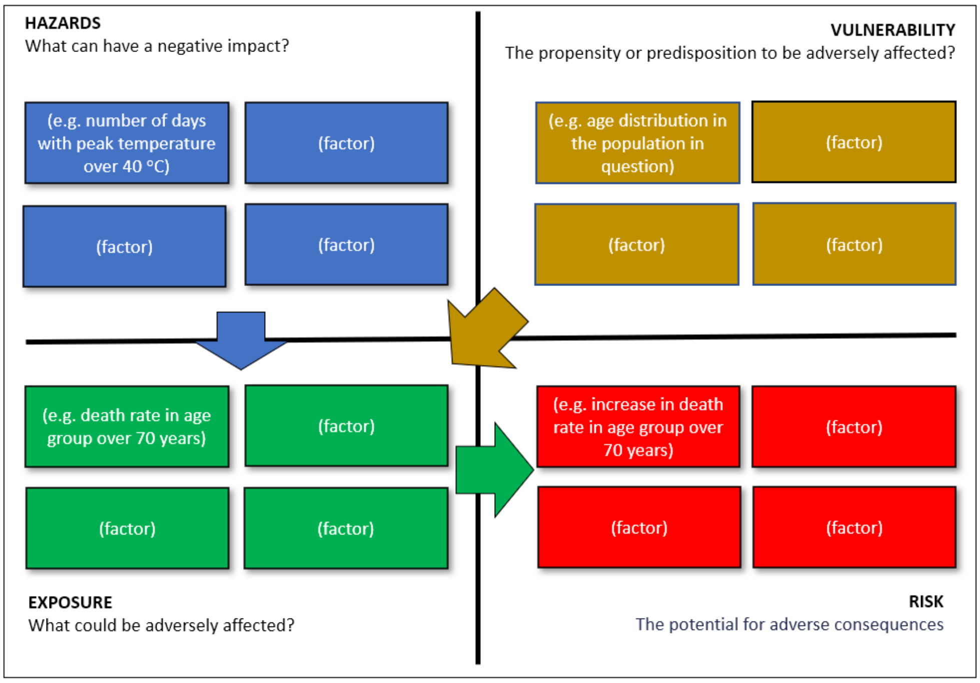

Figure 21. Step 1: Identify factors that determine climate risks.

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 *exposure*, by asking "what could be adversely affected?" The ultimate exposure would be death toll due to excessive heat, which 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 number of factors that predispose 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.

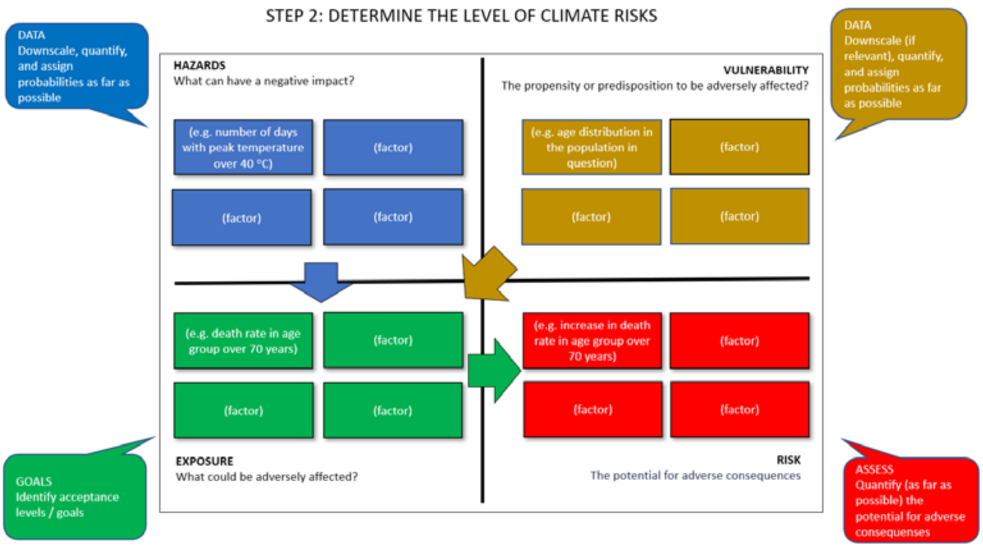

Figure 22. Step 2: Determine the level of climate risks.

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.

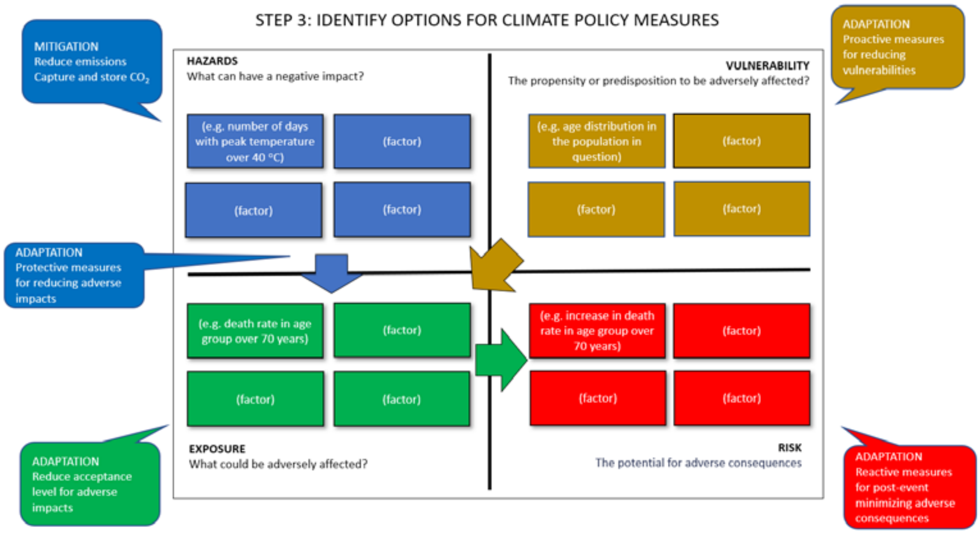

Figure 23. Step 3: Identify options for climate policy measures.

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, an example could be installing air conditioning in existing houses.

In order to reduce the *vulnerability* to urban heat, proactive measures could include planting more trees in the city or establishing green roofs and walls. Also, policies for improving the social and economic status among vulnerable groups, could serve as proactive adaptation measures.

One way of addressing *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 is persistently high.

Reactive adaptation measures that aim to reduce *risk* directly, could be to strengthen the civil protection system, e.g. by improving warning systems or providing 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 (UNFCC) 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 a different pace, 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 change, making 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 means 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 is a 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 shielding and evaporative cooling by tree canopies 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 ecosystem services.

8.4 Combating air pollution and climate emissions - a vital synergy

Cities' efforts to mitigate climate change must happen in accordance 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 pollutants[30], 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 to avoid a global temperature rise of more than 1.5 degrees. However, a 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 public transport in particular; 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 energy efficiency of buildings.

Nature-based solutions to adapt to climate change will have synergies with measures to reduce carbon emissions through carbon sequestration. Furthermore, increased biodiversity, ecosystem connectivity, and vital natural systems capable of delivering ecosystem services will help cleanse 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

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

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 effort to achieve 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'.

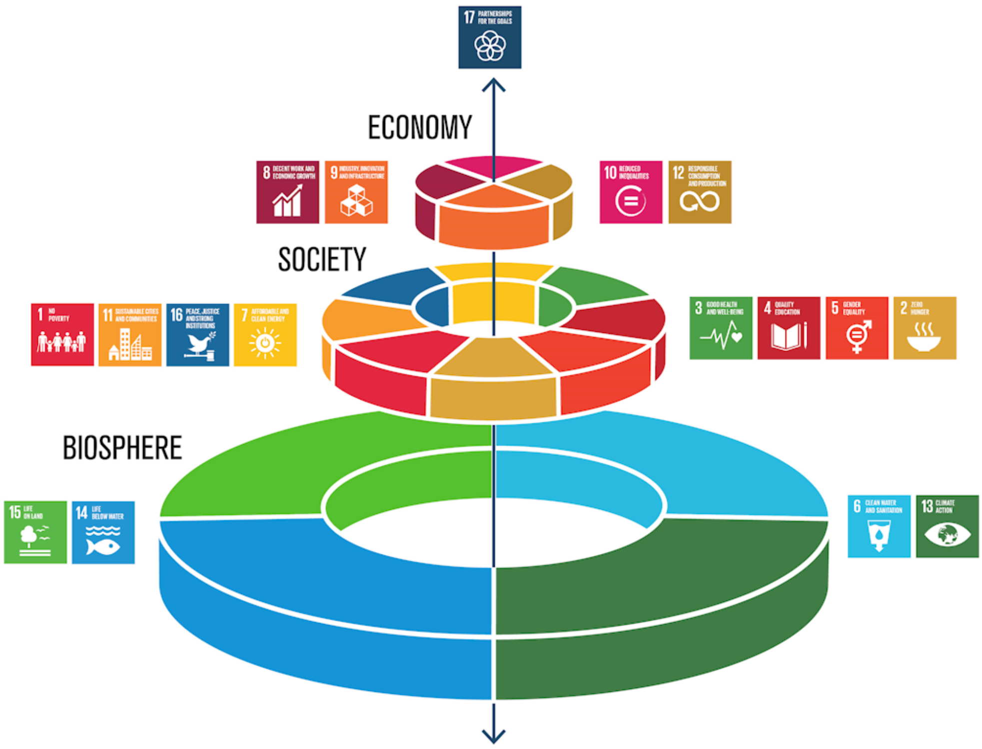

Figure 24. The 'wedding cake diagram' displaying the SDGs across three dimensions of sustainability.

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 what extent this report succeeds in covering the choice of vulnerability themes that have 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 of 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. On 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 as a means 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 a great potential to serve their purpose, but is often 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, and 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 a 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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