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Greening cities: Assessing the implementation of Nature-based Solutions

A comparative case study between Malmö and Malaga

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…and with the writing of this section, my two-year chapter at the IIIEE ends. It has been a fantastic time, full of adventures, experiences and learning, but above all, it has been a time full of wonderful people and good friends. And that, I will always take with me.

It has also been a thesis period of extremes. While in Sweden it was the coldest summer in 155 years, in Spain a heat wave broke the historic temperature record, reaching 47.3 ºC. And if this thesis has shown me something, is how challenging can it be to work in either of those conditions.

I will not mention any names, as it is easy to forget important ones, so I would like to thank the IIIEE, the Sunshine Batch, and everyone who has been involved in any way during the development of this thesis, for making it possible. Thank you.

Abstract

Today, approximately 55% of the total global population lives in urban areas, while in Europe the number is higher than 70%, and both figures are expected to continue growing during the next decades. At the same time, cities are facing an increasing number of challenges, such as sea level rise, increased temperatures, air quality and more extreme weather events. Nature-based Solutions (NbS), although still in its infancy, is a relatively new concept that can harness the power and sophistication of nature to turn environmental, social and economic challenges into innovation opportunities. The aim of this thesis is to estimate the potential impacts of NbS in the cities of Malmö (Sweden) and Malaga (Spain), and study and compare the different mechanisms used for their implementation and use. The thesis uses expert interviews as well as the EKLIPSE framework, a methodological tool used to evaluate NbS initiatives, taking into account their impacts on the triple bottom line and providing a set of indicators and methods for their evaluation. Based on the characteristics of the NbS projects identified in both cities, these solutions are especially effective at tackling challenges in the areas of water management, climate mitigation and adaptation, and urban regeneration. The use of these solutions seems to be driven by their ability to adapt cities to current climates and mitigate the effects of climate change, although some barriers are also identified, such as lack of knowledge of the impacts on the social and economic systems and their effectiveness in the long-term, or lack of political commitment and funding for their application. NbS have potential to address some of the environmental, social and economic problems of cities, but the projects need to be designed with a clear objective in mind in order to be successful, and their effectiveness evaluated through the use of indicators.

Keywords: nature-based solutions, sustainable urban development, urban planning, green and blue infrastructures, green cities

Executive Summary

Problem Definition

Currently, more than 70% of the population in Europe is living in cities, and the number is expected to grow to over 80% by the middle of the century (European Commission, 2015). And according to the Secretariat of the Convention on Biological Diversity (2012), only 40% of the urban areas that are foreseen to exist by 2030 have already been built, suggesting that there will be a significant urban development during the next 10-15 years. Meanwhile, urban areas are facing increasing challenges, such as food security, air quality, water management or an increased risk of natural disaster, as heat waves, flooding, droughts, etc. (European Commission, 2015). This has led cities to focus more on the relationship between sustainability and urban areas, a topic that has been gaining attention during the last few decades.

A relatively new tool to address issues in urban areas and promote sustainability are the so-called Nature-based Solutions (NbS). According to the European Commission (2015), NbS can harness the power and sophistication of nature to turn environmental, social and economic challenges into innovation opportunities. They are usually defined as:

"Solutions to societal challenges that are inspired and supported by nature, which are cost-effective, provide simultaneous environmental, social and economic benefits, and help build resilience Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions" (European Commission, 2016).

But, as a relatively new concept, it is still unclear in many cases what impacts NbS can have on the triple bottom line – environmental, social and economic – or how they compare with more traditional solutions, as well as what the benefits in the long-term are. This research paper has taken the cities of Malaga (Spain), and Malmö (Sweden), using the next research questions as guidance:

1. What are the potential implications of NbS interventions?
2. What are the main similarities and differences in the implementation and use of NbS in Malmö and Malaga?

Methodology

The research follows a Case-Based Research (CBR) approach, and it used site visits, a thorough literature analysis and interviews with experts in the area of NbS in both cities, as methods for data collection. For the analysis, the EKLIPSE framework was selected. The framework was created by a group of experts as an informational tool for the European Commission within the Horizon 2020 Programme. The working group developed a methodological approach to evaluate NbS projects, and it takes into account social, economic and environmental impacts, providing a broad view on the co-production of ecosystem services by the use of NbS in cities.

The EKLIPSE evaluation framework works in five steps: 1) it gives a list of the ten challenges that NbS can address; 2) for each of the ten challenges, it gives a list of potential NbS that can deal with that challenge; 3) for each NbS it gives a list of potential impacts that the action would have; 4) it gives a list of indicators that could be useful to assess those impacts; 5) the framework details specific methods that can be used to measure those indicators.

Key Findings

NbS initiatives being used by Malaga and Malmö have similar potential implications. For both cities, the challenge being addressed the most is water management, followed by climate mitigation and adaptation, and urban regeneration. In both cases, the potential impacts of NbS are aligned with the main environmental issues identified for the cities. In the case of Malaga, water management and flooding, warmer climate and lack of greenery. And for Malmö, increased precipitation and risk of flooding, warmer climate and rise in sea level.

Both cities are using different models of governance and planning, regarding NbS. While Malmö has successfully used NbS projects in many areas of the city to deal with some of their environmental problems, such as flooding (e.g. Augustenborg or Western Harbour), and the concept seems to be embedded in the culture and urban planning, Malaga has still a long way to go. The concept is still at a much earlier stage of development, and at the moment there are isolated examples of NbS, but it is lacking bigger projects that use a myriad of NbS, as in Malmö. The concept is growing fast, and there are new projects involving NbS on the horizon, suggesting that the city is moving in that direction.

There are still a number of barriers hindering the development and use of NbS. Both cities share a lack of knowledge as one of the main ones, regarding what can be achieved with NbS and how to implement these solutions. The rest of the barriers are different in nature, and while Malaga seems to be struggling with the political-side (clashing of NbS with the Urban Development Plans, lack of public participation and public-private collaborations, and little-to-no experimentation), the issues in Malmö have more to do with specific aspects of the design and implementation of NbS (lack of physical space, safety and health concerns in the design and education of citizens for the correct use and maintenance of some NbS). Which, again, clearly illustrates the different stages in which both cities are at this moment.

Conclusions

The concept of NbS is clearly a growing one, with an ever increasing number of research papers and projects addressing its use and development. Many cities are already using the concept as a way to transform their urban space and, at the same time, bring new environmental, social and economic benefits. Additionally, these solutions can also enhance the city's resilience and adaptability to the coming threats of climate change. NbS have proved that they are capable of providing a wide variety of benefits to urban spaces, and with the right design and planning, they can out-compete traditional grey infrastructures. NbS are more effective when they are used jointly in a certain project or area, as they tend to create synergies among them, and their combined effect can bring better benefits. The impacts of an individual NbS project might be very small, but the aggregation of several of them can make a difference.

There is still a need to develop the concept further, and there are several areas that need attention. The main ones identified in this research are: study further the impacts of NbS, especially on the social and economic systems, as well as across different geographic and temporal scales; develop indicators that effectively assess their effectiveness. Indicators that are easy to measure and allow the comparison of different projects; find new models for community engagement and education of citizens; study the possible negative effects of NbS, such as gentrification or ecosystem disservices, and ways to either minimize their effects, or, if possible, completely remove them.

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Abbreviations

BUM – Bosque Urbano de Malaga (Urban Forest of Malaga)

CBA – Cost-Benefit Analysis

EC – European Commission

EU – European Union

FR – Front-Runner

GBI – Green and Blue Infrastructure

GIS – Geographic Information System

IPCC – International Panel on Climate Change

IUCN – International Union for Conservation of Nature

NbS – Nature-based Solutions

OMAU – Observatorio de Medio Ambiente Urbano (Urban Sustainability Observatory)

RQ – Research Question

SDGs – Sustainable Development Goals

SUDS – Sustainable Urban Drainage Systems

UN – United Nations

WHO – World Health Organization

WP – Work Packages

WTP - Willingness to Pay

1 Introduction

Currently, more than 70% of the population in Europe is living in cities, and this number is expected to grow to over 80% by the middle of the century (European Commission, 2015). And according to the Secretariat of the Convention on Biological Diversity (2012), it is estimated that only 40% of the urban areas that are foreseen to exist by 2030 have already been built, suggesting that there will be a significant urban development during the next 10-15 years. Meanwhile, urban areas are facing increasing challenges, such as food security, air quality, water management or an increased risk of natural disaster, as heat waves, flooding, droughts, etc. (EC, 2015). Also, as a great number of cities are located in the coastline, the risk of sea level rise due to climate change and/or storm surges represents another threat (EC, 2015). On later years, cities have started to focus more on the relationship between sustainability and urban areas, a topic that has been gaining increasing attention during the last few decades (McCormick et al., 2013).

While urban areas are facing many challenges, they also show great potential to be home to new solutions. A relatively new concept to address issues in urban areas and promote sustainability are the so-called Nature-based Solutions (NbS). According to the European Commission (2015), NbS harness the power and sophistication of nature to turn environmental, social and economic challenges into innovation opportunities. They are usually defined as:

"*Solutions to societal challenges that are inspired and supported by nature, which are cost-effective, provide simultaneous environmental, social and economic benefits, and help build resilience*" (European Commission, 2016)

Typical examples of NbS would be green roofs and walls, parks and green spaces, blue infrastructures like dams or lakes, etc. They are presented as solutions that can decrease the vulnerability of cities and enhance their resilience, mitigation and adaptation in light of climate change (Raymond et al., 2017; Kabisch et al., 2015; EC, 2015; World Bank, 2008).

As a fairly recent concept which covers a wide range of different techniques and applications, NbS have been addressed in the literature using several names, although the term NbS is gaining traction, especially since the European Commission adopted it in recent years. Some of the most common terms used before were 'green and blue infrastructures', 'ecosystem-based adaptation', 'ecosystem-based disaster risk reduction' and 'natural water retention measures'. But, whilst a myriad of concepts similar to NbS exist, most of the time they have overlaps, and they tend to be complementary with one another (Nesshöver, 2016; Barton, 2016) since they are usually dealing with similar issues.

Although NbS are showing great potential in being energy and resource efficient, the concept needs to be further developed and discussed to determine its added value and effectiveness to achieve the benefits it claims to bring (Nesshöver et al., 2016; Kabisch et al., 2016). Furthermore, NbS must be adapted to local conditions in order to be successful (Raymond et al., 2017), and there are still knowledge gaps and lack of experience on their application and effectiveness under different contexts and circumstances, which makes them difficult to apply and evaluate (Barton, 2016). To address some of these shortcomings, the EU is pushing the research and application of NbS in Europe, to consolidate the term, and aiming to become a leader in Research and Innovation in the growing market of NbS (EC, 2015). Through its Framework for Research and Innovation, Horizon 2020, the EU is promoting its investigation and development, to expand the knowledge on the potential transferability and upscaling of these solutions.

As was previously mentioned, there are some uncertainties about the effectiveness of these solutions, although there is a growing number of studies trying to assess it. One of them was carried out by Zölch et al. (2017), and it studied the effects of trees and green roofs in reducing the volume of surface runoff from stormwater in a high-density residential area of blocks in Munich, Germany. Surface runoff stormwater pollutes water systems by picking up pollutants such as fertilizers, oil and pesticides, and increases the amount of water cities have to deal with, creating flooding issues when the volume is too high. The study concluded that the current greenery in the area was achieving a reduction of 2.4% compared to the baseline scenario without any vegetation, and the surface runoff could be significantly increased to 14.8% by greening all roof surfaces in the area, without applying any other measure.

This study aims to join this dynamic and continue increasing the knowledge on the application and use of NbS.

1.1 Problem Definition

As the concept of NbS is still in a relatively early stage of development, there are many ongoing research papers working on its definition and assessment, and thus, there are still many research gaps.

From a practical point of view, city planners and decision makers need more information about under which circumstances and situations NbS can be effectively applied, and what issues can be tackled with their use, as well as what the main drivers and barriers for their application are (Nesshöver et al., 2016). For this purpose, sharing of knowledge and experiences from different actors and projects is especially important to accelerate the process (EC, 2015).

From a research viewpoint, there is an increasing interest in the concept, and NbS have been identified as a priority area for investment and research under Horizon 2020. But, as a relatively new concept, it is still unclear in many cases what the impacts NbS can have on the triple bottom line – environmental, social and economic - or how they compare with more traditional solutions, as well as what the benefits in the long-term are (Kabisch et al., 2015, EC, 2015).

The aim of this research was twofold. First, to identify what NbS initiatives had been implemented in the cities of Malmö (Sweden), and Malaga (Spain), and analyse and compare their potential implications on the environmental, social and economic spheres. And second, to compare both cases in terms of implementation and use of NbS, with special attention to the drivers and barriers, which either support or hinder the use of these solutions.

1.2 Scope

The study focuses on the cities of Malmö and Malaga. With a population of approximately 350.000 inhabitants, Malmö is the third biggest city in Sweden, and it has gained an international reputation for their considerable efforts toward sustainable development in recent years (Austin, 2013). The administration of Malmö has actively been using the concept of NbS in its urban planning to face some of these challenges during recent years, especially in areas such as Augustenborg Eco-City or the Western Harbour (City of Malmö, 2014).

The second case, Malaga is bigger, with a population close to 600.000 inhabitants, and although it shares some of the environmental concerns of Malmö, they seem to be much less embedded in its urban development plans. Nonetheless, the city started to pay increased attention to its environmental issues starting in 1995, and nowadays there seems to be an increased attention to the use and application of NbS projects. This begs the question of why a comparison of both cities is a relevant exercise.

In many aspects, Malmö and Malaga are facing very similar challenges susceptible of being tackled with the use of NbS. First of all, as coastal cities, both are sensitive to sea level rises, and NbS could be potentially used for this purpose. Secondly, both cities are struggling with water management, though in different ways: in the case of Malmö, storm water management has been an issue for years, and they have been suffering flooding events throughout the city in recent years, making it one of the main environmental issues. In the case of Malaga, water management is also an issue, and although flooding from storm water is occasionally an issue too, lack of water is a recurring problem. Lastly, both cities have expressed their concerns about increased temperatures as a result of climate change, an issue that Malaga, with an annual average temperature of 18.4 ºC (10 ºC more than Malmö), is already experiencing.

These factors make both cities as interesting case-studies to analyse and compare the use of NbS initiatives and how they can help them tackle their environmental, social and economic issues.

1.3 Research Questions

This research has been guided using the following questions:

Table 1-1: Research questions

Research Question
RQ1: What are the potential implications of NbS interventions? *Sub-questions* - What environmental, economic or social impacts can these solutions bringing? - Are those impacts in line with the environmental problems that the cities are facing?
RQ2: What are the main similarities and differences in the implementation and use of NbS in Malmö and Malaga? *Sub-questions* - What governance models are the cities using to use and apply NbS? - What drivers and barriers are the cities facing regarding the use of NbS? - How do the drivers and barriers compare?

In order to be able to answer the research questions, the following steps were taken:

First, as a relatively new concept, there is not a universally accepted definition for it yet. In some occasions, the concept is being used but under a different name, and databases that collect the use of these solutions do not exist, as far as this study was concerned. Thus, a first step required to identify what specific NbS had been used in both cities.

Second, the study identified the main environmental issues for both cities, and then, it focused on analysing why the identified NbS were used and what potential implications could these solutions have on the cities. By implications, this research means on which challenge areas these solutions show a greater potential to have a positive impact (e.g. water management, air quality, creation of green jobs, etc.). For more information, please refer to *Chapter 2.3*. But it is worth noting that this research has not conducted an impact assessment analysis, therefore impacts are not measured in this study. The thesis also compared if there is a match between the main environmental issues and the impacts that NbS can potentially bring to both cities, to analyse if NbS are being used to address the issues or not.

Third, a comparison to determine how both cities were implementing and using the concept of NbS was deemed relevant, considering how different their models for governance and planning were, and identifying and comparing the main drivers and barriers for the application and use of these solutions.

1.4 Limitations

A number of limiting factors were identified during the development of this thesis.

Firstly, there were some discrepancies in the literature about which specific measures should be included as NbS and which should not (for a more thorough explanation on this please refer to *Chapter 3*). Also, the concept of NbS was found to be widely accepted and used in Malmö, but not so much in Malaga. Even though the latter was also applying and using similar solutions in many cases, they were referred using a different name, or no specific name at all, thus, it was harder to identify initiatives that fit the criteria.

Secondly, language was also a limiting factor, especially for the study of Malmö, due to the author not speaking the predominant language of the country, Swedish. Some of the documents used from the Municipality were available only in Swedish, thus translations to English were needed in order to understand the content, which leaves room for misinterpretation and/or possible mistakes in translation. Also, this limits the ability to find relevant material, as keywords for searches were predominantly made in English, not being able to access results in Swedish.

Thirdly, the research could conduct only a limited number of interviews, eight. A higher number of interviews could have maybe provided with more insights and new information to the thesis. Also, the distribution of the interviews in both cities was not even, and while interviewees in Malmö worked mainly for the Municipality as city planners, most of the interviewees in Malaga were academics. A more even distribution could have been beneficial for the results, bringing different perspectives together, but unfortunately it was not possible for the development of this work.

1.5 Audience

The intended target audience is researchers, city planners and policy makers that are working with the concept of NbS and want to understand more about their applicability and transferability. More specifically for those working in the cities of Malaga and Malmö, but also for other urban planners interested and researchers interested in making use of these solutions in their urban context. By analysing and comparing the use of NbS on both cities, this research intends to help better understand the concept of NbS as a whole, strengthening its use and application and helping cities bring new sustainable solutions to their agenda.

1.6 Ethical Considerations

The thesis has been written and developed by the author, independently of any external organization, and due diligence regarding the ethical implications of the research has been maintained. Qualitative information collected through interviews with experts was analysed to the best of the author's abilities, expressing the questions as neutral as possible during the interview. Permission was always asked to record the conversations before starting the interviews, and the recordings were used purely for academic purposes and were not shared with third parties. Also, permission was asked to list the names and positions of the interviewees. Furthermore, the author was well aware and concerned with maintaining academic integrity during the writing process, with special attention to the scrupulous avoidance of plagiarism.

1.7 Disposition

The outline of the thesis is as follows:

Chapter 1 presents the nature of the problems of urban development at its current state and explains why there is a need for new solutions to tackle the issues associated with climate change in the urban context. The section also puts the research in perspective within the NbS literature, addressing why this specific research is relevant and what it brings to the knowledge of NbS. The chapter then identifies research limitations and provides a description of the intended audience, ethical considerations, as well as an outline for the chapters of the thesis.

In Chapter 2, a more thorough analysis of the immediate field of study is presented in the way of a literature review. The concept of NbS is defined and discussed from its origin, introducing related terms as well as the main research gaps in the field.

Chapter 3 outlines the theoretical framework and methodology of the research, including the method and framework used to obtain the information and analyse it.

Chapter 4 presents the main findings, describing the NbS that were found in each city, as well as the main drivers and barriers for their implementation.

Chapter 5 presents the analysis and discussion. In this chapter, the information collected in the findings is analysed and discussed. The potential impacts of the NbS initiatives are identified and compared. The different models of governance and planning are also identified and compared, and the chapter ends with the analysis and discussion of the main drivers and barriers for the implementation and use of NbS in both cities.

Chapter 6 presents the main conclusions of the thesis. It summarizes the key findings and links them to the original research questions. The section also reflects on the framework used during the analysis, and it ends with suggestions for future research.

2 Methodology

This section develops the type of research that the thesis has followed, as well as the methods used for data collection and data analysis.

2.1 Case Study Research

To better understand the use of NbS in Malmö and Malaga and be able to compare them, an in-depth study was considered the most suitable option for this research, and consequently, a Case-Based Research (CBR) was chosen.

6 and Bellamy (2013: Chapter 7), define case study research as:

"The classic 'case study' design, by which we mean the study in considerable depth, and as comprehensively as possible, of a single case (N = 1) or a few cases (small-N research)"

As opposed to other research methods such as Variable-Oriented Research (VOR), which focuses on discrete factors and looks for their independent contributions, CBR puts the focus on the interactions between factors rather than in their individual contributions, thus creating a more holistic view of the issue at hand (6 and Bellamy, 2013). For Postchin et al., (2015, p. 4), case studies in the area of NbS are a key method of research, since they have the opportunity to highlight how NbS have been applied to a particular situation and enrich the debate on the clarification of a concept with place-based examples.

Case selection is a fundamental issue when using CBR, especially if the author intends to use the case study to reflect on a larger population of cases (Elman et al., 2016). By contrast, if the author's intention is not to reflect on a larger set of cases, but rather explain the case – or cases - under study in detail, the process is simpler, and the cases are selected solely by virtue of their intrinsic value (Elman et al., 2016). This research follows the latter approach, and it intends to advance the theory of NbS by applying the existing body of knowledge to study the use of NbS in the cities of Malmö and Malaga, and see if theory on NbS matches what is actually observed in practice. A more in-depth explanation on why the cases were selected can be found in *Chapter 1.2*.

2.2 Methods for data collection

Different methods and sources of information were used in order to create valid results for the research. Most of the data collected was through site visits, a literature analysis and the interviews with experts.

2.2.1 Site visits

Site visits were arranged for both Malmö and Malaga, to collect information in-situ and meet with the experts, as well as to have a closer look at the situation of NbS in the cities. This allowed the researcher to meet directly with some of the experts and to examine in person some of the NbS initiatives. This allowed the researcher to have a deeper understanding of the situation involving NbS in both cities.

2.2.2 Literature Analysis

The literature analysis consisted of two different parts:

First, a thorough literature review was carried out, including scientific papers and grey literature on the concept of Nature-based Solutions (NbS). Related terms, such as Green and Blue

Infrastructure (GBI) or Ecosystem-Based Adaptations were also included. The objective of this method was threefold: first, to fully understand the concept of NbS and how it has evolved over time; second, to analyse what the best practices in the development and application of NbS in cities are; third, to inspect what frameworks and criteria were being used by different authors in the area of NbS.

Second, a more specific search was made for both cities, with regards to research question 1 (RQ1), to review their application and use of NbS. For that purpose, the sustainable development plans for the two cities – Malmö and Malaga– were analysed, as well as other relevant literature. In the case of Malmö, only some the information was available in English, with the majority of the documents being only available in Swedish. Therefore translation using an online translation tool was needed. This literature analysis included NbS initiatives that had already been carried out as well as other NbS actions that were planned for the near future. Scientific studies regarding the application of NbS on the cities were also used when they were available. Furthermore, the search included also news and articles from the grey literature on the specific use of NbS in the cities.

2.2.3 Expert Interviews

Expert interviews were the main source of primary data collection during the research. The profile of the interview candidates was people who had worked or were working directly with the concept of NbS in any of the two cities, and it included people from different backgrounds and sectors, with the intention of bringing more holistic view. A list of all the interviewees can be found in Appendix I. Interviews List.

A total of 16 potential interviews candidates were contacted by e-mail between April and August. Eventually, 8 interviews were held between the 12th of June and the 16th of August, including personal interviews as well as Skype and phone interviews, when it was not possible to meet in person. First, a small group of potential interviewees was contacted, and then these interviewees were asked for recommendations for others to speak to, the so-called 'snowball sampling'.

In order to ease the conversation with the experts, a semi-structured interview guide was developed (see Appendix II. Interview Guide). This allowed the researcher more freedom to adapt the questions to the interviewee's expertise in certain areas and to explore certain topics that would arise during the natural flow of the conversation. The interview guide contained 10 questions, and for its development feedback from the thesis supervisor was incorporated, including the use of previous interview guides that had been used in the development of similar projects in the past.

The interviews were carried out in English and Spanish, and they lasted from 15 to 88 minutes. Upon prior consent, the interviews were recorded and then the relevant sections were transcribed, maintaining the anonymity of the interviewee when that desire was expressed. In addition, notes were taken during the interviews to oversee that all questions had been answered and to facilitate follow-up questions during the interviews.

2.3 Method for data analysis

The framework used to analyse the information gathered was the one developed by Raymond *et al.* (2017) in an expert working group called EKLIPSE. The framework is an impact evaluation tool to support planning and evaluation of NbS projects. It was created as an informational tool for the European Commission within the Horizon 2020 Programme. They developed a methodological approach to evaluate NbS projects. An overview can be found in Figure 2-1.

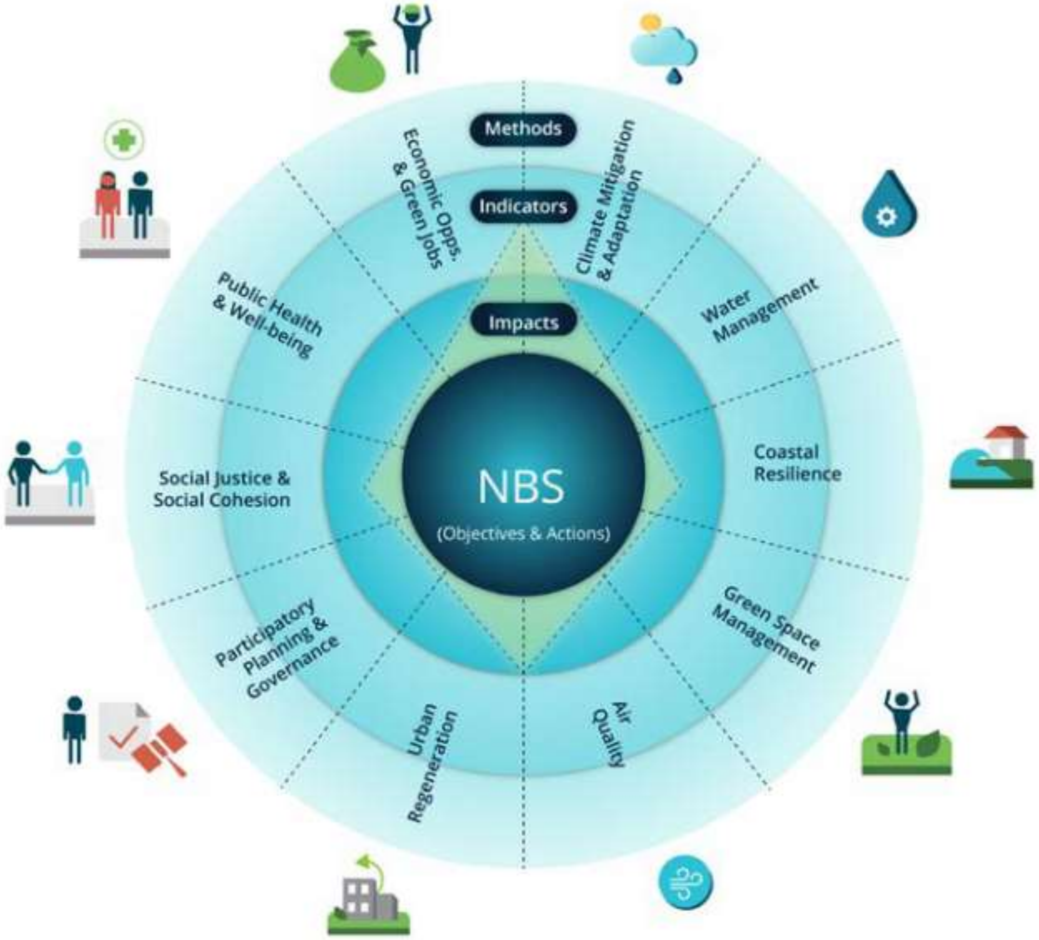

Figure 2-1: Overview of the EKLIPSE Framework

Source: Raymond et al. (2017)

The evaluation framework works in five steps: 1) it gives a list of the ten challenges the framework focuses on; 2) for each of the ten challenges, it gives a list of potential NbS that can deal with that challenge; 3) for each NbS it gives a list of potential impacts that the action would have; 4) it gives a list of indicators that could be useful to assess those impacts; 5) the framework details specific methods that can be used to measure those indicators. A detailed example of the process can be found in Figure 2-2.

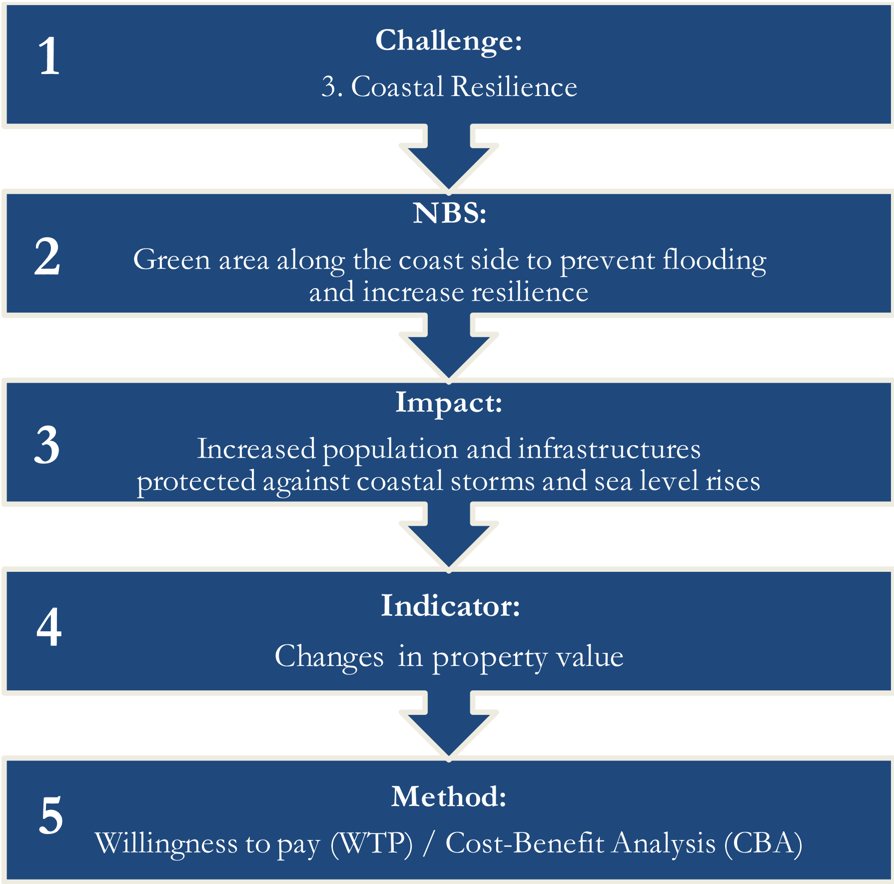

Figure 2-2: Example of how the Framework works

Source: Own elaboration

It is important to note that the framework also considers the socio-ecological context in which NbS are embedded, while more traditional frameworks dealing with ecosystem service assessments, such as the Mapping and Assessment of Ecosystems and their Services framework (MAES) (Maes et al., 2013), focus mainly on the ecosystem services and their benefit to humans, measured usually through their biophysical or monetary values (European Commission, 2013; 2014). The framework proposed by Raymond et al. takes into account social, economic and environmental impacts, providing a broader view on the co-production of ecosystem services by the use of NbS in cities.

Table 2-2 shows the list of ten challenges identified in the framework:

Table 2-1: The 10 climate resilience challenges considered in the impact assessment framework

#	*Challenge*
1	Climate mitigation and adaptation
2	Water management
3	Coastal resilience
4	Green space management (including enhancing/conserving urban biodiversity)
5	Air/ambient quality
6	Urban regeneration
7	Participatory planning and governance
8	Social justice and social cohesion
9	Public health and well-being
10	Potential for new economic opportunities and green jobs

Source: Raymond et al. (2017)

It is also worth noting how the challenges are linked with each other, and they present opportunities for co-benefits and potential negative impacts or disservices. For example, carbon sequestration will have an impact on climate mitigation, but also on air quality or public health and well-being. In contrast, increases in property prices as a result of the improvement of an area and creation of new economic opportunities may affect negatively social justice and social cohesion, as it could create gentrification. For a complete list of potential co-benefits and negative impacts please see Appendix III. Potential co-benefits and negative impacts across the challenges.

This thesis has used the information embedded in those ten categories to analyse the NbS used in Malaga and Malmö, and then, assess which challenge areas are being addressed the most by the NbS initiatives, and which ones have less NbS projects potentially impacting them. This creates a rank of challenges for each city (e.g. can the NbS used in Malaga have an impact on water management? Can they improve air quality? Can they create green jobs? Etc.). This way, it is possible to have an overview of what the potential impacts that NbS actions can have on each of the cities are. As this thesis does not perform any kind of impact assessment study, the actual impacts are not calculated. Therefore, the results only show which challenge areas have more – and less - NbS initiatives dealing with them, but they should not be taken as actual impacts, since those could not be measured. The results are presented in *Chapter 5*.

3 Literature review

The Nature-based Solutions (NbS) term was first introduced to scientific literature in the early 2000s, as a way to provide solutions to agricultural problems (Postchin et al., 2015). Soon after that, the concept started to expand to other areas such as land-use and water resource management, even reaching the area of industrial design (Postchin et al., 2015). In recent years, the concept has gained increased attention, especially in the area of sustainable urban development, and has been developed by the European Commission and other organizations, such as the International Union for Conservation of Nature (IUCN) (Cohen-Shacham et al., 2016).

3.1 Origin of the concept

As a relatively new concept, NbS are not yet completely established in the scientific literature, although researchers have been working for a long time with similar concepts such as 'ecological restoration', 'green and blue infrastructures (GBI)', 'ecological engineering', 'ecosystem approaches', 'ecosystem-based management', as well as various area-based conservation approaches (Cohen-Shacham et al., 2016). However, the concepts are clearly linked, and even if they are not referring exactly to the same concept, they can sometimes complement one another (Balian et al., 2014). For example, GBI could be considered to be part of NbS, and NbS could also be used to develop adequate GBI (Balian et al., 2014).

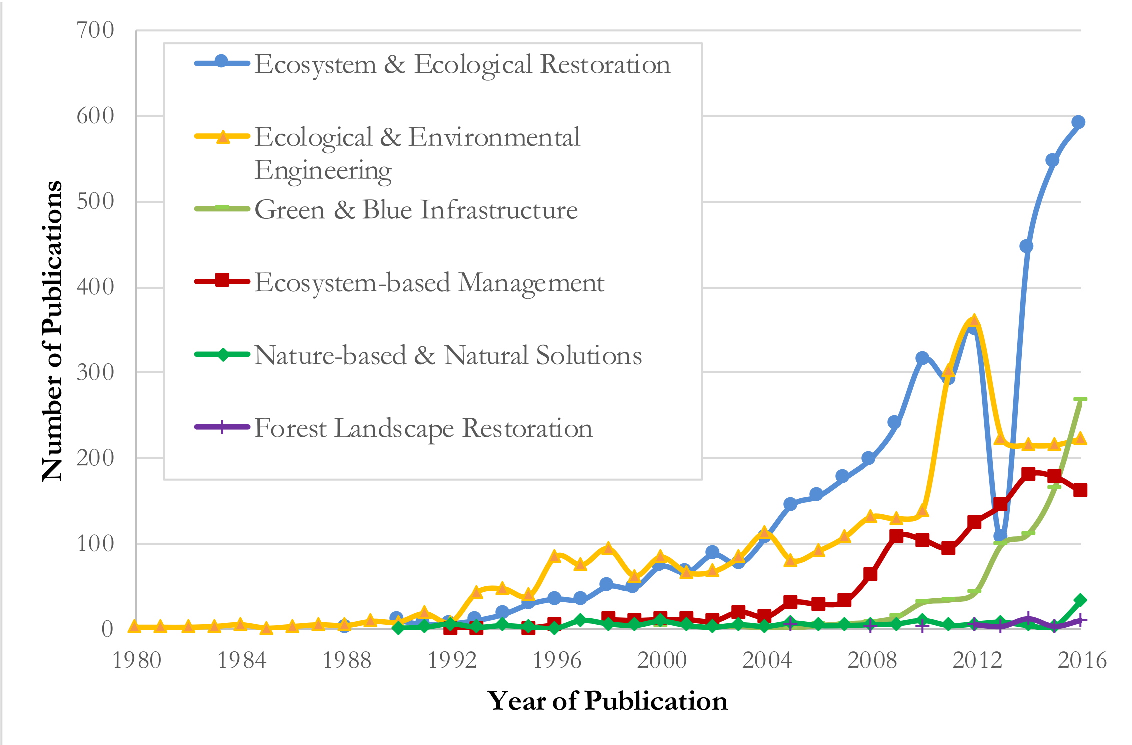

Figure 3-1: Trends in number of research papers mentioning NbS approaches during the period 1980-2016

Source: Own elaboration. Information obtained from 'Web of Science – https://webofknowledge.com'

Figure 3-1 shows the evolution of NbS approaches over time. The recognition of the fundamental role that ecosystems play in assisting and supporting human well-being has been part of traditional knowledge systems for centuries, but it was not until the 1970s that those ideas started to be established in the modern scientific literature (Cohen-Shacham et al., 2016). During the 1990s different terms started to be used in literature, in an attempt to document and better understand the relationship between societies and nature. During the 2000s, the term 'Nature-based Solutions' emerged, and brought in a new perspective: protecting, managing and restoring natural ecosystems was not seen as something that could just bring passive benefits for society, but it was considered rather as a tool with potential to strongly contribute to addressing major environmental, social and economic challenges (Cohen-Shacham et al., 2016).

The concept continued its development, and from the mid-2000s, it started to be used also in industrial design, with the concept of 'biomimicry'. Biomimicry refers to innovative and sustainable solutions to human challenges that emulate nature's strategies and patterns (Biomimicry Institute, n.d.). Just to mention an example, authors such as Singh et al., (2007), focused their study on researching materials that mimicked the hydrophobic and sliding properties of water-repellent leaves to solve issues of erosion and friction in automated systems.

Organisations such as IUCN and the World Bank started to look at ecosystems as potential partners to bring new solutions to adapt and reduce the effects of climate change, rather than having to rely on conventional engineering solutions, such as extensive sewage systems to deal with stormwater, or sea walls (Mittermeier et al., 2008). Figure 3-2 shows a timeline of the main events in the development of the concept of NbS.

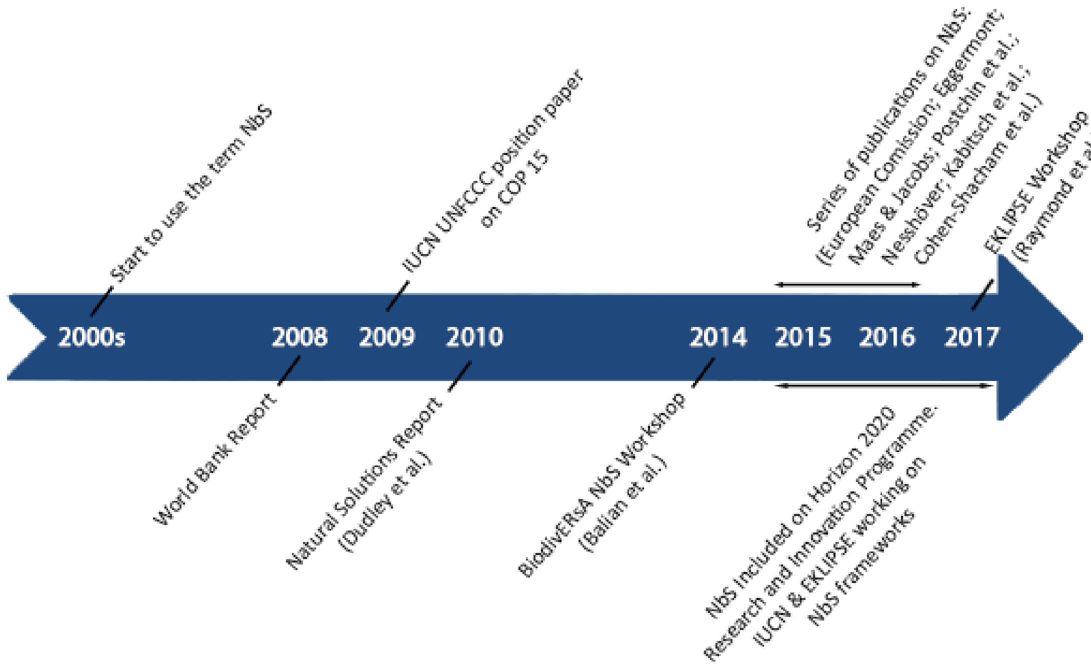

Figure 3-2: Timeline of the evolution of NbS

Source: Own elaboration. Adapted from Cohen-Shacham et al. (2016)

3.2 Definition

One of the first challenges that come with NbS in literature is the apparent lack of consensus on its definition, as NbS are understood and defined differently by different authors. While for some authors this lack of consensus could be seen as a limitation for its applicability and expansion (European Commission, 2015), others view the openness of the concept as an useful way to encourage the participation of a variety of stakeholders in the dialogue, as it allows the concept to be interpreted in different ways (Postchin *et al.,* 2015).

Despite the differences in definition, the core concept usually remains the same (addressing major societal challenges through the effective use of ecosystem and ecosystem services), although there are some discrepancies. The European Commission (2016), define NbS as:

"Solutions to societal challenges that are inspired and supported by nature, which are cost-effective, provide simultaneous environmental, social and economic benefits, and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions"

It can be added that they provide also co-benefits, as they improve human well-being and enhance biodiversity at the same time (Balian et al., 2014; Cohen-Shacham et al., 2016). Balian *et al.* (2014, p. 7), agreed on a very similar definition in the BiodivERsA workshop with experts, where they discussed the concept of NbS:

"NbS refer to solutions that are inspired by, using, copying from or assisted by Nature, and with the aim of bringing economic, social and environmental benefits all together".

Both definitions understand the concept of NbS as a very broad range of instruments and solutions. However, there were also authors who were using the term much more narrowly, as the World Bank (2008), who used it as a synonym for biodiversity projects (e.g. agriculture, forestry, coastal management, etc.). While the IUCN (Cohen-Shacham et al., 2016, p. 5) takes a slightly different definition, and they define them as:

"Actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits."

For IUCN, the central part of any NbS needs to be a well-managed or restored ecosystem, while the previous definitions from the European Commission and the BiodivERsA workshop are somewhat broader, and they include the use of solutions that not only use nature directly but are also inspired by and supported by nature (e.g. biomimicry).

Postchin *et al.* (2015, p. 3) goes one step further, and tries to define the concept by separating its different elements and defining them:

- Nature – refers to individual elements of biodiversity, biodiversity aggregate and/or ecosystem services.
- Nature-based – relates to the use of ecosystem-based approaches, including biomimicry, or the direct use of elements of biodiversity.
- Solutions – refers to a specific challenge or problem. A specific method/tool to address the issues must exist.

For this author, the inclusion of the term "solution" in the concept recognizes that there is a problem that needs to be dealt with in the first place, and this is a key characteristic that differentiates the term of NbS from some of the similar terms that were discussed before, which are more inclined toward the management of ecosystems, without a special interest in solving also other issues (Postchin et al., 2016).

Therefore, it is important to identify first what kind of challenges can effectively be addressed by NbS, and then determine which solution would work best to do it. With that objective in mind, the workshop organized by BiodivERsA (Balian *et al.,* 2015) identified three main categories or NbS:

- Type 1: Better use of existing ecosystems, improving their ecosystem services while reducing the intervention on the systems themselves
- Type 2: Managed ecosystems, developing sustainable and multifunctional ecosystems which provide enhanced ecosystem services
- Type 3: Extremely managed ecosystems, or even creation of completely new ecosystems

Although Postchin *et al.* (2015), argues that 'biomimicry' should be also considered a NbS, and could, therefore have its own category. Another aspect that is also usually addressed is how, ideally, these actions should be resilient to change, as well as energy and resource efficient, and how they must be adapted to local conditions in order to be effective (Balian *et al.* 2014; European Commission, 2015; Kabisch *et al.,* 2016; Cohen-Shacham et al., 2016; Raymond et al., 2017). The latter is thereby something that is repeatedly addressed by almost all the main authors working with the concept, talking about how NbS are very context-specific, both in time and space. That means that if a common issue is affecting several areas (e.g. issues with flooding, or social injustice), the problem can be dealt with in different ways and at different scales on different parts of the world. Therefore NbS need to be adjusted to each specific case.

Furthermore, it is repeatedly mentioned how these solutions are not aimed exclusively at environmental, and they can also have effects on the economic and social development of the area where they are applied (Postchin *et al.,* 2015; Cohen-Shacham et al., 2016; Balian *et al.,* 2014), although those benefits are usually hard to evaluate (Raymond *et al.*, 2017). The development of the concept still continues, and the European Commission has recently included NbS on its Horizon 2020 Research and Innovation Programme, with the aim of investing in a series of projects to increase the knowledge on the concept of NbS, and help Europe become a frontrunner on its use and application (Maes & Jacobs, 2015).

This thesis has used the definition provided by the European Commission (2016), as a baseline for the development of the research. Since it started to be shared by a growing number of authors, and it allows for a wider range of measures to be included under the NbS category.

3.3 Research gaps

Several research gaps are identified by different authors. To begin with, the usual focus in the research of NbS application tends to be in the technical area of implementation as well as its environmental performance, leaving aside other areas such as social impacts (e.g. social justice, and social cohesion), economic implications (e.g. creation of green jobs and new business opportunities), or stakeholder involvement (Raymond et al., 2017). For Postchin *et al.* (2015), the development of case-studies is especially important, since they allow to understand how NbS have been applied in different situations, enriching the debate on the concept with concrete examples. Other authors such as Kabisch *et al.* (2016, p. 4), detected four areas where more research is needed:

1. The effectiveness of NbS in creating positive impacts for cities
2. The relationship between society and NbS
3. The design and development of NbS projects
4. Implementation and policy aspects

There is also a need for research on the evidence on the economic, social and environmental impacts of NbS under different conditions, which would offer opportunities to study their transferability in other regions of Europe and maximise its uptake (EC, 2015). Furthermore, some authors also mention the importance of the creation of a knowledge platform or platforms, focused on cities that are making use of these solutions, so they can share knowledge and experiences, and act as a NbS stewardship community in the use and development of these solutions (Kabisch *et al.,* 2016, Balian *et al.,* 2014).

3.4 Benefits of NbS

In theory, NbS are expected to support communities and cities in achieving their sustainable development goals (SDGs), protect people's well-being with the provision of ecosystem services and at the same time improve the resilience of existing ecosystems to the increasing effects of climate change (Cohen-Shacham et al., 2016).

However, a more detailed analysis of how these solutions - and their potential benefits - look like in practice is necessary. The following section will provide such an overview.

3.4.1 NbS initiatives

There are several examples of NbS that have been identified in the literature, and there are several examples of them being applied in many parts of the world. NbS have been implemented in a wide variety of areas and they have been used to address a large range of issues. Some of the most commonly used actions include the following (adapted from Cohen-Shacham et al., 2016):

- Forest protection and reforestation to provide clean water, increase energy and food security, reduce flood risk, support climate change adaptation, enhance carbon sequestration and increase biodiversity.
- Use of natural infrastructures such as mangrove swamps and reefs to protect coastal communities from erosion and flooding, diminishing the effects of severe storms and reducing the impacts of sea level rise.
- Development of green and blue infrastructure in urban areas, such as green roofs, green walls, street trees, parks, lakes and ponds, etc., to improve air quality, wastewater treatment and reduce the runoffs from storm water
- Sustainable management of wetlands and riparian ecosystems to provide flood protection, boost biodiversity and provide recreational values.
- Restoration of terrestrial ecosystems such as grasslands, to improve water security, provide forage for livestock and enhance resilience to climate change impacts.
- Selective use of species in certain ecosystems, such as deep-rooted, nitrogen-fixing plants on soils with lack of nutrients. Different plants can also be used to filter water from sediments and contaminants while acting as carbon sinks.

As the concept develops, new actions and interventions are being developed, tested and employed (EC, 2015). IUCN developed a hypothetical scenario to show how the use of NbS can be applied and what the benefits that it could potentially bring are. It can be seen in Figure 3-3.

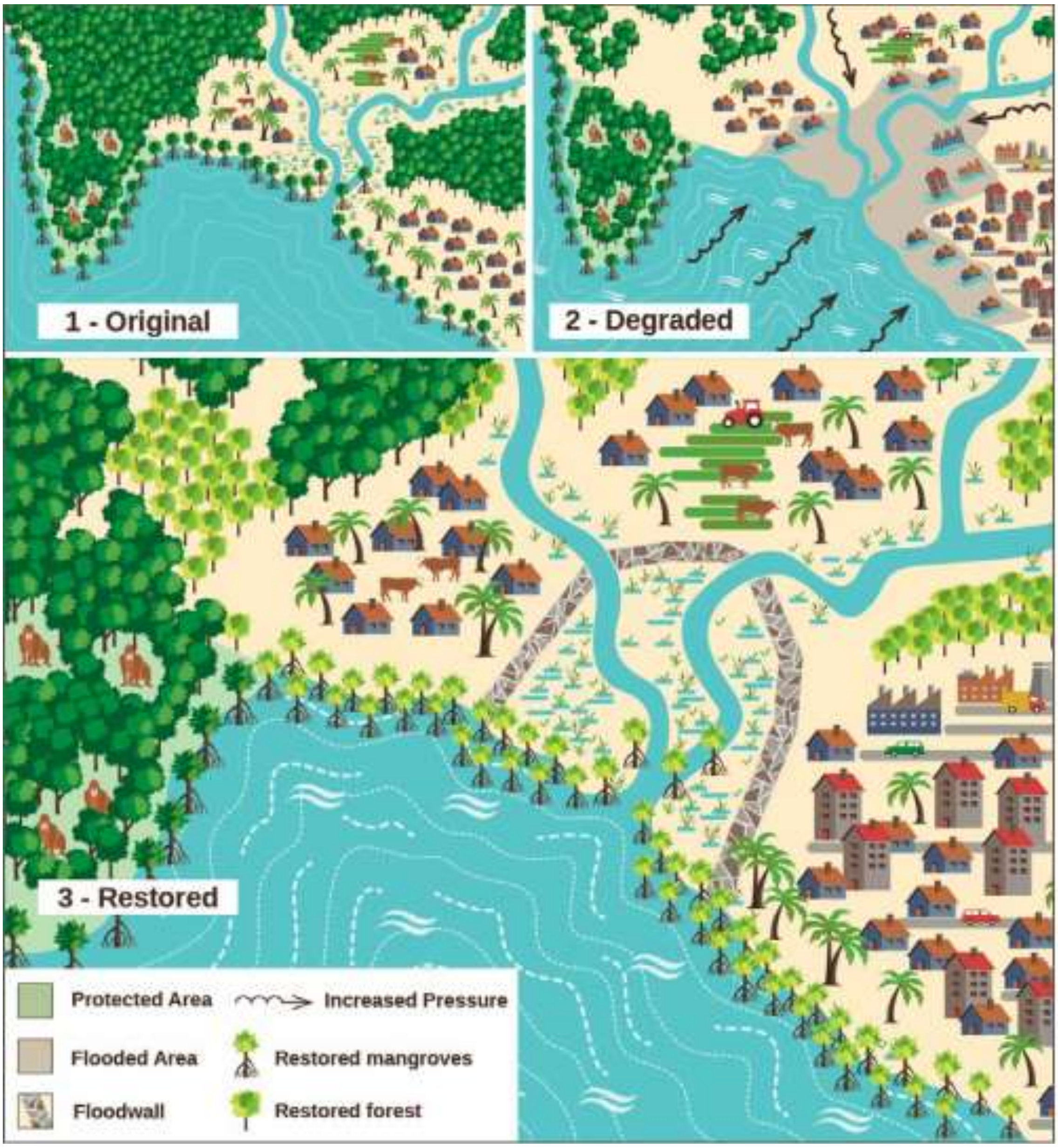

Figure 3-3: Hypothetical scenario of NbS being used to protect a coastal area

Source: Cohen-Shacham et al. (2016)

The figure shows an area that originally did not have issues with flooding, as the natural forest and wetlands acted as barriers, absorbing most the effect of any storm surges that could hit the area. Over time, urbanization and deforestation removed the forest and wetland ecosystems, leaving the area unprotected against flooding. The main interventions consist of a mix of NbS with traditional measures, including replanting the mangrove along the shoreline and growing vegetation inland, as well as wetland restoration, combined with the use of more conventional measures, such as a concrete flood barrier to secure the river area. Together these actions reduce the risk of flooding, support biodiversity in the area and increase local livelihoods (Cohen-Shacham et al., 2016).

For the authors, this example highlights two important aspects of NbS interventions:

i. They can be implemented alone or in an integrated manner with other types of solutions (e.g. engineering and technological solutions)
ii. They can make use of natural or conservation areas which original purpose was other than being used as NbS (e.g. the protected area in the scenario, which was created for protection of a particularly rare species, but then it was also used as flood protection)

3.4.2 Examples of NbS

In this section, a list of specific studies regarding the application of NbS is presented. It is split into four subsections: Air quality, water management, coastal resilience and climate mitigation and adaptation. The aim is to give the reader a deeper understanding of the concept of NbS and its application by presenting real and specific examples of their use. The four areas of focus selected are part of the ten challenge areas identified by Raymond et al., (2017) on the EKLIPSE framework.

This section does not intend to provide an exhaustive list of NbS actions, but rather a sample of how these actions are being used and what benefits they can bring to urban areas.

Air quality – Säo Paulo (Brazil)

Lamano Ferreira et al., (2017) analysed the adsorption of atmospheric pollutants – specifically heavy metals (Cd, Pb, Ni, Cu) - on the soil surface of two forests located near the city of São Paulo. Their results showed that the levels of heavy metals were generally high, especially in the case of the Guarapiranga forest, located approximately 20 km from the city centre. The other forest, located 70 km from the urban area showed typically lower levels of heavy metals. The authors found that precipitation played a key role in the dispersion of pollutants, and they suggested in their conclusions the development of green areas in the urban area for two reasons: First, it would help regulate rainfall patterns, which is affected by absorption and evaporation of soil water and vegetation transpiration; and second, the vegetation would also act as a filter, capturing pollutants and reducing the concentration of heavy metals.

Water management – Gorla Maggiore (Italy)

This research, by Liquete, Udias, Conte, Grizzetti & Masi (2016), assesses the benefits (social, economic and environmental) provided by a multi-purpose green infrastructure – a series of wetlands surrounded by a park - and it compares the project with other alternatives, such as the use of grey infrastructure and the previous situation in the area, a poplar plantation. The results reflected that the green infrastructure performed very similar or even better than the grey infrastructure on flood protection and water purification, it had a very similar cost and it provided additional benefits that the grey infrastructure could not offer, such: i) reduce some water-related issues in the area, and increase the ecological status of the local river; ii) boost biodiversity in the area; and iii) add recreational and educational services to the residents. The poplar plantation turned out as the worst possible option in the study.

The authors highlight the importance of using a multi-criteria analysis (including social, environmental and economic values) to assess the effectiveness of NbS projects, as they usually offer benefits that are not measured by traditional analysis methods, which usually focus mainly on the economic aspects.

Coastal Resilience – The Holland Coast (The Netherlands)

As a flat country with a very low geographical position, The Netherlands is an interesting example for coastal resilience projects. On their paper, Van Slobbe et al., (2013) compared the use of traditional 'hard' engineering strategies (e.g. dams, reinforcements and acceptance of beach erosion), with two dynamic scenarios that make use of natural elements; a small-scale nourishment method, and a mega-nourishment project, called 'Delfland Sand Engine'.

Before 1990 the coastal protection was managed with hard engineering strategies, and after 1990 the method changed, and the coast was maintained with sand mined offshore. The sand was applied whenever the coastline was retreating beyond a certain point, and typically 1 million m^3 were applied each year. The traditional methods stopped being used because they were not considered resilient nor sustainable, but the small-scale nourishment method also had its downsides. It needed repeated interventions, there were constant disturbances of the shoreline and it was not cheap (around € 60 million per year). For those reasons, The Netherlands decided to test a new project, the so-called Delfland Sand Engine, which consisted of the construction of a 'sand deposit' of 20 million m^3 in the area of the Holland coast. The idea was to create a one-time disturbance that will last for approximately 20 years, and it will protect the beach from erosion without the need of constant interventions. Van Slobbe et al. argue that this strategy naturally adapts to changing conditions within its lifetime, it makes use of waves and the wind for sediment distribution and habitat creation without constantly disturbing the ecosystem, and although it is expensive at first (€ 70 million over 20 years for an experimental location), it will probably be cheaper once upgraded to regular practice.

This mega-nourishment project is expected to reduce some of the negative aspects of the previous management methods, as well as create additional benefits, such as new habitats for wildlife or opportunities for economic and recreation activities in the area (Van Slobbe et al., 2013). Figure 3-4 shows a picture of the project.

Figure 3-4: Aerial view of 'Delfland Sand Engine' after its completion in 2011

Author: Joop van Houdt, picture used with permission of the author

Climate mitigation and adaptation – Medellin (Colombia)

Reynolds et al., (2017) explored the role of urban trees in mitigating carbon dioxide (CO_2) emissions. They estimated and assessed carbon dioxide sequestration, storage, and emission offsets by urban trees in the Metropolitan Area of Medellin, Colombia. The results showed that the existing urban forests offset 1,744 Mg CO_2/year or 0.06% of the total emissions of the city. If all available space in the city were to be used for the development of green areas, the potential offsets could go up to 11,211 Mg CO_2/year, which would represent a 0.39% reduction of total CO_2 emissions. The authors estimated that the value of the co-benefits provided by the already existing urban trees were $ 3.5 million per year or $ 19 per tree and year.

The study gathered a list of similar studies carried out in different cities. The results can be found in Table 3-1.

Table 3-1: CO2 offsets from transportation and/or city level in different cities

City	*Gross or Net*	*Emissions Source*	*Reported Emissions (Mg CO_2)*	*Offset (%)*	*Reference*
Medellin, Colombia	Net	City	2,864,090	0,08	1[1]
Bolzano, Italy	Gross	Transport	300	0,10	2[2]
Barcelona, Spain	Net	City	4,053,766	0,02	3[3]
Gainesville, US	Net	City	2,097,627	0,16	4[4]
Miami, US	Net	City	31,967,000	0,07	4

Source: Reynolds, Escobedo, Clerici, & Zea-Camaño, (2017)

[1] Reynolds, Escobedo, Clerici, & Zea-Camaño, (2017).

[2] Russo, Escobedo, Timilsina, & Zerbe, (2015).

[3] Baró, Chaparro, Gómez-Baggethun, Langemeyer, Nowak & Terradas, (2014).

[4] Escobedo, Varela, Zhao, Wagner, & Zipperer, (2010).

4 Findings

The findings are divided into two sections, one for each city that was studied during this research. For each one, there is first a short introduction to the city and the use of the NbS concept in it. Then, the main NbS initiatives are laid out, continued by a section describing drivers and barriers for the use and application.

4.1 Malaga

Malaga is the sixth biggest city in Spain, with a population of 559,009 during the year 2015 (Census of Malaga, 2016). The city is located in the Southern region of the Peninsula, in Andalusia, and it is the second wealthiest city in the area, only after the capital, Seville. The region, known as 'Costa del Sol', is a hotspot for tourism, and it receives thousands of tourists every season. In the year 2012, the *Services Sector* accounted for 84.12% of the GDP, followed by construction (7.16%) and industry (6.41%) (Instituto Nacional de Estadística, INE – National Institute of Statistics, 2013). Therefore, the region was especially impacted by the effects of the economic crisis of 2008, as it relied heavily on external actors for the economy to work, reaching an unemployment rate of 35.29% in 2012 (INE, 2013).

Between 1960 and 1980, a period of great economic growth, the city doubled its population, growing from 267,000 to 503,000 inhabitants. This event supposed the construction of 95,000 new houses in a very short period of time, houses that are nowadays considered obsolete in terms of design and energy efficiency (Agenda 21 Malaga, 2015). The growth of the city was uneven and chaotic, as result of an almost non-existent city planning, which caused the apparition of slums and the enhancement of some environmental issues, such as water and waste management and a lack of green areas and open spaces (Carta Verde de Malaga – Malaga Green Charter, 1995). It was in the early 90s when the city growth stabilized, and the municipality started to focus on the issues aforementioned.

Sustainability issues gained increased attention, and in 1995 Malaga became a pioneer in the development of an urban sustainability strategy under the Agenda 21 framework. It was called 'la Carta Verde de Malaga' (Malaga Green Charter), and it made a deep analysis of the environmental situation of Malaga (Junta de Andalucia, n,d.). The plan boosted the sustainability work in Malaga, which started by focusing on greening the city. While in 1995 there were only 1.30 m^2/inhabitant of green areas, the area reached 7.10 m^2/inhabitant in 2013. In 1997, the city ranked second on the European Prize for the Sustainable City of that year, awarded by the Council of Municipalities and Regions of Europe, due mainly to the work done in the Malaga Green Charter (UN Habitat, 1998). More recently, in 2016, Malaga won the award 'Civitas City of the Year', a prestigious award in sustainable urban mobility. The award was given to Malaga for its efforts in improving the public bicycle system, electric car infrastructure, city centre access, logistics, metro, etc. As well as its commitment to implement the UN Climate Change Summit recommendations, to reduce emissions and monitor air quality (Civitas, 2016).

The city also hosted the Innovation Week in June 2017, as part of the eighth edition of Greencities. A meeting point for institutions, companies and professionals involved in the development of smart cities and in improving the quality of life of citizens. They have the chance to showcase their products, services and experiences (Greencities, 2017). The city also approved recently (2016), the development of a green block, in the area of El Duende. All this is converting Malaga in a possible strong candidate for being the EU Green Capital in 2020, a distinguished award for sustainability in the EU arena.

4.1.1 Environmental Problems

Even though the city of Malaga is progressing in the sustainability agenda, there are still a number of environmental problems that require attention. This thesis, through interviews with experts in the field of sustainability and the use of NbS, has identified lack of greenery, flooding and increased temperatures as the problems which require more immediate attention.

Lack of Greenery

Indubitably the presence of green areas in a city is essential to reach a good quality of life and comfort for its citizens (Haase et al., 2017), as well as to improve air quality. Furthermore, not only do they improve the physical well-being of the citizens, but green areas also reduce pollution and act as CO_2 sinks. The existence of green spaces give structure to the city and constitute the main areas for recreation, relax and leisure (Haase et al., 2017).

As was previously mentioned, the green areas grew rapidly, with 1995 as the starting point, and reached 7.10 m^2/inhabitant in 2013. Figure 4-1 shows the evolution.

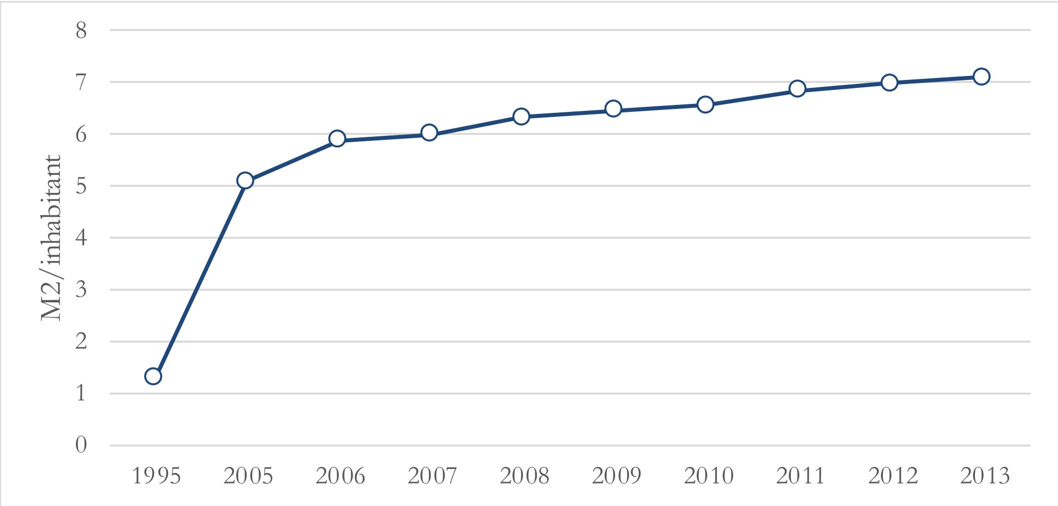

Figure 4-1: Evolution of Green Areas (m^2/inhabitant) during the period 1995-2013

Source: Own elaboration. Information gathered from Agenda 21 Malaga, 2015

The number is still far from the recommendation of the World Health Organization (WHO, 2016), which recommends a minimum of 10 to 15 m^2 of green space per inhabitant. But the distribution of green areas in Malaga is not uniform in all the city districts. Some districts show numbers above the WHO optimal value, such as Campanillas (25.19 m^2/inhabitant), Teatinos (13.19), Centro (13.41) or Guadalhorce (11.87). While other areas are still behind, such as Prolongación (1.87), Rosaleda (1.90) or Puerto de la Torre (2.61). Figure 4-2 shows a map with this information.

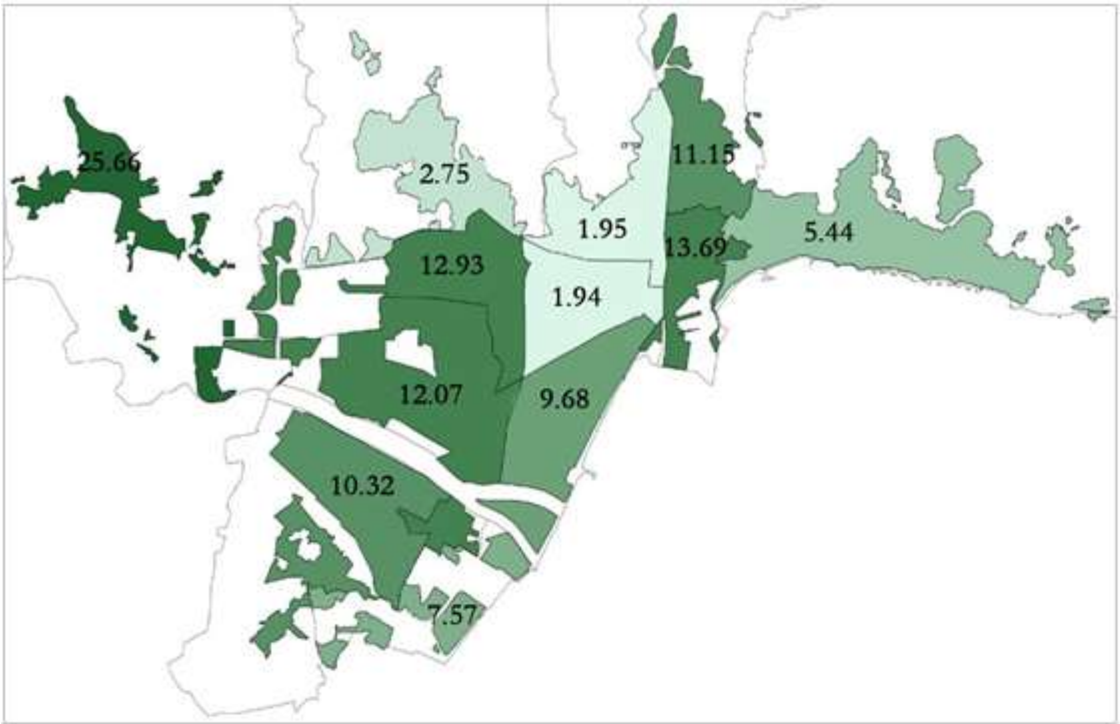

Figure 4-2: Green Areas (m2/inhabitant) per district for the city of Malaga

Source: Adaptation from Agenda 21 Malaga, 2015

Another aspect that needs to be taken into consideration is the number of trees per inhabitant. Here, WHO recommends at least one tree per three inhabitants, which would result in a ratio of 0.33 trees/inhabitant (WHO, 2016). In Malaga, with a population of 575,127 inhabitants, and an estimated number of trees of 133,038, the ratio results in 0.23 trees per inhabitant (Trigos et al., 2013), still far from the WHO recommendation. It is worth noting that the calculations did not include trees located in peri-urban parks, which could have increased the number slightly. From those 133,038 trees, 28.34% (37,701) are located in green areas, while 71.66% (95,337) are street trees. During one of the interviews, Trigos defined lack of urban trees as one of the main environmental concerns for the city, as it would need to at least 60,000 new urban trees to reach the minimum set by WHO.

Lastly, another aspect worth studying for urban vegetation is the ratio of endemic versus introduced species. Endemic species are usually adapted, and they thrive under local conditions, while introduced species may or may not develop under such circumstances. Furthermore, introduced species can be harmful to local ecosystems, altering the ecological niche of other species, although that is not always the case, and usually a deeper case-by-case analysis is required (Naylor, 2001). In the case of Malaga, a study by the Department of Vegetal Biology of the University of Malaga (Trigos et al., 2013), concluded that only 20% of the urban trees belonged to endemic species.

Increased temperatures

During another interview with a professor at the Plant Biology Department at the University of Malaga, the temperature was identified as another environmental challenge for the city.

Following the Köppen climate classification[5], created by Wladimir Peter Köppen in 1900, Malaga belongs to the Hot-summer Mediterranean climate area, a subtype of the Mediterranean climate characterized by average temperatures higher than 22 ºC during the warmest month and between 18 and -3 ºC on the coldest month of the year (Peel et al., 2007). Temperature in Malaga seems to have been slowly increasing over the last 20 years, as it is shown in Figure 4-3.

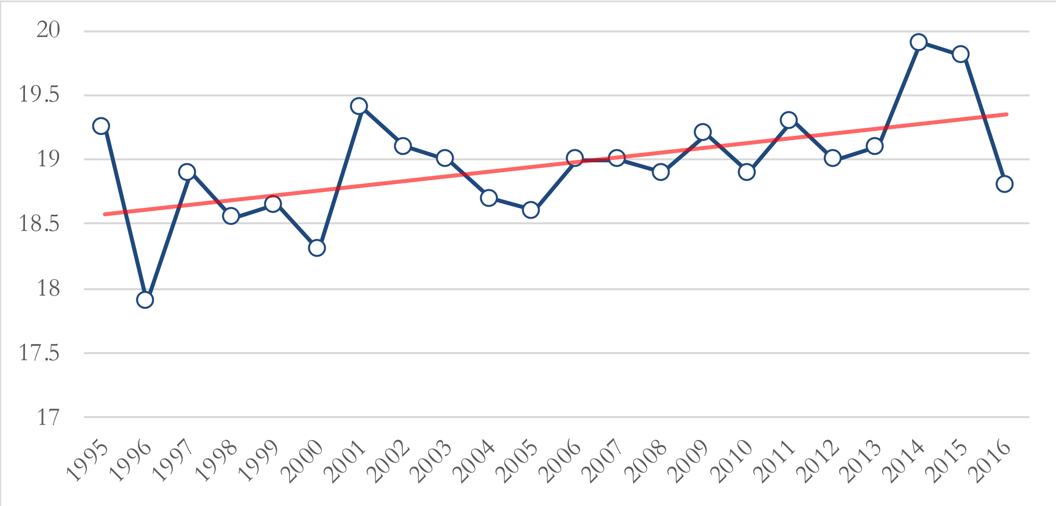

Figure 4-3: Average temperature in Malaga (ºC), with trend. Period 1995-2016

Source: Agencia Estatal de Meteorologia (AEMET), 2017

The temperatures have been rising not only in Malaga, but in Spain a whole, and during recent years it has been common to find news about temperature records being broken all over the territory. At the moment of writing this thesis (13th of July, 2017), a heat wave broke the historic temperature record in Spain, reaching 47.3 ºC in the city of Montoro (Cordoba, Andalusia), while in Malaga the temperature reached 45 ºC (La Vanguardia, 2017).

During the period 1 June – 15 July 2017, a total of 55 people had to be assisted by the medical services due to heat-related conditions, with 27 of those being heat strokes (Malaga Digital, 2017). In the same period, three people lost their lives due to heat strokes in Andalusia, one of them in Malaga. To prevent this, Malaga has 2,408 patients from the most vulnerable groups under telephonic-monitoring, providing fast access to the medical services if needed.

Water management and risk of flooding

The geographical and climatic situation of Malaga, with a very irregular rainfall regime, cause water courses to be intermittent and drought periods. The irregularity of the rains causes also recurrent flooding in the city, causing considerable damages to infrastructure and even some casualties.

Malaga has struggled historically to store enough water to cover the needs of its citizens, and it is not uncommon for the local government to apply restrictions on water consumption, especially during summertime, when the population grows due to tourism and the water

[5] The Köppen climate classification is one of the most commonly used climate classification systems. It divides the world in climatic areas according to their main climate group (Tropical, dry, temperate, continental and polar), and it then adds letters according to their precipitation type, and their average temperatura.

demand increases (Agenda 21, 2015). This thesis' author remembers several summers while growing up, when the city was facing water scarcity and there were measures in place to save water, such as restricting filling up swimming pools, or times during the day when water was not available altogether. Figure 4-4 shows the rainfall evolution for the city during the period 1995-2013.

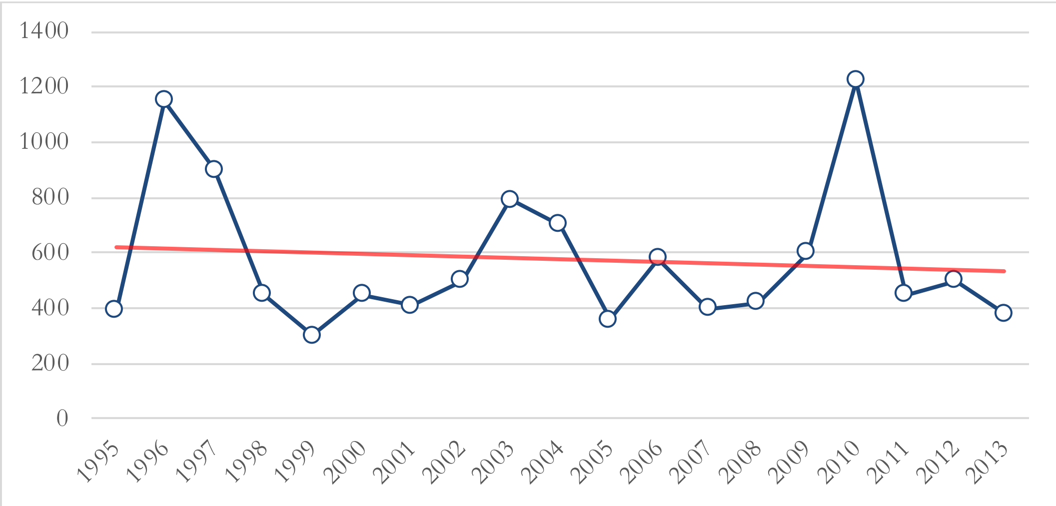

Figure 4-4: Average rainfall in Malaga (mm/year), with trend. Period 1995-2013

Source: Agencia Estatal de Meteorologia (AEMET), 2017

AEMET also has statistics for data collected since 1971. For the city of Malaga, during the period 1971-2000, the average rainfall per year was 524mm, and it rained on average 43 days per year (AEMET, n.d.).

The city relies on reservoirs to get water, most of them artificial, where water is stored during rainfall events. 2015 and 2016 were especially dry years, and the capital needed water from nearby reservoirs to cover its demand (La Opinión de Malaga, 2017). According to EQUO – the so-called green party in Spain - Malaga lost 28% of its water reserves during 2015, placing Malaga as second-to-last in the amount of water stored in Andalusia, only after Almeria (EQUO, 2016).

Moving on to the issue of flooding, as rivers run dry most of the year, there seems to be a tendency to build infrastructure over the course of some rivers. When heavy rains come, flash floods sweep away everything in its path, causing devastation when the river overflows. One of the worst flooding events occurred in 1989, when it rained heavily for 25 days straight, causing enormous economic damages, and also, eight people lost their lives during the event (Diario Sur, 2012).

Not so heavily, but the city usually suffers from flooding every few years. The most recent ones were in 2016, 2015, 2013, 2012, 2007 (El Pais, n.d.). For one of the interviewees, the reasons are clear: first, constructions in the river beds that are susceptible to flash flooding with heavy rains, as well as heavily modified river courses that are not allowed to overflow naturally during such events; second, insufficient sanitary infrastructures, not capable of handling the amount of water that comes with torrential rains; and third, not enough green and blue infrastructures to help the sanitary system in events of heavy rain, absorbing water and slowing down its flow and peak time.

4.1.2 Initiatives

This section includes all the NbS-related initiatives for the city of Malaga. It is structured according to the categories of NbS they belong to: greenery, blue areas, coastal resilience, urban farming, and lastly, multi-dimensional initiatives. Table 4-2 shows a summary of them.

Table 4-1: List of initiatives containing NbS in Malaga

Area of action	*Initiatives*
Greenery	***Vertical Gardens*** - 'Pericon' square - 'Jose Carlos Garcia' restaurant - 'Acer' building - 'Paseo de los curas' - 'Muelle uno' gardens ***Green Roofs*** - Roof of Limasa (not a real green roof) ***Parks and Green Areas*** - Park of Malaga - West Park - Botanical Garden - *(Urban Forest of Malaga)* ***Peri-urban Parks*** - 'Montes de Malaga' Natural Park - *(Green Belt)*
Blue Areas	- Mouth of the Guadalhorce River (Natural Park) - *(Guadalmedina River)*
Coastal Resilience	- Nothing specific
Urban Farming	- 'Jardín de Bailén' - 'Huerto de Moliére' - 'El Vergel de Malaga' - 'El Caminito' - University – 'Jaulas Abiertas' - 'La Salvia' - 'Huerta la Yuca' - 'Huerta la Dignidad' - 'Tunesia' - University – 'Huerto Docente de la Facultad de Ciencias' - Urban farms in Schools
Multi-dimensional Initiatives	- *(Regreeneration)* - *('El Duende' Green Apple)*

**Projects in parenthesis and in italics are projects that are still in planning or early stage of development*

Source: Own elaboration

Greenery

This section includes all the green-related projects or initiatives that were found, including vertical gardens, green roofs, parks or green areas and peri-urban forests (forests that are not inside the city, but in its direct periphery).

Vertical Gardens

Regarding vertical gardens, often referred to as 'green walls' in literature, a few examples were found, as Table 4-3 shows.

Table 4-2: Vertical gardens in the city of Malaga

Location	Dimensions
'Pericon' square	$300m^2$
'Jose Carlos Garcia' restaurant	$250m^2$
'Club Mediterraneo' restaurant	$30m^2$
'Acer' building	$10m^2$
'Paseo de Los Curas'	*
'Muelle Uno' gardens	*

**Dimensions could not be found*

Source: Own elaboration

While also a few examples of vertical gardens situated in private houses exist, they were not considered for the research as they were not available for the general public. Most of the vertical gardens follow a similar design, a modular arrangement with a metallic grid fixed to the wall, and a specific kind of moss to act as a substrate, between 15 and 30cm thick (Acer, n.d.). According to one of the companies that install them, these kind of gardens are very easy to install, they can adapt to any surface and the maintenance is very low (Acer, n.d.).

From the list of vertical gardens found in Malaga, probably the most emblematic one is the one situated in the Jose Carlos Garcia restaurant, in the area of the city harbour. The area was remodelled in 2011 to act as a link between the city and the harbour area, and it became an area with museums, restaurants and shops. The vertical garden, located on the wall of a restaurant, next to the Pompidou Museum, has a surface of $250m^2$, and it was considered 'the 4^{th} best vertical garden in the world' by 'ABC Viajar' (ABC Travel, 2013). A picture can be seen in Figure 4-5, although it is worth mentioning that the garden continues on the inside of the restaurant, and the picture only shows a part of it.

Figure 4-5: Vertical garden in Jose Carlos Garcia restaurant

Author: Maria Solé, picture used with permission

Green Roofs

Concerning green roofs, no examples of them were found in the city of Malaga, only a few terraces and rooftops with some vegetation on it, most of them belonging to hotels and restaurants (Diaz, 2016). The only initiative that comes close to the concept of a green roof is the one being developed at the roof of Limasa, a cleaning and recycling company. The project, led by Trigo Pérez, a professor at the plant biology department at the University of Malaga, is experimenting with roof gardening. The project is testing the effectiveness of different soils and substrates – including recycled materials and construction waste shredded -, to grow various species of plants.

The project, in collaboration with 'Fundación Mujeres y Biodiversidad' (Women and Biodiversity Foundation), and funded by the bank 'La Caixa', is being used also to give formation courses on roof gardening. And according to Trigo, the ambition of the project is to identify which soils and species combination work best, to then start expanding the project to other areas of the city.

Parks and Green Areas

There are several parks and green areas distributed around the city. For the purpose of this study, this section is going to talk in more detail about the three biggest ones: first, 'Parque de Malaga' (Park of Malaga); second, 'Parque Del Oeste' (West Park); and lastly, the Botanical Garden.

'Parque de Malaga' is situated in the city centre with a surface of 3 hectares. It was created during the 19th century (1879), as an expansion area to the harbour. It has plant species of the five continents, and it is considered to contain the most tropical and subtropical flora biodiversity of any park in Spain, as well as to be one of the top ones in Europe, with an estimated 360 species (Díez-Garretas & Asensi, 2014). The park, which connects the harbour area with the city centre, also has an auditorium where different musical and cultural events take place throughout the year.

'Parque Del Oeste' is, as its name suggests, located in the west region of the city. With an area of 7.4 hectares, it was inaugurated in 1992, and it has since then become one of the most transited parks of Malaga. With a much lower botanical diversity than the other two parks, the West Park combines the use of green areas with the use of other spaces such as areas dedicated to sports, animals or blue areas such as lakes and watercourses. The park is estimated to contain around 14,000 plants and flowers, and almost 800 trees (Agenda 21 Malaga, 2015).

The Botanical Garden was founded in 1855, thus it has more than 150 years of history. The garden started as a recreational area for a rich family until it was made accessible to the public in 1990. The Botanical Garden contains more than 50,000 plants and trees, which belong to 2,000 different species. Unlike the other two parks, the entrance is not free, and there is a fee to access it.

Another park that deserves attention, although it is still a proposal, is the 'Bosque Urbano de Malaga' (BUM – Urban Forest of Malaga). The idea was born as a public initiative by a group of citizens, and it has now reached almost 26,000 signatures in the platform www.change.org. The park would be located in an area of 177,000 m^2 that was previously used for storing enormous deposits of fuel, owned by Repsol. The deposits were removed in 2001, and the area is unused since then.

Soon after the dismantling of the containers, the Municipality of Malaga started a project to build a residential area with four skyscrapers (with a total of 932 individual houses), a shopping mall, offices, a hotel, 400 social housing residences, and a park of 130,000 m^2 (BUM, n.d.). But a strong movement against the project started, arguing that the city of Malaga does not need any of that infrastructure, especially bringing four skyscrapers to one of the already more densely populated areas of the city (BUM, n.d.). Therefore, the platform for the Urban Forest wants the whole area to be developed into a park, with a natural lake and no presence of buildings. As of summer 2017, it is still unclear what will happen in the future: if the park will be built, the project from the Municipality involving skyscrapers, a mix of the two, or none of the above.

Peri-urban Parks

The best example of peri-urban park in the city is 'Montes de Malaga Natural Park'. Located on the northern border of the city, the park, with an area of 4996 hectares. According to one of the interviews, it is a prime example of NbS, with a smart utilization of natural resources to prevent natural disasters.

The history of the park started in the 1400s when the Catholic Kings regained control of the area, which was in possession of the Muslims. Soon after that, the land – covered in Mediterranean forest - was given away to farmers to plant vineyards, almond trees and olive trees. After most of the forest was cut down, flooding events started to devastate the city, since the protection that was before provided by the forest was now gone. Projects to dredge the Guadalmedina River – the river that crosses the city north to south – started to be carried out, but eventually, a dam had to be built to stop the river from overflowing. Soon after, in the 1930s, a plan that included several reforestation projects began in Montes de Malaga as a measure to prevent the flooding issues that were affecting the city. The area was declared Natural Park in 1992.

The efforts to continue increasing the area of peri-urban parks are still ongoing, and the city has developed a plan 2016-2020 to plant 1,000,000 new trees in the province of Malaga, to fight climate change, soil destruction and reduce the risk of flooding (Council of Malaga, 2016). The plan, which focuses not only on the city of Malaga but also villages and smaller regions, intends to create a 'green belt' around the city that connects 'Monte San Antón' (East), 'Montes de Malaga' (North) and the mouth of the Guadalhorce River (West). The process started in 2016, with the plantation of 60,000 new trees, although the survival rate is expected to be of 20-40% (La Opinión de Malaga, 2016), and it will continue until 2020.

Blue areas

There are not many blue areas in the city of Malaga. Nevertheless, two main ones were identified: first, the mouth of the Guadalhorce River; and second, the Guadalmedina River.

The Guadalhorce River is located on the west side of the city, where the mouth of the river forms a delta. The area was declared 'Paraje Natural' (Natural Park) in 1989, and it is delimited on both sides by the two courses of the Guadalhorce River, the original one, and a second one that was artificially added to prevent the overflow of the river. The park is situated in between the two courses. The delta, with a total surface of 67 hectares, is filled with artificial lagoons that were created in the 1970s and 1980s when the area was used to extract materials for construction, and it connects directly with the sea through a band of natural dunes. It is now a thriving area for a wide range of species, including aquatic plants, reptiles, amphibians, and even mammals such as the otter. But especially, the Park is well known for being a resting place for hundreds of species of migratory birds. As it is placed right at the border between Europe and Africa, it has become a usual spot for migratory birds to stop and regain energies to continue their travel.

The other example of a blue area is the Guadalmedina River. This river is the so-called 'river of Malaga', since it runs through the city north to south, dividing it into two halves, and its mouth is located right at the city centre. It is a peculiar river since it runs dry most of the year on its lower course because of the Limonero Dam, constructed in the late 1900s to prevent the flooding that was affecting the city. Therefore, the course of the river is used for recreational activities during the periods that there is no water flowing. It is not uncommon to see young people playing sports there, such as football or volleyball, or simply people talking a walk. A few years back, the margins of the riverbed had a constant flow of water, with a system of working fountains, but now the river looks abandoned and there is no water, except when it rains heavily or the dam is opened to discharge (Diario Sur, 2017).

Due to the current state that the river is in now, at the time of writing the Municipality was planning, a full reform of the river for its course through the city. According to sources from the local government, the remodelling shall be finished within ten years (Diario Sur, 2017). Although the details of the project are still unknown, the idea is to remove the traffic from the river margins, improve the connectivity between neighbourhoods and boost the landscape value of the whole area (La Opinión de Malaga, 2017). Nonetheless, the project is now open for public tender, and the city still has to decide what proposal will be moved forward.

Coastal resilience

According to a study by the Spanish Oceanographic Institute, the sea rose in Malaga more than in any other Spanish Mediterranean city, with 17 centimetres during the period 1990-2005 (Vargas Yánez, 2010). The rise per year is expected to be of 1-3 mm per year, which would result in a rise of 50 or 60 cm by the end of the 21st century (Alcántara, 2016).

Even though Malaga is a coastal city that is already experiencing the effects of climate change, the author of this thesis could not find any projects or measures to improve coastal resilience in the event of sea level rise or storm surges. Regarding the risk of storm surges or tsunamis due to earthquakes, the situation of Malaga, located in the Strait of Gibraltar, and only 180km away from the African coast, leaves a very low risk of suffering a big tsunami, since there is not enough space between the two coasts for a big wave to form (Leceta Ostolaza, 2014).

Nonetheless, there seems to be an apparent lack of planning regarding coastal resilience and sea level rise, even though there is research suggesting that it might be a threat by the end of the century.

Urban farming

The development of urban farming initiatives has been important during the last decade, but it grew especially during the last five to six years. But for Pérez-Lara et al., (2016) the plan that promoted the appearance of these initiatives – called 'Plan PROTEJA 2011' -, was not created as a tool to promote green spaces or improve the urban metabolism. It was a way to reduce the maintenance costs of the suddenly abandoned lots after the 'real estate bubble' went down, starting the economic crisis of 2008. This way, the municipality tried to promote the conversion of these lots into public spaces managed by the neighbours, so they would not end up being used as landfills.

But the authors argue that this was the case only for some of the urban farms that can be found today in Malaga. Other projects were born as a result of public demand, and while some of the urban farms are managed in a very institutional way, others are completely self-organized and rely on community efforts to function and grow (Pérez-Lara et al., 2016). It is worth noting how there is not any regulation in place from the Municipality to regulate the use of these spaces, unlike other municipalities of Andalusia, where some sort of regulation is usually in force (Puente-Asuero, 2015). For that reason, almost every urban farm follows a different management method, and there is no consensus on what the best way to manage them is.

The urban farming momentum seems to continue increasing, and at the time of writing this, the author was able to find several workshops on the concept of urban farming and how to do it. Moreover, it is also gaining political support, and the relatively new party 'Malaga Ahora' has been trying to increase the support for these projects. In a vote held at the Municipality on December 2016, the following measures were approved (Malaga Ahora, n.d.):

- Urgent financial support to the urban farms already in place
- Support to new urban farms and also to those located in schools
- Creation of a regulatory ordinance for urban farming (still not created at the time of writing this thesis)

Table 4-4 shows an exhaustive list of the urban farms active at the time of writing this thesis.

Table 4-3: Urban farms in Malaga

Name of the Urban Farm	*Area (m^2)*	*Farming units*	*Time active (years)*
'Jardín de Bailén'	900	*	5
'Huerto de Moliére'	2890	33	5
'El Vergel de Malaga'	1000	13	5
'El Caminito'	1103	*	5
University – 'Jaulas Abiertas'	*	*	4
'La Salvia'	*	*	3-4
'Huerta La Yuca'	*	*	3
'Huerta la Dignidad'	1300	19	2-3
'Tunesia'	*	*	2-3
University – 'Huerto Docente de la Facultad de Ciencias'	*	*	2
Urban Farms in Schools	*	*	*

**Information could not be found*

Source: Own elaboration. Partially adapted from Pérez-Lara, Matas, & Quesada (2016)

The first four on the table were the ones that were promoted first by the Municipality. At first, the idea was to have one urban farm per district of the city, but economic difficulties and problems to access to some of the lots allowed only those four to be constructed. Each of them cost an average of 40,000 € (Municipality of Malaga, 2013).

Multi-dimensional Initiatives

Under this section, there are projects that did not fit into any of the other categories. It includes projects that, due to their nature, cover the concept of NbS from a more holistic perspective.

Regreeneration

The project belongs to the Horizon 2020 Programme, and it intends to use the concept of NbS to achieve the environmental and social sustainability objectives of cities along with their economic development goals (Regreeneration, 2017).

It wants to '*provide a robust EU-wide evidence base and develop a European reference framework on NbS for regional and local authorities*' (Regreeneration, 2017, p.2). To achieve that, the project has selected a 'front-runner' (FR) and 'follower' cities approach, to enhance the replication, exploitation and up-scaling of the solutions (Regreeneration, 2017). The cities have been selected to complement each other and represent a wide range of urban areas and socio-economic characteristics, to ensure the replicability of the model for other cities. The three cities selected to act as front-runners are:

- Miskolc (Hungary). Miskolc is the study-area, representing a classic city centre.
- Malaga (Spain). With the Perchel-Lagunillas neighbourhood, with a mixed use of residential and businesses
- Stockholm (Sweden). Where the area selected was Skärholmen, with a mostly residential use

The project achieves its objectives following a ten work packages (WP) program divided into three main phases (Regreeneration, 2017, p. 8):

- **The planning phase** (WP1) – This phase defines the overall framework of the model, characterising and modelling the best existing practices and experiences – also called demonstration cases - in the area of NbS.
- **Implementation phase** – The demonstration cases will be carried out in the FR cities (WP2-4), showing how the solutions help to tackle the main vulnerabilities and challenges detected in each of the cities. This phase also measures quantitatively how effective those solutions are, using the previously defined environmental, social and economic indicators (WP5). And once the projects are working, new business models are developed (WP7) for the new defined solutions.
- **Replication phase** – In this phase, the FR cities define their Regreeneration City Strategy (WP6), for the replication of the model in other areas, and follower cities use that information to determine their own City Strategy using NbS. A network of cities is then created to enhance the replication and up-scaling (WP8), and the dissemination strategy (WP9) then integrates the model into a certification label system.

For the case at hand, Malaga selected the area of Perchel-Lagunillas, a neighbourhood in the city centre with roughly 24,000 inhabitants living in it. The pre-study for the project showed that the area has a high level of physical degradation, with a high number of abandoned lots and almost no economic activity. In addition, the area has high rates of unemployment (more than 32% among young people), with a high percentage of one-person households and a high percentage of elderly residents with low income. The risk of social exclusion and vulnerability are high, and levels of education are low. Furthermore, public spaces, green spaces and community equipment are degraded and the buildings are old with poor energy efficiency (Regreeneration, 2017).

The project has planned a set of NbS for the area focused on two factors: first, the physical and social problems of the area; and second, to improve the economic activity and employment rate to increase social cohesion and reduce vulnerability. To achieve those targets, the project is going to make use of the following NbS (Regreeneration, 2017, p. 6):

- **Increase the green areas in the neighbourhood**. Examples would be vertical gardens, green roofs, green pergolas and green retaining walls to stabilize slopes and reduce soil erosion.
- Creation of associations to **educate and incorporate vulnerable groups into the labour market**. This will be made by training vulnerable groups (immigrants, women...) in the maintenance and management of NbS.
- Creation of **green and blue corridors through the use of Sustainable Urban Drainage Systems (SUDS),** in order to connect the area with the adjacent districts. This would include a mix of filtering material, innovative paving and green infrastructure, to create public spaces with rain-water management as well as ecosystems that make use of the hydric network and new integrated functions (e.g. animals islands, urban mobility, etc.).

'El Duende' Green Apple

The project of 'El Duende' is a pilot project of urban regeneration, it belongs to the framework of the MED Programme (a translational programme of European Territorial Cooperation), and it is co-financed by the European Regional Development Fund. In Malaga, the project is co-managed with OMAU (Observatorio de Medio Ambiente Urbano – 'Urban Sustainability Observatory'). The project aims at combining the characteristics of a classic Mediterranean city: compact buildings, complex functions and uses, and proximity to basic equipment and services, to create a green block (OMAU, 2016). The project was approved on the 22nd December 2015, and it involves the participation of 11 Mediterranean cities. Each city will develop its own green block, and it will measure its effectiveness using a series of indicators that will be determined beforehand by the 11 metropolises involved (MED Programme, n.d.).

In Malaga, the area selected was 'El Duende', with an area of 94,000 m^2, and it includes the creation of 963 dwellings with infrastructure and services. These are expected to meet optimal environmental, social and economic sustainability levels (OMAU, 2016). Traffic will not be allowed to drive inside the block area, and only residents and traders will be allowed to drive through it. Furthermore, the block has to follow strict energy efficiency, water and waste management and CO_2 emissions criteria (OMAU, 2016).

The project started a public tender process that ended in May 2017, to select the best ideas for the development of the green block, although the final project had not been announced yet at the time of writing this thesis. The project will also make use of NbS, such as reaching a minimum ratio of one tree per person (MED Programme, n.d.). That would mean at least 2,311 new trees for the new district in Malaga. The use of NbS is expected to include more initiatives, although as the project is still being developed, this research could not find further details on the specifics, besides the number of new trees that are expected.

4.1.3 Drivers and Barriers

A total of six interviews involved people that were working directly or indirectly with the notion of nature in the city of Malaga, three of which were working directly with the development of the concept of NbS for the city. This section details the main drivers and barriers for the development and use of NbS in the city of Malaga, using the interviews with experts as the main source of information. A summary of the drivers and barriers as well as their analysis can be found in *Chapter 5.2.2*.

Drivers

When asked about what would be the main drivers for the use of NbS in the city of Malaga, the most common answer by the interviewees was that it could be a way to deal with some of the environmental, social and economic problems that the city is facing. To begin with, Malaga does not meet the WHO standards in surface of green areas and trees per inhabitant, which combined with the increased temperatures due to climate change, and the struggles of the city in terms of water and flood management, leaves the city as a good candidate to try out some of the NbS, which claim to tackle those and more issues. Furthermore, these solutions could bring also social and economic benefits, such as integration of marginal sectors and employment in, for example, managing and taking care of the new infrastructures.

Becoming a front-runner in the use of NbS could position the city in an advantageous position, bringing international attention as well as funds to try out new projects and ideas. A perfect example of this was the selection of Malaga as one of the three front-runner cities for the Regreeneration project, as was explained in the previous section.

A different driver that came across one of the interviews was the use of institutions, such as the University, as innovation centres and role models for the rest of the city. For a concrete example, the University of Malaga decided to create an urban farm in the Faculty of Science, and then use the coffee grounds from the cafeteria to compost them and use them on the farms, since they had no other use and it was being thrown away. This shows how Universities could be used as an environment to test new ideas and projects.

Another driver that came up during the interviews was the possibility to use public participation as a tool to promote new projects and ideas. As 5% of the budget from the Municipality is dedicated to community projects, it is possible for people to bring up new ideas, which could potentially be used for the development of local NbS projects. Although that is not always an easy task, and it relies on the premise that people are interested in the use of these solutions in the first place.

Barriers

When asked about what was hindering the development of NbS for the city of Malaga, lack of knowledge about the concept itself and what it entails was one of the most common answers. Even some of the interviewees were not as acquainted with the term, and used other ones such as 'green and blue infrastructures'. This lack of knowledge opens up questions about how aware policy makers and citizens are about the existence and implications of these solutions. Unfortunately, this research could not conduct interviews with people from the political sphere to investigate this area in more detail.

Regarding politicians and urban planning, lack of political commitment and NbS projects going against the Urban Development Plan of the city were also identified as a barrier to the use and development of NbS. It would be probably fair to say that lack of knowledge and lack of commitment are closely linked since it is hard to show commitment for something that someone is not fully aware of. To illustrate the point about the Urban Development Plan acting as a barrier, one of the interviewees used the case of the Urban Forest of Malaga as an example, a project that started as a demand from the community, but without almost any political support. According to this interview, even if the support were there to do the project, it would still be hard to get it done because it would go against the Urban Development Plan of the area. Thereby, to get the project done, the Urban Development Plan would need to be changed first, a process that is usually long and complex, and that requires of consensus from different political parties. That led Francisco Pomares – city councillor of Urban Development in Malaga -, to say about the project of Urban Forest that:

"As an idea, we (the Municipality) respect it, but it needs to be seen that it is only an idea, and in this case, considering the reality of the land, it is inviable, because it does not adjust to the Urban Development Plan for the area (…) the project is perfect, but detached from reality"

Another aspect that was mentioned during the interviews was the apparent lack of public-private collaboration for the development of innovative projects. From the six people that were interviewed, none of them could think of a single project related to NbS that had been born as a result of a public-private collaboration, a tool that is commonly used in other areas such as Malmö, with relative success. Besides, public participation does not seem to be encouraged either, with projects either not being clearly communicated or local people not being involved in the design and planning process at all. This is something that has been often discussed in the literature, and how important is to involve local communities in the projects from the beginning, so they can be part of the design process, understand what benefits these projects bring, and how and why they should be maintained (Haase et al., 2017).

About the effectiveness of NbS, there seems to be a lack of spaces where to test new ideas or projects, such as the concept of 'Urban Living Lab' – an area for experimentation and testing where everything is monitored, to measure how effective, or not, these experiments are. Without the use of concepts like that, it is hard to evaluate and test new ideas and projects, and see how effective they are in bringing benefits to the city. According to one of the interviews, ideas are, in some occasions, copied directly from other cities, without being tested first or adapted to the local conditions, often resulting in failed projects. It was also mentioned how even though currently there is little work being done in terms of effectiveness, that work seems to be growing fast in the academic sector.

4.2 Malmö

With a population of above 300,000, Malmö is ranked as the third largest city in Sweden, only after Stockholm and Gothenburg, and the fifth largest in Scandinavia. It is situated in the southern part of Sweden, in the region of Skåne. Malmö was one of the earliest and most industrialised towns in the region of Scandinavia. With the recession that Sweden experienced in the mid-1970s, the city of Malmö struggled to maintain its industries, mainly shipyards and manufacturing industries, and the population lowered as people started to move to more thriving areas. But it was in the mid-1990s when Malmö started to change its strategy, trying to become a centre of culture, innovation and knowledge. The changes were accelerated after the construction of the Øresund Bridge, which connects Malmö with Copenhagen, and the inauguration of Malmö University, which opened in 1998.

It was in the early 1990s when the local government started to put sustainability issues in their agenda (Stahre, 2008), and since then, the city of Malmö has made considerable efforts towards sustainable development, gaining an international reputation for it (Austin, 2013). Its compactness makes the provision of collective services easier, which creates favourable conditions for sustainable urban development (Municipality of Malmö, 2014). The underlying ambition of Malmö's urban development is to create a sustainable and attractive city that is ready to face the future challenges that are expected to come, such as temperature changes, rising sea levels, and increased precipitation (Municipality of Malmö, 2009).

Malmö's ambition to grow in a sustainable way is tied very closely with the challenges that the city is expecting to face in the coming years. With an expected growth in its population (Municipality of Malmö, 2014) as well as the expected effects of climate change, they adopted in 2009 a new Environmental Programme with four sustainability-related goals:

- Become Sweden's most climate-friendly city
- Become an example of sustainable urban development
- Use natural resources in a sustainable way
- Take advantage of the natural conditions of the city

And the Municipality goes even one step further, saying:

> *"Malmö will be the Best City in the World for Sustainable Urban Development by 2020"*
> - Municipality of Malmö (Environmental Programme 2009-2020, p. 2)

And to achieve some of those goals, the city has implemented many projects that fall under the category of NbS in some of the neighbourhoods. Many of them related to storm water management, since the city is prone to flooding due to the high volumes of rain that it receives and a sewage system that is not capable of handling those volumes (Kazmierczak & Carter, 2010).

4.2.1 Environmental Problems

The city of Malmö, which has been working hard on sustainability-related issues for the last 25 years or so, still has problems to face. When asked about the main environmental issues for the city today, the effects of climate change showed to be the main area of concern. In this case: increased precipitation and risk of flooding, the rise in sea level and warmer climate.

Increased precipitation and risk of flooding

Currently, the annual average precipitation in Malmö is about 603 mm, with 169 rainy days per year. With the effects of climate change, precipitations are expected to be higher and also with a greater proportion of heavy rainfalls in shorts periods of time, both of which will increase the amount of storm water (IPCC, 2007). The area of Malmö is expected to get drier summers and wetter winters, with precipitations falling in summer by 30mm per month and increasing during winter by 30mm in the 2020s and 50mm in the 2080s, compared to the 1961-1990 baseline (Swedish Commission on Climate and Vulnerability, 2007).

That, combined with a surface distribution system that is not ready to handle vast volumes of water, like the ones received during extreme precipitation events, presents an extra challenge for the city (Municipality of Malmö, n.d.). This could become an issue especially in densely populated areas, where the storm water runoff system can overflow and flood the area. In that event, overflowing sewage water can also cause health hazards, bringing contaminants or releasing those pollutants found in land and soil, contaminating fields, water supplies or irrigation systems (Municipality of Malmö, n.d.).

Another event that is expected to be more common if the flooding along riverbanks. For the city of Malmö, the flooding is expected to happen mainly along the Riseberga brook and Sege River (Municipality of Malmö, n.d.).

Rise in sea level

With the expected effects of global warming, sea level is expected to rise 22 – 66 cm above the current sea level by the end of the century (Municipality of Malmö, n.d.). That means that the current flood levels will also increase. The estimations suggest that it could, in extreme cases such as high tide, strong wind or big waves, reach as high as three meters above today's sea level (Municipality of Malmö, n.d.). A figure of the areas that are expected to be affected can be found in Figure 4-6.

Figure 4-6: Sea level rise of 3m in Malmö

Source: Municipality of Malmö (n.d.)

Entire areas such as the Western Harbour or the harbour areas of Nyhamnen are located under the three meters threshold, and they would become completely flooded if the sea rises to the predicted levels. In case of a three-meter sea level rise, an area of 10.1 km^2 is expected to be affected in the city, with an estimated value of 30,000 SEK M (Municipality of Malmö, n.d.).

Warmer climate

A warmer climate for the city of Malmö will mean that days with an average temperature of over 20 ºC will become more ordinary, and the peak temperatures in summer will also become higher. Malmö sits currently on an average daily temperature of 9 ºC, the result of averaging the mean temperatures of the whole year. According to the Swedish Commission on Climate and Vulnerability (2007), the average temperatures in January will increase 2ºC by the 2020s and up to 6ºC by the 2080s, while temperatures in July are expected to increase by 2ºC and 6ºC by the 2020s and the 2080s, respectively. Respecting to the number of days in the summer with average temperatures above 20ºC, the number could increase from 10 days in the 2020s to over 50 in the 2080s (Swedish Commission on Climate and Vulnerability, 2007).

An increased temperature would bring many changes to the area, such as variations of the growing season, which is expected to be expanded by two months (Municipality of Malmö, n.d.). A warmer climate would also have effects on the reproduction of animals and plants, and it could mean an increase in the number of pests, with new diseases spreading more easily on the new climatic conditions. Also, new species of animals and plants could expand northwards, bringing new risks for contagious diseases and parasites.

Furthermore, higher temperatures are especially dangerous for vulnerable groups, such as children, the elderly or sick people. Even though Malmö does not reach temperatures as high as Malaga, the effects of even a few degrees more can be dangerous. According to a study carried out in the Stockholm area, an increased mean temperature of four degrees would increase mortality by more than five percent (Schweden, 2007).

4.2.2 Initiatives

There are several environmental projects around the city of Malmö that are making use of different NBS. Although the projects had a different structure than the ones found in Malaga. In Malaga, the NbS projects usually involved the use of one specific solution or project in a very specific area, thereby this research was able to identify them individually and list them. For the case of Malmö, the use of NbS is usually carried out in entire neighbourhoods or areas of the city, and they usually involve the combined use of several NbS. For that reason, it was harder to identify individual NbS, so 'greenery' and 'blue areas' have been combined together under the name 'Project Areas', as they usually appeared jointly on the same projects. Table 4-4 shows a summary of the initiatives.

Figure 4-7: Building with vegetation in its walls in Malmö

Author: Jack Fraser, used with permission

Table 4-4: List of the initiatives containing NbS in Malmö

Area of action	*Name*	*Description*
Project Areas (Greenery & Blue Areas)	- Eco-City Augustenborg	Green roofs/walls, swales, canals, ponds, permeable pavements, controlled flooding, green spaces
	- Western Harbour	Rain gardens, water artwork, open canals, green roofs/walls, green spaces
	- Hyllie	Green roofs/walls, green spaces, detention ponds
	- Rosengård	Green roofs/walls, green spaces
	- Sorgenfri	Green corridors, parks and gardens
	- Toftanäs Wetland Park	Wetland, controlled flooding
	- Gyllins trädgård	Meadow, forest, arable land
	- Bomhögsgatan	Green areas, retention ponds, dam
	- Per Josephssons Gata	Green areas, retention ponds, dam
	- Kasernparken	Pond, reedbed
	- Husie Lake	Detention lake
	- Olof Hågensen	Wetland, controlled flooding
	- Vanåsgatan	Swales
	- Svågertorp	Ponds, soakaways
	- Limhamsfältet	Swale
	- Sallerupsvägen	Drainage corridor, pond, creek
	- Vintriediket	Drainage corridor, detention ponds
	- Annestad	Controlled flooding, detention canal
	- Gottorpsvägen	Ponds, filter wall
	- Amiralsgatan	Detention pond
	- Växthuparken	Eco-corridor, pond, watercourse
	- Fjärilsparken	Eco-corridor, swale
	- Tygelsjö	Eco-corridor, wetland, ponds
Coastal Resilience	- Under study by Malmö	
Urban Farming	- 16 Urban farms around the city	
	- Sege Park	
	- 'Greenhouse'	
	- Rosengårdsfältet	
Multi-dimensional Initiatives	- Green Space Factor	
	- Green Points	
	- Naturvation	
	- Urban Nature	
	- Green Surge	

Source: Own elaboration, partly adapted from Stahre (2008)

Project Areas (Greenery & Blue Areas)

Due to the high number of areas and projects currently using NbS involving green and blue areas, this section develops in more detail three of the projects that have been considered most relevant during the conversations with the interviewees: Eco-city Augustenborg, the area of the Western Harbour, and the Toftanäs Wetland Park. For the full list of initiatives, please refer to Table 4-5.

Eco-City Augustenborg

The project was launched in 1998 as a collaboration between MKB housing company and the City of Malmö, and it underwent a significant regeneration process until 2002. It is nowadays considered as one of Sweden's largest urban sustainable projects. Some of the main drivers for the regeneration were flood risk management, the challenging social and economic situation in the area, biodiversity improvement and waste management (Kazmierczak & Carter, 2010).

The project was developed in collaboration between the social housing company and the city council, and one of the key elements of the project was the collaboration and participation of residents, who were actively asked to take a leading role in the development of ideas, design and implementation of the project (Kazmierczak & Carter, 2010). All the buildings were designed and constructed following energy-saving guidelines, and several NbS were applied in the area, such as the creation of Sustainable Urban Drainage Systems (SUDS) through the use of retention ponds, green roofs, ditches and green spaces. The project involved also the renewal of all 30 gardens in the area.

Prior to regeneration, one of the main problems of the area was related to storm water management, which created flooding issues. They were caused by an old sewage drainage system which could not deal with household waste water, rainwater run-off and pressure from other areas of Malmö (Kazmierczak & Carter, 2010). The project developed a strategy to successfully overhaul the storm water system, which decreased rainwater runoff by half, improved biodiversity in the area as well as its overall image. Since the incorporation of the system, no floods have affected the area, and even during the 50 year rainfall event that happened in 2007 in Malmö, which affected the whole city and cut it from the rest of Sweden, the area of Augustenborg was not affected, suggesting that the system is working and the area is ready to cope with heavy rainfall events in the future (MKB and City of Malmö, n.d.).

These are some of the NbS included in the area (Kazmierczak & Carter, 2010; MKB and City of Malmö, n.d.):

- 6km of water channels and canals
- 10 retention ponds
- Natural ditches and reservoirs to collect rainfall before sending it to the sewer system
- Trenches, ditches and wetlands to channel rainwater
- 30 courtyard areas with green spaces that can be temporarily flooded
- 30 green roofs with a total green surface of 2,100 m^2
- A Botanical Roof Garden with a surface of 9,500 m^2

Western Harbour

An international housing exposition, called Bo01, or 'The Sustainable City of Tomorrow', was held in Malmö in 2001, in the area of the Western Harbour, and it was then when the transformation of the area started. The goal of this project was to revamp an old industrial area of the city, by creating a sustainable and visually appealing neighbourhood. Its completion is expected for 2030, and it is a combination of several projects, with a special focus on aesthetic and energy efficiency, and it includes architectural and environmental innovations (Stahre, 2008). As far as NbS goes, the area is rich in parks and green spaces, which serve as an enhancement for biodiversity as well as acting as a drainage system, they also include (Stahre, 2008; Barton, 2016):

- Green roofs
- Green walls
- Mobile plant systems and three-dimensional greenery to provide shading
- Permeable gravelled surfaces
- Some areas were elevated to favour the natural flow of rainwater to the sea
- Vegetated ponds and wetlands
- Aquapoints (i.e. places for contemplation and inspiration that also act as buffer areas to retain water)

Figure 4-8: Green roof with solar panels in Malmö

Author: Jack Fraser, picture used with permission

Also as a result of the convention, Malmö started to use the concepts of 'Green Space Factor' and 'Green Points' in the area of the Western Harbour. The Green Space Factor is a planning instrument that guarantees a minimum volume of greenery for new developments. The aim was to secure a certain amount of green in every building lot, minimizing the share of paved surfaces in the development. Developers were encouraged to use permeable surfaces to capture runoff water before it reached the drainage system (Stahre, 2008). The method assigns values to different surface types, which are then multiplied by their total surface and divided by the total area. The minimum target of Green Space that had to be reached in the area was of 0.5.

In order to achieve better standards, the system of Green Points was added, because, with the Green Space Factor, a green roof with a thin layer of soil had the same value as a thicker green roof which could support a higher biodiversity and have a bigger impact intercepting rainwater. To address that issue, developers in each residential courtyard of the Western Harbour had to pick and use at least 10 Green Points from a list of 35 (for the full list, please see Appendix IV. Green Points System). The possible actions included in the Green Points ranged from having a bird or bat box per apartment, to have all surfaces in the courtyard being permeable to water, or installing green roofs. The systems of Green Space Factor and Green Points were then modified and continued in other areas of Malmö such as *Flagghusen* or in the *Miljöbyggprogram Syd* (Kruuse, 2010). Although in those areas the Green Space Factor was applied less rigorously, and the minimum factor of 0.5 was not required anymore, and they used instead, a factor relative to the building rate. So if the building covered 70 % of the site, the Green Space Factor to be reached was only 0.3, and for buildings that covered only 50 %, the Green Space Factor would be 0.5 (Kruuse, 2010).

The Toftanäs Wetland Park

The project for this park started in 1988 when a new development area was started for Malmö. The construction finished two years later, in 1990. The area has 60 hectares, and the construction of single family houses and areas for commercial use was planned. As the area had issues with storm water management, the Municipality started to consider different ways to drain storm water runoff from the new development area. The existing pipe could only handle 500 l/s, but the expected runoff was in the order of 1,600 l/s (Stahre, 2008). Therefore, Malmö had to choose between handling the extra flow with the construction of a new pipe, or use a detention pond to retain the water.

The city was reluctant to construct the pond at first, but Malmö Water, working together with the Parks & City Environment developed a proposal for the Toftanäs Wetland Park, and it got accepted by the city's Department of Planning (Stahre, 2008). The wetland is three hectares big, with a depth of about three meters below the ground level. It also has deeper sections with stone fillings to simulate reefs and enhance aquatic life. Part of the wetland was designed as a dry pond, to be flooded only during wet weather events, with the idea that it could be used by the public during the dry periods.

The Toftanäs Wetland Park brings several benefits to the area. One of the most obvious is that it gives some treatment to the storm water, removing pollutants from the water while it stays in the pond (e.g. nitrogen and phosphorus) (Stahre, 2008). The area has also become an important asset in terms of biodiversity, with the development of a rich aquatic fauna, and also an important sanctuary for birds, maintaining a wide variety of bird species throughout the year. Last but not least, the park also brought economic benefits to the area. The costs of construction were approximately the same as they would have been for a traditional drainage system, but the main economic benefit comes from the flow retention capabilities of the wetland. Without that retention, the downstream system would have to handle a much higher hydraulic load, and that would have meant the construction of a new pipe downstream to transport the runoff from the new development area. That new pipe, which would have been 1 km long and 1m in diameter, was estimated to bring up the costs of construction by around 30 % (Stahre, 2008).

Coastal Resilience

Coastal resilience, as protection against a rise in sea level due to climate change and/or storm surges, is one of the main environmental concerns for the city of Malmö. The city is well aware of the potential issues related to a higher sea level and the effects it would bring, and they are planning in advance to mitigate them. Table 4-5 shows the main actions Malmö is considering today respecting rise in sea level.

Table 4-5: Planned actions against sea level rise in Malmö

Tool	*Actions*
Planning	• Level allowed for new developments increased from +2.5m to +3.0m above sea level
Protective measures	• Study the benefits and cons of different types of coastal protection measures to provide a strategy to follow in the future • Construct protective barriers along the seashore
Risk level	• Evaluate the acceptable risks for strategically important areas • Cost-benefit analysis where the cost of a protective measure is weighed against the risk faced by that zone • Identification of vulnerable areas

Source: Adaptation Strategy for the city of Malmö (2015)

The use of NbS is not specifically mentioned, although some of the interviewees confirmed that it is an area that the Municipality is looking at, and these solutions are being considered when the city says that they plan to "*study the benefits and cons of different types of coastal protection measures to provide a strategy to follow in the future*". The issue with using NbS as coastal protection actions is that there is still little evidence of how effective these solutions are, and cities are still trying to assess what options work best, and under which circumstances, because there is no 'one size fits all' solution to address specific conditions (Saleh & Weinstein, 2016).

Urban Farming

The urban farming movement in Malmö appears to be well-developed, with urban farms covering almost all areas of the city. Most of the farms are making use of social media platforms, such as Facebook, to stay in contact with their users and promote their activities and events. Some of the farms offer farming lots for own cultivation, where users can go to grow their own vegetables, and even some of them offer bags of vegetables for a fixed price (e.g. 150 SEK for a big bag of vegetables at Happy Onion Farm).Table 4-6 summarizes the urban farms in the area.

Table 4-6: Urban farms in Malmö

Name	Surface	Year of opening
Happy Onion Farm	2,250 m²	2017
OlliÅke Farms	*	2017
Färgfältet	*	2016
Los Perros Urban Farming	2,500 m²	2015
Bönskiftet	*	2014
Urban Organic	*	2013
Havslotten	*	2013
Plantparken	*	2011
Odla Rosengård	*	2011
Odlingslotten Valdersmarsro	850 m²	1980s
Landet Oss	1,200 m²	*
Rosengårdsfältet	~15,000 m²	*
Lyckligt Lottad	*	*
Hyllierankan	*	*
Tre Bönor	*	*
Flansbjers Koloniområde	*	*

**Information was not available*

Source: Own elaboration. Information retrieved from Facebook group 'Urban Farms in Malmö' and the websites of the farms when they were available

Although several urban farms can be found around the city of Malmö, the Municipality is also promoting the concept in other areas and for future projects. For example, Sege Park, a park situated in the northern region of Malmö, is currently under study by the city, and the intention is to transform the whole district into a sustainable area with urban farming as one of the core elements (Municipality of Malmö, n.d.). Another project where urban farming is involved is in the development of the 'Greenhouse', one of Sweden's most sustainable building projects (MKB, 2015). The building, located in the Augustenborg neighbourhood, combines a sustainable use of energy, transport, waste management and a green construction process, with urban farming as one of the key elements of the building. Each apartment has a 20 m^2 balcony with 11 m^2 of cultivation area, and the balcony is divided into two climatic zones – some are open in order to use sunlight during summer, while others are glazed to extend the growing season (MKB, 2015). The building is designed in a way that protects the cultivation area from the heavy accumulation of snow strong winds. It also offers a storage room in the communal basement, to safely store the harvested crops.

Of special mention is the area of Rosengårdsfältet ('The Rosengårds field'), an area located in Rosengård, with 145 cultivation lots with a size of about 100 m^2 each. This enormous cultivation area is planning to be refurbished by the end of 2017 and the beginning of 2018, improving its character through cleaning of the entrances and creating four new ones, repairing the fences and cleaning bushes and trees around the cultivation area (Municipality of Malmö, n.d.: 2).

Multi-dimensional Initiatives

Under this section, there are projects that did not fit into any of the other categories. It includes projects that, due to their nature, cover the concept of NbS from a more holistic perspective.

Naturvation

NATure-based URban innoVATION (NATURVATION) is a 4-year project involving 14 institutions across Europe in the fields of innovation, urban development, geography and economics, and it is funded by the European Commission (Naturvation, n.d.). The project is developing the understanding of what NbS can achieve in cities, analysing how innovation can be promoted in the area, and contributing to the body of knowledge on how NbS can help to respond to urban sustainability challenges (Naturvation, n.d.).

The project, which started in November 2016, belongs to the Horizon 2020 programme, funded with € 7.8 million by the European Commission. Naturvation works closely with six partner cities: Barcelona (Spain), Györ (Hungary), Leipzig (Germany), Malmö (Sweden), Newcastle (UK) and Utrecht (The Netherlands). And the six cities are expected to provide insights into how NbS are being used in different contexts and urban conditions.

Naturvation intends to develop evidence and the tools required to move forward the concept of NbS, taking into account the triple bottom line – benefits on the environmental, social and economic sectors. The project is also looking at new governance arrangements, business models, finances and forms of citizen engagement that can make the use of NbS a reality (Naturvation, 2017). As a project that has started recently, there were still no results from it at the time of writing this thesis, although they are expected to come out soon.

Urban Nature

The project of Urban Nature started in December 2016, and it is a five-year long project funded by the Swedish Research Council for Environment, Agricultural Science and Spatial Planning (Formas). The project is using the Swedish cities of Helsingborg, Malmö, Ystad and Gothenburg as core case-studies to assess the ability of NbS to tackle different urban challenges, such as improving the public well-being or mitigating the effects of climate change (Lund University, 2017).

The project of Urban Nature is planning on doing the following (Lund University, 2017):

1) Map the NbS projects developed in the four case-study cities and investigate their potential to bring ecosystem services to the urban context
2) Identify possible drivers and barriers for the implementation of NbS, to support the use of NbS in cities
3) Create future scenarios for how the use and distribution of NbS can be optimized

The project also intends to take into account a broad range of stakeholders: from local municipalities to regional and national authorities as well as private actors and organizations. As it happened with Naturvation, as the project started very recently there were still no results to analyse at the time of writing this, although they are also expected to start coming out soon.

Green Space Factor & Green Points

These two initiatives were mentioned earlier during *Chapter 4.2.2,* as they were born in the Western Harbour area and therefore, they are not going to be developed again here. But this research has considered them to be different enough so they do not fit exactly in any of the other categories, therefore they have been included in this section, and they have been considered as 'multi-dimensional initiatives' for the analysis in *Chapter 5*.

Green Surge

The Green Surge is an EU Research Project to explore the environmental, social and economic virtues of urban green infrastructure. The project started in 2014 and it is due to finish in 2017, it involves the collaboration of 24 partners distributed in 11 countries. The project's results will be presented in a conference in Malmö soon after the finalization of this thesis. The conference will be held in Malmö the days 20-21 of September 2017. The conference invites leading researchers, policy-makers and practitioners to share their experiences and grow their knowledge in the use of green infrastructure to improve equality, health, biodiversity aspects and climate adaptation. Malmö expects people from more than 35 countries to join the event to share their research and projects regarding the use and application of NbS.

4.2.3 Drivers and Barriers

Several drivers and barriers for the implementation and use of NbS in Malmö were identified, primarily via interviews with relevant stakeholders, as well as through related literature.

Drivers

One of the most commonly mentioned drivers was the willingness of the city of Malmö to become a front-runner in the development and use of NbS. This driver is especially visible in some of the urban plans for the city, such as their Adaptation Strategy (2015), Comprehensive Plan (2014), or their Environmental Programme for 2009-2020 (2009). In all these plans the city expresses its interest in investigating and developing the concept more, to uncover all the possible benefits that NbS can bring and use them to their full potential. This aligns well with the ambition of Malmö to transition from an industrial city to a knowledge-based city with high ambitions for sustainability.

In that spirit, the city also sees these solutions as a direct way of dealing with some of their environmental, economic and social problems, thereby their interest in the concept. As was detailed in the previous section, Malmö has become an example of successful use of NbS for climate adaptation, for example with water management projects such as the ones carried out in Augustenborg or the Western Harbour. And the city is already exploring the use of NbS as a way to mitigate the effects of climate change, especially looking at increased temperatures and precipitations, and sea level rise. This could also help to improve quality of life in the city and increase its attractiveness.

Another of the drivers that was identified is the highly participative character of some of the projects involving NbS (e.g. Augustenborg). The involvement of the residents during the planning and implementation of the initiative meant that people had a sense of ownership and empowerment, and it raised awareness among the residents, leaving the project with little to no opposition. There were regular workshops, community meetings and informal gatherings, where citizens had the chance to bring their own ideas or suggest improvements to the project.

One aspect that was described during the interviews, is how difficult can be sometimes to implement projects involving NbS in areas that are already developed and have their own infrastructure. Since NbS require their own space, it can be tricky to take the old infrastructure away, or just find space for these initiatives. However, in newly developed areas that problem does not exist, since NbS can be planned and implemented from the beginning, and the project can be easily designed around them.

The last driver is one that can usually work both ways, and it will also be discussed later as a possible barrier: funding. In the case of Malmö, the political will to use NbS seems to be present, and it brings funds with it. It is worth mentioning the case of Augustenborg, where extensive funding was one of the main reasons for the success of the project. It was funded primarily by MBK and the City of Malmö, but other sources also played an important role, such as the Swedish Government through their Local Investment Programme for Ecological Conversion and Eco-Cycle Programme, and the Swedish Department of the Environment, or EU programmes such as LIFE and EU URBAN. The availability of funds and the willingness to use them on NbS can go a long way for the development of new NbS projects.

Barriers

As happened also in Malaga, lack of knowledge comes as one of the main barriers for Malmö. Specifically, the effectiveness of these solutions in bringing environmental, social and economic benefits is hard to evaluate since they are supposed to bring a mixture of benefits that can be, at times, hard to estimate. For particular challenges, such as mitigating sea level rise, the city has expressed their interest in studying NbS as possible alternatives to traditional engineering solutions, although more studies need to be carried out before a final decision can be made. With this barrier in mind, the city of Malmö is currently involved in several research projects to increase the knowledge in NbS and their applicability to the urban context, and that knowledge is expected to continue growing during upcoming years.

Another barrier is funding. As was discussed in the last section, it is something that can work both ways. Even though projects involving NbS can be cheaper than traditional solutions (e.g. the Toftanäs Wetland Park, which was estimated to be around 30% cheaper than a traditional pipe-solution), it is usually something hard to estimate beforehand, as it involves not only the costs of construction but also possible maintenance costs. This can create uncertainties that can act as barriers for these initiatives. Furthermore, education of citizens can also play a big role, since there are initiatives that depend heavily on their behaviour. As a specific example, one of the interviews mentioned how putting vegetation along the curbside to absorb water runoff can be a really inefficient measure if drivers are not careful and drive over the vegetation, destroying or damaging it. This can lead to higher costs of maintenance than those that were previously expected, affecting the overall effectiveness of the project.

In addition, lack of space can also be a limiting factor, and act as a barrier in some areas of the city. Space for emergency vehicles needs to be maintained, and NbS initiatives have to fit around existing water, electricity, heating and telephone infrastructure. While new areas do not present this issue, older areas of the city with high construction density can be challenging. As it happened in the Western Harbour, the great challenge was that the whole area was very densely developed with very limited open green spaces (Stahre, 2008). In addition, the areas need to be accessible and safe for everyone, and in some of the projects carried out in Malmö, there were concerns about safety and possible health-related issues. As in some occasions, schools or residences might be located nearby these interventions, and there were concerns that they might be dangerous for children, the elderly and/or people with disabilities. Thus, the designing phase is crucial to take these concerns into account.

5 Analysis and discussion

This section presents a detailed analysis and discussion of the findings, using the framework introduced in *Chapter 2.3*. It analyses and compares the implications, drivers and barriers of the cases at hand.

5.1 Assessment of the implications of NbS initiatives

Analysing, evaluating, or even categorising NbS interventions is a challenging task since they cover a wide range of actions, which can bring one or many benefits to the urban environment. The framework this study has used to do such an analysis is the one created by the EKLIPSE group (Raymond et al., 2017). The framework presents ten challenges for which NbS can bring solutions or, in other words, ten areas in which NbS can potentially have an impact. As this study has not performed a detailed impact assessment of the specific NbS found in the cities, the results show the potential implications of these solutions on the ten challenges areas identified by the framework, and then, it uses that information to check if the environmental challenges previously identified for both cities are being addressed or not with these solutions.

5.1.1 Main implications of NbS

Table 5-1 shows a summary of all the initiatives found in Malaga and Malmö, organized by categories: Greenery, blue areas, coastal resilience, urban farming projects and multi-dimensional initiatives. It is worth noting that the numbers shown under the columns of Malaga and Malmö for the sections 'greenery' and 'blue areas' represent different things. In the case of Malaga, the numbers represent the amount of NbS that were found in the city (e.g. 5 vertical gardens means that there were only 5 units of vertical gardens), whereas for Malmö the numbers represent the number of areas, or projects that were making use of that solution (e.g. 4 vertical gardens means that 4 areas of the city were making use of that solution). Ergo, continuing with the example for vertical gardens, the total number of vertical gardens is much higher in Malmö than in Malaga – where only 5 were found. To provide a better perspective, in one of the areas in Malmö, Augustenborg, 31 vertical gardens were found. Due to the fact that this quantitative information could not be found for all instances in Malmö, this research has worked with areas instead. Thus, the numbers should *not* be compared directly. This is only true for 'greenery' and 'blue areas', for all other NbS – coastal resilience, urban farming projects and multi-dimensional initiatives, the numbers refer to individual projects in both cases, thus, direct comparisons can be made.

The right side of the table shows which challenges are being addressed by each of the NbS initiatives. Following the framework, the list of challenges goes as follows:

1. Climate mitigation and adaptation
2. Water management
3. Coastal resilience
4. Green space management (including enhancing/conserving urban biodiversity)
5. Air/ambient quality
6. Urban regeneration
7. Participatory planning and governance
8. Social justice and social cohesion
9. Public health and well-being
10. Potential for new economic opportunities and green jobs

Table 5-1: List of initiatives and challenges being addressed

Malaga	*NbS Initiative*	*Malmö*	*Challenges*
	GREENERY		
5	Vertical gardens	4	*1 2 5 6 10*
-	Green roofs	4	*1 2 5 6 10*
3	Green spaces	9	*1 2 5 6 9 10*
(1)	Green corridors	4	*1 2 4 5 6 10*
1	Forests	1	*1 2 5 9 10*
	BLUE AREAS		
-	Ponds & Lakes	15	*2*
1	Dams	2	*2*
1	Controlled flooding area	4	*2*
1	Wetlands	4	*1 2 5*
-	Creeks	1	*2*
1	Watercourses	1	*2*
-	Swales	4	*2*
-	Canals	3	*2*
-	Permeable pavements	2	*2*
-	Drainage corridors	2	*2*
-	**COASTAL RESILIENCE**	(1)	*3*
11	**URBAN FARMING PROJECTS**	20	*1 2 4 6 8 9*
2 + (2)	**MULTIDIMENSIONAL INITIATIVES**	9	
	European projects		
Regreeneration			*1 2 4 5 6 7 8 10*
'El Duende' Green Apple			*1 2 4 5 6*
		Naturvation	*4 7 8 9 10*
		Urban Nature	*4 7 8 9 10*
	Own initiatives		
(BUM)			*1 2 5 6 7 9 10*
(Guadalmedina River)			*4 6*
		Green Space Factor + Green Points	*1 2 5*
		Green Surge	*7 8 10*
		Augustenborg	*1 2 4 5 6 7 8 9 10*
		Western Harbour	*1 2 4 5 6 7 8 9 10*
		Hyllie	*1 2 4 5 6 7 8 9 10*
		Rosengård	*1 2 4 5 6 7 8 9 10*

**The initiatives in parenthesis are still in development or in a very early stage*

Source: Own elaboration

It is worth noting that the categorization – or the process of assigning specific challenges to each one of the NbS initiatives - seems to be arbitrary and highly subjective, and in the end, it depends on the perspective of each researcher. For example, why can a green space have an impact on water management and urban regeneration (challenges 2 and 6), but not on social justice and cohesion (challenge 8)? This thesis has assigned the challenges to the best of the researcher's abilities, experience and knowledge, but if another researcher attempts to replicate the process, he or she might decide to use different criteria for his/her selection and come up with a different – but hopefully similar – list.

Table 5-2 shows each of the challenges, with the total number of initiatives dealing with them for both cities.

Table 5-2: Summary of challenges being addressed

Challenge	*Malaga*	*Malmö*
1. Climate mitigation and adaptation	**25**	**47**
2. Water management	**28**	**81**
3. Coastal resilience	-	x
4. Green space management	15	26
5. Air/ambient quality	14	27
6. Urban regeneration	**24**	**41**
7. Participatory planning and governance	2	7
8. Social justice and social cohesion	12	27
9. Public health and well-being	16	36
10. Potential for new economic opportunities and green jobs	12	25

Source: Own elaboration

Interestingly, the results show that the NbS initiatives being used by Malaga and Malmö have potential to address similar challenges. For both cities, the biggest potential implication of NbS is in water management, followed by climate mitigation and adaptation, and urban regeneration.

Climate mitigation and adaptation

Both cities are devoting considerable efforts to climate mitigation and adaptation, as it ranks second in their NbS challenge areas. The increment in temperatures due to climate change and the effects of the urban heat island are aspects that trouble both cities, as they are expected to continue growing in the future. NbS seem to offer good solutions to some of these issues, as vegetation sequestrates carbon from the atmosphere and reduce the temperatures in urban areas, by evapotranspiration and shading. But also, by decreasing the energy demand for cooling, the associated carbon emissions, and lightening the urban heat island effects and heat stress. As many of the most widely used NbS involve some sort of greenery, it is not surprising that they rank high in dealing with this challenge.

Water management

Water management is the area where NbS seem to bring more benefits to the cities. It was identified as one of the main environmental issues in both cities, and something that needed immediate attention, especially in the case of Malmö. NbS are showing to be valuable alternatives to grey infrastructure in dealing with this issue. As Malmö has shown in the areas of Augustenborg or the Western Harbour, the use of nature can transform the water management system completely, reducing considerably the risk of flooding by decreasing the run-off load that goes into the sewage system, thereby reducing costs. And also, reducing the flooding risk from rivers, improving water retention capacity, increasing evapotranspiration, and increasing human well-being and biodiversity values in the area. Using green and blue infrastructure as a NbS has been found to be an effective way to improve water management systems and at the same time, bring social and economic benefits to cities.

Coastal resilience

Coastal resilience represents an important issue for both Malaga and Malmo, due to their geographical location, an issue that Malmö seems to situate higher on their agenda than Malaga. The potential of NbS in this area is still unclear. Although some ideas already exist, such as the use of wetlands or coastal marshes (Saleh & Weinstein, 2016), or the use of beaches and dune barriers (Temmerman et al., 2013), to mitigate the possible effects of sea level rises and storm surges. But there is still little evidence of how effective these measures may or may not be. While this research could not find any plans for the city of Malaga in this regard, Malmö has expressed its interest in researching the use of NbS as a possible way to deal with this challenge. Consequently, the city has devoted financial resources on increasing its knowledge in this regard, aiming at being able to make use of the most effective way to deal with it.

Green space management

Green space management is something that both cities want to improve. It is not only about the quality and quantity of those areas, but also about how connected they are, and how involved are stakeholders and citizens in their management. While Malmö has been working on this aspect for quite some time, in the case of Malaga, the lack of quantity and quality of green areas is one of the main environmental concerns. Consequently, the city is in the process of developing projects to improve its green space management in the near future, for example with the development of the 'green belt', which intends to connect all the main green and blue areas around the city. And also with the transformation project for the Guadalmedina River, as well as the Urban Forest Project (BUM).

Air/ambient quality

Air quality, just as climate mitigation and water management, is an area where NbS are showing great potential. The negative effects of air emissions from transport and industries are well-known for bringing serious health and respiratory problems. They can even reach levels where it is not advised to be on the street without a mask (e.g. some cities in China). In Malaga and Malmö, air pollution does not seem to be that much of a threat, although it is something that can always be improved. NbS, with urban trees, green spaces and green walls and roofs are effective tools in removing pollutants from the air, and their effects are noticeable. It is worth noting, that the potential of being able to remove pollutants from the air is dependent on what species are involved, since different species have different rates of absorption for CO_2 and pollutants. The potential of NbS to contribute to the reduction of air pollution has not been properly investigated yet, and in many occasions, species selection for new plants and trees is guided by concepts such as water consumption or their growth rate, but usually, elements such as their capacity to absorb and remove pollutants or CO_2 is ignored.

Urban regeneration

Urban regeneration was found to be the third highest challenge area for NbS in both cities. It involves improving the physical, economic, social and environmental conditions of an area. For example, enhancing biodiversity and community engagement, improving building design and efficiency or creating more and better green and blue spaces to promote street life and ease of movement in the city. In the case of Malmö, the concept has been applied in some of the big restructuring projects such as Hyllie, Augustenborg, the Western Harbour or the area of Rosengård, where connectivity among NbS and the creation of new shared spaces for citizens have received increased attention. For Malaga, it is still an ongoing process, and some of the new projects such as Regreeneration or the remodelling of the Guadalmedina River are emphasising the concept of urban regeneration as one of the main areas to take into account. The concept of urban agriculture seems to fit perfectly into this category, creating shared green spaces for citizens to meet and enjoy, and creating social and economic benefits at the same time.

Participatory planning and governance

Participatory planning and governance is one of the areas where major differences between the two cities were found. The concept includes the involvement of different stakeholders, as well as the citizens, in the design, implementation and management of NbS, promoting cross-sectoral partnerships and supporting community-based projects. This is something that Malmö has been extensively working on in the past, and it was considered one of the main reasons for the Augustenborg project to be a success. Having learned from this experience, the city is including this aspect in the development of new projects involving NbS. In the case of Malaga, almost no participatory planning was found. Even in cases where people tried to suggest new NbS projects, such as the BUM project (the Urban Forest of Malaga), the municipality hindered the initiative, and instead pushed for its own project – the construction of four skyscrapers. Only new projects, such as Regreeneration, appear to be trying to change this trend.

Social justice and social cohesion

Social justice and cohesion refer to how distributed the different NbS across neighbourhoods are, with the overall aim to ensure that the initiatives are equally spread – or as equally as possible - among people from different socio-economic backgrounds. It takes into consideration the needs of often excluded social groups, including them in the design, implementation and monitoring of NbS, as well as increasing the communities' sense of ownership of the projects. For Malaga, the best example that could be found addressing this challenge was, again, urban farming. The municipality developed a project to spread out the urban farms to ensure that there would be, at least, one in each neighbourhood. Also, the Regreeneration project mentions how it intends to work directly with excluded social groups to include them in the development and maintenance of NbS initiatives, so they can become an active part of the projects. For Malmö, social inclusion has become one of the main priority areas for the city, and there is a much higher number of NbS projects working directly with this challenge.

Public health and well-being

Public health and well-being are supposed to be improved by NbS, by bringing citizens benefits through the provision of ecosystem services. It includes urban green spaces and its design, ensuring that the risk of injuries is minimised and that the detrimental effects, such as allergic reactions to pollen from the species selected, are reduced as much as possible. Malmö appears, once again, to be more experienced in this area. The issue is addressed in the design and implementation phases of different NbS throughout the city. In Augustenborg, for example, one of the main concerns from the citizens was how dangerous and accessible the new areas would be for children and people with disabilities, so those concerns were included in the design phase of the project. In Malaga, it is also being addressed, although arguably not as much, with a lower number of projects taking this aspect into consideration.

Potential for new economic opportunities and green jobs

Besides all the previously mentioned advantages that NbS are supposed to bring to cities, such as health benefits, improved water management, aesthetic values, etc. (Postchin et al., 2016; Nesshöver et al., 2016), they can also support the creation of green businesses (OECD, 2013) and jobs in the green sector (Falxa-Raymond et al., 2013). An example in Malmö can be found in the Augustenborg area, where after the restructuring, unemployment fell from 30% to 6%, and soon after the finalisation of the project, three new local companies started: the Green Roof Institute, Watreco AB, and a car pool company (Kazmierczak & Carter, 2010). These opportunities are also being explored in Malaga, with the Regreeneration project, which wants to educate people from socially excluded groups in jobs related to NbS, such as maintenance of new green areas or green roofs. But the new jobs do not offer only the opportunity for low-skill or entry-level positions, but also for high-skill, technically-advanced positions, in areas such as ecological restoration, arboriculture, horticulture and landscape design (Falxa-Raymond et al., 2013).

5.1.2 NbS and environmental challenges

As this research – and many others - have pointed out, NbS can bring a myriad of benefits and co-benefits to cities. And urban areas are facing several environmental challenges, some of which are expected to increase with the effects of climate change. Therefore, it is worth analysing if NbS are being used as a tool to tackle those environmental issues or not. Table 5-3 shows the main potential impact areas identified in both cities, as well as their main environmental challenges.

Table 5-3: Impact areas and environmental challenges

	Impact areas being addressed the most	*Main environmental challenges identified*
Malaga	1. Water management 2. Climate mitigation and adaptation 3. Urban regeneration 4. Public health & well-being 5. Green space management	- Water management and risk of flooding - Warmer climate - Lack of greenery
Malmö	1. Water management 2. Climate mitigation and adaptation 3. Urban regeneration 4. Public health & well-being 5. Air quality | Social justice	- Increased precipitation and risk of flooding - Warmer climate - Rise in sea level

Source: Own elaboration

The city Malaga is developing and using a set of NbS that can address the three main environmental problems identified. While most of its NbS initiatives can enhance primarily water management and climate mitigation, lack of greenery is also being focussed on, with urban regeneration and green space management in the top-5 of challenges potentially being impacted by the NbS initiatives. And even those NbS directed to water management or climate mitigation bring greenery to the city, as they usually involve some sort of green infrastructure.

For Malmö, a very similar scenario was found. NbS used can potentially bring benefits mostly to water management – the main environmental issue for the city – as many of the projects were designed exclusively to deal with this problem (e.g. Augustenborg or Toftanäs Wetland Park) due to the flooding issue the city was suffering from. Respecting the increasing of temperatures due to climate change, the city of Malmö also makes use of NbS, as climate mitigation ranks second on their list. One aspect worth mentioning is how some NbS can bring benefits to different areas, and while a green space with a lake can address water management and flooding prevention, it can also mitigate the effects of climate change through CO_2 sequestration, shading, etc. Regarding the issue of sea level rise, no projects are currently in place addressing this challenge. The city of Malmö has nevertheless expressed its interest to study different options for the future, including the possible use of NbS to tackle this problem. Although there are currently not many studies assessing the effectiveness of these solutions in that regard, Malmö is expecting to obtain the needed information before making a decision, as they are involved in several projects which intention is to increase the knowledge in these solutions (i.e. Naturvation, Urban Nature and Green Surge).

5.2 Similarities and differences in the use of NbS

This section is devoted to discussing the different models of governance and planning for NbS implementation and use found in both cities. It also analyses and discusses their drivers and barriers for NbS use.

5.2.1 Different models of governance and planning for NbS

Although it was discussed in the previous section how the potential impacts of the NbS initiatives appear to be very similar in both cases, the approach to the concept of NbS and how to use it was, indeed, very different. Unlike the case of Malmö, where the concept seemed to be embedded in the urban development plans for the next years, as well as in the culture of the city, with NbS having helped to reshape some of the areas completely, in Malaga the concept was not nearly as developed. It was used mostly in isolated cases, rather than being part of an overall plan for urban development. That is, as far as this research has been able to identify, one of the biggest differences in the use of NbS in both cities.

NbS are proving to be capable of bringing several benefits to cities, and even if they can tackle a specific issue effectively, they usually produce co-benefits, too. But if a neighbourhood has problems with water management and flooding from heavy rains, it is unlikely that a single green roof will make much of a difference. On the contrary, the combined effect of different NbS can possibly achieve better results, as it happened in Augustenborg or the Western Harbour, in Malmö. The concept of NbS in those areas was used with a clear objective in mind – reduce water run-off and the risk of flooding, and transform the area – and they successfully used a myriad of NbS projects to achieve that objective. But the same approach could not be found in Malaga. There, NbS initiatives identified were usually disconnected from one another, without the possibility of creating synergies between them. Only one project in Malaga – Regreeneration - seemed to use the same approach as in Malmö, using several NbS to transform an area of the city with a set of different solutions. Although at the time of writing this, it was still at a very early stage of development, thus, no conclusions could be extracted from it. Though it seems to be a change of direction in the way NbS projects were approached up until this point, and further research could analyse if future projects will continue following that trend or not.

Another aspect where both cities seem to act in very different ways is in the field of public participation. Engaging citizens in the design, development and implementation phases of NbS is something that Malmö ismdoing much more often than Malaga, where it was found only in two projects - BUM (the Urban Forest), and Regreeneration. The former, an idea that was born as a public project, but it got almost shut down by the local government, and it is still very unclear if it will be done or no. And the latter, which involves the regeneration of a specific neighbourhood, and where the projects specify that public participation will be encouraged and maintained. Although, due to the early stage of development of the initiative at the time of writing this research, information on how the process will be handled was not available. Malmö, on the other hand, has successfully involved local residents in their NbS projects, by providing a space to facilitate the exchange of ideas and give feedback. This also increases the 'sense of ownership' for the project among citizens, as they can actively participate in the design process and contribute with their own ideas or suggestions, which increases the likelihood of the projects to be accepted by the local population.

5.2.2 Drivers and barriers for NbS implementation

This section uses the drivers and barriers that were identified for both cities as a baseline to discuss how differently – or not – the cities of Malaga and Malmö are approaching the implementation and use of NbS. Table 5-4 shows a summary of drivers and barriers. In the table, blue represents the drivers and barriers for Malmö, and the ones for Malaga appear in colour green.

Starting with the drivers, both cities expressed their interest in using NbS as a way to address some of their environmental, social and economic issues. Nonetheless, Malmö is one step ahead, having included already the use of NbS as a way to adapt and mitigate the effects of climate change. Also, in both cases there was a strong will to become a front-runner in the application and use of NbS, to create more attractive and resilient cities for the upcoming years, and both cases are involved in European projects which aim to increase the knowledge in these solutions.

Universities can also play an important role regarding NbS. In Malaga, universities were identified as a possible source of knowledge that could even take a role model position – although it is more an idea than a reality for the moment. Also, the city of Malmö encourages sharing information and knowledge with universities and different stakeholders, but takes it further, making use of the concept of Urban Living Lab in areas such as the Western Harbour. While the area never called itself an Urban Living Lab, it met all the criteria: ambitious goals, design competitions, experimentation, exploration, entrepreneurship and collaborative models (McCormick, 2015).

Some of the interviewees – working as City Planners in Malmö – also mentioned how straightforward it is to make use of these solutions in new development areas, as no infrastructure is in place, making it easy to find the necessary space for NbS with proper planning. This could very well be true also for Malaga, as any new development is like a white canvas, waiting to be filled with colours and shapes, or, in this context, NbS initiatives. Last, but not least, funding was seen as a potential driver in both cases, but in slightly different ways. On the one hand, in Malaga, a 5% of the annual budget is devoted to community projects, but that, of course, involves all kinds of projects, and not only those related to NbS. On the other hand, in Malmö, a political commitment exists, which supports the use of these solutions. Consequently, several projects have been funded in the past, and more are expected to come in the future as the city moves forward.

Table 5-4: Drivers and barriers

Drivers		Barriers
• 5% of the budget dedicated to community projects	*Economic*	• Lack of funding
• Become a front-runner (both) • University as a role model • Political will and extensive funding	*Political*	• Lack of political commitment • Issues with the Urban Development Plan • Lack of public-private collaboration
• Improve quality of life and make the city more attractive • Highly participative character of the initiatives (e.g. Augustenborg)	*Social*	• Lack of public participation • Education
• Deal with environmental, social and economic problems (both)	*Environmental*	
• Development in new areas with no previous infrastructure	*Operational*	• Lack of physical space • Safety and health concerns
• Use of the Urban Living Lab concept (e.g. Western Harbour)	• • • *Other*	• Lack of knowledge (both) • No use of Urban Living Labs • Effectiveness of NbS not being measured

**In blue, Malmö, in green, Malaga*

Source: Own elaboration

Regarding barriers, the first and more obvious barrier identified was a lack of knowledge about NbS, but again, this lack of knowledge came in a slightly different way. In Malmö, the concept of NbS was used explicitly as a tool to address some of the sustainability-related problems of the city. All the actors contacted for the development of this thesis had a pretty clear idea about the concept and what it entails. But lack of knowledge was present in other aspects, such as their effectiveness in creating positive impacts, or their application in specific issues such as sea level rise. In Malaga, this was not always the case, and lack of knowledge meant that, in some cases, the concept of NbS itself was unknown, and had to be defined and explained. This goes in accordance with how little support the use of NbS appears to be getting in the city. Of course, it could be argued that these solutions can still be used, even without being acquainted with the concept of NbS, as many of them involve the use of common green and blue infrastructure that can be found in every city, such as trees, green spaces or lakes. But as was discussed earlier, NbS are more effective when they are used in combination, and with a specific objective in mind. That way, different NbS projects create synergies and work together creating a positive impact in the area – or areas – desired.

The rest of the barriers are different in nature, and while Malaga seems to be struggling with the political side of things (clashing of NbS with the Urban Development Plan, lack of public participation and public-private collaborations, and little-to-no experimentation), Malmö's issues have more to do with specific aspects of the design of NbS (lack of physical space, safety and health concerns in the design and education of citizens for the correct use and maintenance of some NbS). This, again, clearly illustrates the different stages at which both cities seem to apply the concept at this moment.

5.3 Considerations about the findings

It is worth mentioning that the findings obtained from this research are probably hard to extrapolate to other cities, as the number of cases and interviews were limited. A higher number of cases and/or interviews could have probably provided more insights on the topic at hand (please refer to *Chapter 1.4. Limitations).* Therefore, the results from this study should be taken from what they are, and further conclusions or generalizations should be drawn with due caution.

5.3.1 NbS and their impacts

This research has identified different areas where NbS interventions in the city of Malmö and Malaga have potential to have impacts, ranking them according to which challenge areas were being addressed the most by the solutions. With the areas of water management, climate mitigation and adaptation, and urban regeneration being on top of the list, as the impact areas with the potential to be receiving the most benefits from these solutions.

Nonetheless, the research did not measure any of the impacts. What this research has done is to list which challenges from the list are receiving more attention, but it does not necessarily mean that NbS are having a bigger impact on them. The results only show that those three challenges have more solutions dealing with them, but this study has not attempted to measure how big those impacts are. To determine, or estimate, how big the impact is for all ten challenges, a thorough impact assessment should have been undertaken, using indicators to measure them, and making also use of some method to rank them with one another. Unfortunately, such study would have required a much more in-depth and complex study than the one developed for this thesis.

To exemplify how this study is measuring potential implications of NbS and not real impacts, one can think about the challenge *air quality*, for example. This challenge area got 14 NbS addressing it in Malaga, and 27 in Malmö. Nonetheless, as no method was used to measure the real impact that those seven and two NbS are really having on the challenge, the research cannot confidently say that "NbS in Malmö have a greater impact on water management (with 47 NbS initiatives addressing it) than in air quality (where only 27 initiatives were found)". Because those 27 initiatives might very well have a bigger total impact (i.e. the NbS initiatives could be more impactful, or more efficient, or better designed, etc.). Furthermore, it would be also necessary in that case to find a method to compare impacts on different challenges in order to rank them with one another. For example, is it more impactful the effect of a park in providing clean air, or the effect of a lake in absorbing stormwater and reducing the risk of flooding? Of course, economic methods could be used. Calculating how much money the city would save in hospital bills on people being affected by respiratory diseases due to air pollution, against how much money would that reduction in the risk of flooding mean for the city in the case of a flooding event. Those would be questions that should be asked if a study wants to measure impacts and compare them with one another. But one can also wonder if it would be useful to even attempt to make such a comparison.

This study does not intend to show such differences, and it only highlights in which areas NbS show a bigger potential to have certain implications. It would be relevant for future research to take on the next step and measure the actual impacts of NbS in each of the ten challenge areas. Maybe not to rank them with one another, but to have a general idea about what the impacts of these solutions in each category are.

5.3.2 Policy approaches

The data used for this section was mainly sourced from the site visits, the expert interviews and the literature analysis on both cities and their use and implementation of NbS. As was mentioned during *Chapter 1.4. Limitations*, it is worth noting the differences in the nature of the interviews, while in Malmö the interviewees were working directly for the Municipality in sustainable urban planning, most of the interviewees concerning the case of Malaga were academics. A more even distribution of interviewees could have potentially brought different results to the study. Unfortunately, that was not possible for the study at hand.

Governance and planning

The way Malmö is making use of NbS is proving to be efficient and successful, and it could be analysed and used by other cities who want to start making use of these solutions. The system identifies a problem, prepares a plan which involves the use of several NbS working together to fix it, and involves citizens in the development and execution phases of the project to increase their sense of ownership and improve the overall design of the plan. It is simple and straightforward, and it is bringing the expected results to the city.

In the case of Malaga, although the people interviewed were very knowledgeable and experienced in the political situation and tools used by the Municipality, it would have been interesting to gain also the perspective of some policy makers or city planners. That way the view could have been more holistic. Nevertheless, the findings for Malaga also showed that their planning model appears to be changing, especially with the involvement in EU projects. If that trend continues is something that should be examined again in future years.

Drivers and barriers

Regarding the identification of drivers and barriers in both cities, it should be noted that the list is, of course, not exhaustive, and again, a different set of interviews could have shown different results. Involving people from different spheres in the interviews could have probably brought new points of view and perspectives to the analysis. Furthermore, as the number of cases is only two, the identified barriers and drivers might not be relevant for other cities working with the concept of NbS. Nonetheless, the findings could help city planners, researchers or policy makers to have a better understanding of the elements that are moving forward and hindering the development of these solutions in the cities of Malmö and Malaga. Hopefully, that information can be useful to highlight some of the dos and don'ts that should be considered when working with and developing NbS initiatives elsewhere.

6 Conclusions

This section is split in three: key lessons, framework reflections, and lastly, suggestions for future research.

Key lessons

The concept of NbS is clearly a growing one, with an ever-increasing number of research and projects addressing its use and development. Many cities are already applying the concept as a way to transform their urban space, and, at the same time, bring new environmental, social and economic benefits, while – allegedly - enhancing the city's resilience and adaptability to the expected threats of climate change. NbS have proven to be capable of providing a wide variety of positive impacts to urban spaces. This research has identified water management, climate mitigation and adaptation and urban regeneration as the main areas where NbS can have a significant impact in both Malmö and Malaga. And those potential impacts are in consonance with the main environmental challenges identified in both cities, suggesting that NbS are suited to help cities deal with their issues and increase their resilience. Furthermore, with the right design and planning, they can out-compete traditional grey infrastructure. One of the best examples for this is the area of Augustenborg, in Malmö, where the flooding problem disappeared after completely revamping the area with a set of different NbS. The new solutions brought also diverse co-benefits to the area, and it was also estimated to be cheaper than the price a traditional pipe approach would have cost.

In the context of the implementation of NbS initiatives, it is key to develop a plan and have a clear objective in mind, and then select the best set of NbS to achieve that objective. Thus, NbS are more effective when they are used jointly, as they tend to create synergies with each other, and their combined effect can deliver better benefits. The impacts of an individual NbS project might be very small, but the aggregation of several of them can make a difference. For example, while the capacity of a single green roof to store rainwater and reduce runoff and, consequently, the risk of flooding, could be potentially measured at the micro scale of a single building or structure, it will probably not be enough to reduce pressure in the sewer system at the meso (urban) scale – if that is the objective of the project - but a combination of green roofs, green walls, a green area and a detention pond, might be enough to do the work. This understanding of creating and utilising the synergies between different NbS seems to be less developed in the city of Malaga at the moment of writing this thesis, while Malmö has incorporated this approach for the majority of its NbS-related projects.

When assessing the impacts of NbS actions, the use of indicators is fundamental. They enable researchers and policy makers to assess how effective these solutions are at creating positive impacts in cities, and how they perform in comparison to traditional approaches. Here, an economic approach is the most common, such as Cost-Benefit Analysis (CBA), but some of the benefits connected to the impacts of NbS initiatives are usually hard to translate into monetary terms (e.g. health benefits or effects on social justice), and are therefore often excluded from the assessment. Furthermore, it is important to take into account the temporal scale of different NbS, as even though NbS actions usually start to have an effect immediately after implementation, some have a certain delay until they reach their full potential. For example, effects on air quality, which may vary gradually over a certain amount of time, or the water retention power of a newly created green area will small trees, against the same green area 5 or 10 years later, where the trees had time to grow bigger, and the vegetation around is also fully grown.

Framework Reflections

The EKLIPSE framework, created by Raymond et al., (2017), is a useful instrument for practitioners, researchers and policy makers to discover more about the concept of NbS and how these solutions can bring benefits to the urban environment. The ten challenges selected by the framework do a good job at covering all the possible areas where NbS can have a positive impact in urban areas. And as each challenge comes with a list of possible NbS and what are their expected impacts, it can be a very valuable tool for policy makers and governments to learn which specific NbS projects can help them face a certain issue (either environmental, social or economic), and increase their climate resilience. Also, the framework has an extensive list of indicators, with methods to assess the effectiveness of NbS. It is an area where very little research has been made so far, and one of the main added values of this framework is how effectively it compiles different indicators that are scattered in the literature. Putting them all together in a single report.

Nonetheless, some of the challenges have overlaps with one another, as it is common for NbS to have an impact not on one, but several challenges. Therefore, it can be hard at times to differentiate between them (e.g. between 'urban regeneration', 'social justice and social cohesion' and 'public health and well-being'). Also, some of the challenges are less developed than others (e.g. 'coastal resilience' or 'potential for economic opportunities and green jobs'), something understandable considering how NbS is still a concept in development, and more research is needed. This is discussed further in the next section.

Future research

Most research at the moment is devoted to the environmental impacts of NbS, but little attention is being put on researching their potential impacts on the social and economic systems. Also, more focus should be put on studying the potential NbS impacts across different geographic and temporal scales, as these solutions need to be adapted to local conditions, and their effectiveness can change over time. Furthermore, there are still knowledge gaps when it comes to the impacts of NbS on certain challenge areas, such as coastal resilience or their ability to create green jobs and new economic opportunities.

The development and use of indicators, which is currently in its infancy, is one of the key areas for further research. There is a need to develop indicators to assess the effectiveness of NbS on different aspects – environmental, social and economic. Most projects involving NbS at the moment are not being evaluated, and there is little information on how effective – or not – these projects are. Indicators that work across different geographic scales, that are capable of assessing the potential impacts and co-benefits of NbS on different challenge areas, from an either qualitative and/or quantitative perspective. And moreover, develop indicators that allow to easily compare different projects and alternatives. Finding new models to increase community engagement and education of citizens is another area where attention is needed. The success of many NbS initiatives depends on how accepted the projects are by local communities, and what use they give to them. The sense of ownership on the projects among local residents, as well as proper education on how to use and/or maintain NbS projects, may play a big role in the success – or not – of these initiatives.

Last, but not least, NbS can also have negative impacts, along with the positive ones. For example, concerns about possible effects on gentrification, or NbS bringing ecosystem disservices (negative effects of ecosystems on human well-being), such as increased allergies due to pollen, waterborne diseases, insects, etc. Further research needs to address the possible effects of these negative impacts, as well as ways to minimize or, if possible, completely remove them.

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Appendix I. Interviews List

#	Name	Organization	Position	Date
1	Åke Hesslekrans	Malmö Municipality	City planner	12th June
2	Lucia Argüelles Ramos	GreenLULUs	PhD student	15th June
3	M. Mar Trigo	University of Malaga	Professor	11th July
4	Enrique Salvo Tierra	University of Malaga	Professor	12th July
5	Andrés Alcántara	IUCN	Corporate Dept.	12th July
6	Natalia Rojas González	IUCN	Intern	12th July
7	M. Ángel Quesada Felice	University of Malaga	Professor	24th July
8	Pär Svensson	Malmö Municipality	City planner	16th August

Appendix II. Interview Guide

1. **Presentation** – Could you please introduce yourself, and say a few words about your job?
    a. Do you work directly with NbS?

2. **Origin of NbS** - How did the use of NbS start in the city?
    a. Why did the city decide to start making use of these solutions? What were the main drivers for its implementation?

3. **Main examples** – What are some of the primary examples of NbS that can be found today in the city?
    a. How about urban farming? Is it also being used or promoted?

4. **Sustainability challenges** – What are the main sustainability challenges in the city?

5. **Impacts of NbS** - What have been the environmental, social, economic and political impacts of NbS interventions?

6. **Barriers to NbS** – Is there a priority for traditional approaches? What are the main barriers to the diffusion of NbS?

7. **Problems with NbS** – What are the main problems with the use of NbS? (E.g. implementation, maintenance (leakage of green roofs), public acceptance…)

8. **Public participation** – How important is, in your view, public participation for the successful implementation of NbS? How has been participation enabled or supported in the projects in the city?
    a. Are there any studies about public acceptance or preference for these solutions?

9. **Effectiveness** – How is the effectiveness of NbS being measured? (E.g. effects in temperature in the city, reduction on flooding risk, water retention measures…)
    a. Is it being measured, or are there plans to do it in the future?
    b. Is failure being evaluated?

10. **Closure -** Is there anything else you would like to add?

Appendix III. Potential co-benefits and negative impacts across the challenges

Ch	Indicators	Ch 1 Climate Resilience	Ch 2 Water	Ch 3 Coastal Resilience	Ch 4 Green space	Ch 5 Air quality	Ch 6 Urban regeneration	Ch 7 Particip planning & governance	Ch 8 Social justice & cohesion	Ch 9 Public health & well-being	Ch 10 Economic opps & green jobs
Ch 1	Carbon sequestration	*	+	O	+	+	+	O	O	O	
Ch 1	Temperature reduction	*			+	+				+	
Ch 2	Flood peak reduction		*	+	+		O	O	O	+	+
Ch 2	Increasing ground water quality		*		+			O	O		
Ch 3	Erosion protection			*	+		O	O	O		+
Ch 3	Enhanced recreation			*	+			O		+	O
Ch 4	% of citizens living within a given distance from accessible, public green space		O		*	+	O	O	+	+	+
Ch 4	Increased species richness				*	O		O		O	+
Ch 5	Amount of pollutants captured by vegetation		+		+	*		O	O	+/-	+
Ch 5	Premature deaths and hospital admissions averted				+	*	+		O	+	O
Ch 6	Urban food production		O		+		*	O	O	+	+
Ch 6	Increased ecological connectivity				+	O	*	O		O	O
Ch 6	Energy efficiency: building layout and design		O		+		*	O	O	+	+
Ch 7	Legitimacy of knowledge in participatory processes			+	+	+		*	*	O	O
Ch 7	Social values for urban ecosystems and biodiversity	+					O	*	*	O	
Ch 8	Being able to move freely and safely from place to place				+		O	O	*	O	O
Ch 8	Attachment to neighbourhood				O				*	+	
Ch 9	Reduction in chronic stress and stress-related diseases				O		O	O	O	*	O
Ch 9	Reduced percentage of obese people				O			O		*	O
Ch 10	Number of jobs created				+				+	+	*
Ch 10	Increase in property prices				+		-		+/-		*

Key: Ch = challenge; * Main challenge addressed; + Co-benefits that will follow; **O** Opportunities that could be taken; - Potentially negative impacts or disservices

Source: Raymond et al., (2017)

Appendix IV. Green Points System

1. A bird box for every apartment
2. A biotope for specified insects in the courtyard
3. Bat boxes in the courtyard
4. No surfaces in the courtyard are sealed, and all surfaces are permeable to water
5. All non-paved surfaces within the courtyard have sufficient soil depth and quality for growing vegetables
6. The courtyard includes a rustic garden with different sections
7. All walls, where possible, are covered with climbing plants
8. There is 1 square metre of pond area for every 5 square metres of hard-surface area in the courtyard
9. The vegetation in the courtyard is selected to be nectar rich and provide a variety of food for butterflies (a so-called 'butterfly restaurant')
10. No more than five trees or shrubs of the same species
11. The biotopes within the courtyard are all designed to be moist
12. The biotopes within the courtyard are all designed to be dry
13. The biotopes within the courtyard are all designed to be semi-natural
14. All storm water flows for at least 10 metres on the surface of the ground before it is diverted into pipes
15. The courtyard is green, but there are no mown lawns
16. All rainwater from buildings and hard surfaces in the courtyard is collected and used for irrigation
17. All plants have some household use
18. There are frog habitats within the courtyard as well as space for hibernation
19. In the courtyard, there is at least 5 m^2 of greenhouse for each apartment
20. There is food for birds throughout the year within the courtyard
21. There are at least two different old-crop varieties of fruits and berries for every 100 square metres of courtyard
22. The facades of the buildings have swallow nesting facilities
23. The whole courtyard is used for the cultivation of vegetables, fruit and berries
24. The developers liaise with ecological experts
25. Greywater is treated in the courtyard and reused
26. All biodegradable household and garden waste is composted
27. Only recycled construction materials are used in the courtyard
28. Each apartment has at least 2 square metres of built-in growing plots or flower boxes on the balcony
29. At least half the courtyard area consists of water
30. The courtyard has a certain colour (and texture) as the theme
31. All the trees and bushes in the courtyard bear fruit and berries
32. The courtyard has trimmed and shaped plants as its theme
33. A section of the courtyard is left for natural succession
34. There should be at least 50 flowering Swedish wild herbs within the courtyard
35. All the buildings have green roof