Universidade de Aveiro Departamento de Ambiente e Ordenamento
2019

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Impactes, custos e benefícios de soluções baseadas na natureza para a adaptação urbana às mudanças climáticas

Multiple impacts, costs and (co-) benefits from nature-based solutions for urban climate change adaptation

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Multiple impacts, costs and (co-) benefits from nature-based solutions for urban climate change adaptation

Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Engenharia do Ambiente, realizada sob a orientação científica do Professor Doutor Peter Roebeling, Equiparado a Investigador Auxiliar no Departamento de Ambiente e Ordenamento da Universidade de Aveiro e co-orientação do Doutor Ricardo Martins, Investigador Doutorado no Departamento de Ambiente e Ordenamento da Universidade de Aveiro.

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palavras- chave

Soluções baseadas na natureza; alterações climáticas; urbanização; dano de cheias; valorização do mercado imobiliário

Resumo

O desenvolvimento urbano contínuo e rápido trouxe mudanças nos padrões de uso do solo, tendo ocorrido uma grande conversão da paisagem natural em urbana e uma impermeabilização dessas superfícies. Isso trouxe problemas de diferentes níveis que se tornaram exacerbados com as mudanças climáticas: aumento do risco de inundações, "ilhas urbanas de calor", aumento da concentração de poluentes atmosféricos e declínio da qualidade de vida. As soluções atuais para a adaptação aos desafios urbanos geralmente exigem mudanças na paisagem, manutenção e desvalorizam ao longo do tempo. As soluções baseadas na natureza (SBN) vieram como soluções eficientes e amigas do ambiente que, além de agregar valor à estética da paisagem urbana, podem ajudar a mitigar e adaptar as cidades aos desafios das mudanças climáticas e da urbanização. O objetivo desta tese é avaliar os múltiplos impactos, custos e benefícios da implementação das SBN, com um foco específico nos danos causados pelas inundações, expansão e gentrificação urbana e valorização do mercado imobiliário. Para este fim, dois modelos da *Systemic Decision Support Tool* (SDST) são usados para avaliar os impactos da SBN sobre o risco de inundação (usando o InfoWorks) e sobre o mercado imobiliário (usando o SULD). Um caso de estudo é fornecido para a cidade de Eindhoven, na Holanda. Os resultados mostram que a implementação de soluções baseadas na natureza conduz a um aumento do valor imobiliário (+6,1 M€/ano) devido à melhoria da estética do meio urbano e tem também um impacto nos danos causados pelas inundações, atuando na mitigação das inundações e reduzindo os custos dos danos (-27,4k€/ano).Para além das suas principais funções, as SBN mostram também um efeito nos padrões de distribuição da população, favorecendo a densificação urbana em detrimento dos processos de expansão urbana.

keywords

nature-based solutions; climate change; urbanization; flood damage; real estate valuation

Abstract

The on-going and fast-urban development brought along changes in land-use patterns having resulted in a major conversion of natural landscapes into urban ones and a subsequent impermeabilization of surfaces. This came with problems of different dimensions which are expected to be exacerbated by climate change: increased flood risk, “urban heat islands”, increased air pollution and reduced quality of life. Current ‘hard’ engineering solutions to adapt to urban challenges usually require landscape changes, maintenance and depreciate over time. Nature-based solutions came as efficient and eco-friendlier solutions that besides adding value to urban landscape aesthetics can help mitigate and adapt cities to climate-change and urbanization challenges. The objective of this thesis is to evaluate the multiple impacts, costs and benefits of NBS implementation, with a specific focus on flood damage and sprawl, gentrification and real estate valuation. To this end, two models of the Systemic Decision Support Tool (SDST) are used to assess the impacts of NBS on flood risk (using InfoWORKS) and sprawl, gentrification and real estate valuation (using SULD). A case study is provided for the city of Eindhoven in the Netherlands. Results show that the implementation of nature-based solutions leads to an increase in real estate values (+6.1 M€/yr) due to upgraded aesthetics and has an impact on flood damages acting on flood mitigation and reducing damage costs (-27.4 k€/yr). Besides its main functions, NBS also show an effect on population distribution patterns – favouring urban densification over urban sprawl processes.

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Abbreviations

AR – Attributable Risk

CPI – Consumer Price Index

CRF- Concentration-Response Function

CVD – Cardiovascular Diseases

COPD – Chronic Obstructive Pulmonary Diseases

ES – Ecosystem Services

EU – European Union

GI – Green Infrastructure

GIS – Geographic Information System

HA – Hospital Admissions

IPCC – Intergovernmental Panel on Climate Change

IR – Inflation Rate

Inhab – Inhabitants

NBS – Nature Based Solutions

NO_2 – Nitrogen Dioxide

PM2.5 – Particulate Matter (diameter of 2.5 μm or less)

PM10 – Particulate Matter (diameter of 10 μm or less)

RR – Relative Risk

SDST – Systemic Decision Support Tool

VOLY – Value Of a Life Year

YOLL – Year Of Life Lost

VSL – Value of a Statistical Life

1.Introduction

1.1 Problem setting

The promise of better jobs and business opportunities as well as economic and social benefits, such as higher levels of education, effective healthcare and greater access to social and cultural services, has driven populations to move from rural to urban areas in search of a better lifestyle and quality of life. The migration of the population from rural to urban areas leads to an expansion and growth in size of the cities, requiring more land and space to accommodate this population. Currently the percentage of people living in urban areas (54%) exceeds the population living in rural areas, and the future tendency is not only the growth of the overall population but also the increase of the urbanization – with two-thirds of the world´s population living in urban areas by 2050 (see Figure 1) (United Nations, 2014), resulting in an sprawl/densification of urban areas (Haaland & van den Bosch, 2015).

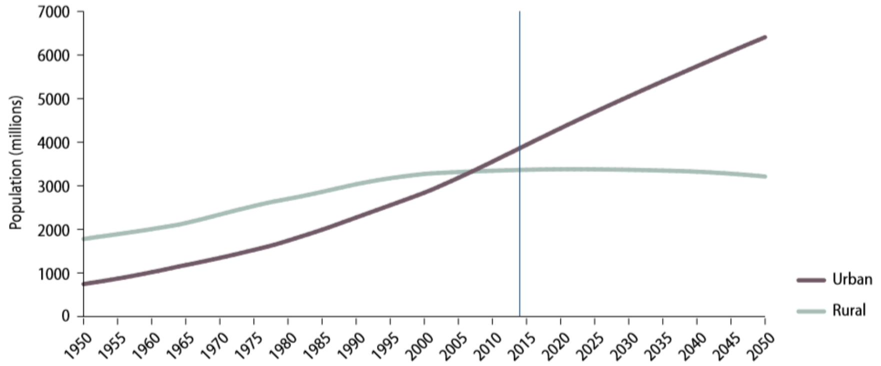

Figure 1- Urban and rural population in the world over the period 1950-2050, as projected by the UN World Urbanization Prospects (United Nations, 2014)

The economic growth of cities leads to a continuous growing of the population, migration to urban areas and expansion of the industry putting at stake the cities' capacity to deal with the increasing demands and incoming pressures on water resources supply and management. This phenomenon induces a conversion of green and agricultural areas, as well as natural wetlands, into urban ecosystems, resulting in a waterproofing of the urban surface in which pollutants from anthropogenic activities (nonpoint source pollution) are accumulated and runoff into the streams, thus affecting and degrading water quality (Ren et al., 2003; Jung et al., 2016). The increase of these impervious surfaces leads to a decline on the soil natural capacity to infiltrate and store water, thus resulting in surface runoff and higher flooding risk frequencies (Chan et al., 2018).

Urban areas also affect and change local climate as compared to rural areas, as they present a quite different climate dynamic. The urban medium is composed by a high percentage of radiation-absorbing materials and in combination with the increase in anthropogenic heat sources, due to human activities and energy consumption and the lack of green infrastructure, this results in a significant increase in temperature relative to the surrounding rural areas (Seto et al., 2011).

Nowadays numerous cities struggle to keep their air quality standards to levels in a way of not causing harmful impacts on the health and environment. The major contributor for the poor air quality within the cities is anthropogenic emissions derived from urban population and economic growth of cities, causing the consequent increase in the emission and concentration of air pollutants, among them: ozone (O3), carbon monoxide (CO), sulphur dioxide (SO2) and particulate matter with an aerodynamic diameter less than 2,5 µm (PM2.5) and 10 µm (PM10) (Nowak et al., 2018 ; Zhou et al., 2018).

The lack of proper and sufficient green/blue infrastructure through the urban space, makes these types of amenities valuable for its residents, influencing buyers' choices when choosing a property, consequently impacting the local real estate market (Mayor et al., 2009).

Although there are advantages of urban areas over rural areas in several aspects (economy, healthcare, education, etc), urban living conditions and quality of life are deteriorating over time due to the lack of adequate infrastructure, policies and a strong and solid urban planning (United Nations, 2014).

Current cities are vulnerable and unprepared to deal with climate change, so there is an emergent need for urban areas to adapt and become more resilient to climate change and on-going urbanization impacts (Haase, 2015). At the same time, there are opportunities to address the challenges that threat cities' sustainability by ensuring a better resource efficiency and protecting them against unwelcome foreseeable future changes (European Commission, 2015).

So far, the adaptation and mitigation to climate change has been relying on grey infrastructure or technological solutions. Grey infrastructures are engineered, and physical structures/systems made by long-lasting materials, which usually can be monitored, replicable and controlled over time and usually require limited amount of land. These infrastructures usually are conceived for a limited set of specific functions and may include “dikes, floodgates, sea walls and breakwaters for riverine and coastal flood protection, drainage systems for storm water management such as storm sewers, pipes, detention basins” (Depietri & Mcphearson, 2017). These types of solutions usually require maintenance, have significant changes in the landscape, are difficult to adapt to changing conditions, have high implementation costs moreover, they can depreciate in performance over time and may have also some environmental impacts (WRI, n.d).

Nature-based solutions (NBS) are solutions developed to cope with sustainabilty challenges which are inspired and based in natural processes that are locally adaptable, resource-efficient and help build up resilience in cities (Fini et al., 2017). NBS sustain itselves and rely on ecossystems’ functioning as the fundamental part and pillar for climate change adaptation and mitigation (European Commission, 2015). Hence, the implementation of NBS, green and blue infrascture in urban areas - green roofs, floodplain restoration, green urban spaces, street trees, constructed wetlands, pervious pavement, etc., (Depietri & Mcphearson, 2017; Lafortezza et al., 2018; Sörensen, 2018) has been increasing in order to adress the challenges and pressures that threatens society, being this solutions recognised for their capacity of not only *“protecting, sustainably managing and restore natural or modified ecosystems”* (Walters et al., 2016) but also to perform different functions and generate additional environmental, economic and social benefits simultaneously and over time (Kabisch et al., 2016). When comparing gray to green infrastructure most studies show the last to be the most cost-effective and flexible when coping with urban challenges, acting on several issues at the time and contributing for urban environment restoration with a positive impact on the urban landscape (Daigneault et al., 2016; Depietri & Mcphearson, 2017; Winkelman, 2017)

1.2 State of knowledge

Through the literature review it was possible to infer that, so far, the majority of the studies partly assess the impacts, costs and/or (co-benefits) of NBS implementation, focusing individually on one or two of these, existing few or no studies doing a simultaneous and integrated analysis which assesses the multiple impacts, costs and/or (co-) benefits. This gap in knowledge gives purpose for the definition of our research objective.

1.3 Objective

The overall objective of this research is to perform an integrated and systematic evaluation of the multiple ecosystem services' impacts, costs and (co-) benefits from NBSs for global change adaptation to urban challenges, with a specific focus on flood damage and sprawl, gentrification and real estate valuation. In order to map those effects, the NBS is applied and monitored in "urban living labs"- being also these effects modelled and calculated in disciplinary models such as InfoWORKS and SULD that are integrated in the Systemic Decision Support Tool (SDST).

The specific objective of this study is the economic quantification of the NBS scenarios impact at a landscape scale on the different urban challenges referred throughout this report (flood damage and real estate valuation) and its contribution to the SDST with the respective costs and/or benefits associated with them individually and the total gains (see additional box on right-hand-side of Figure 2).

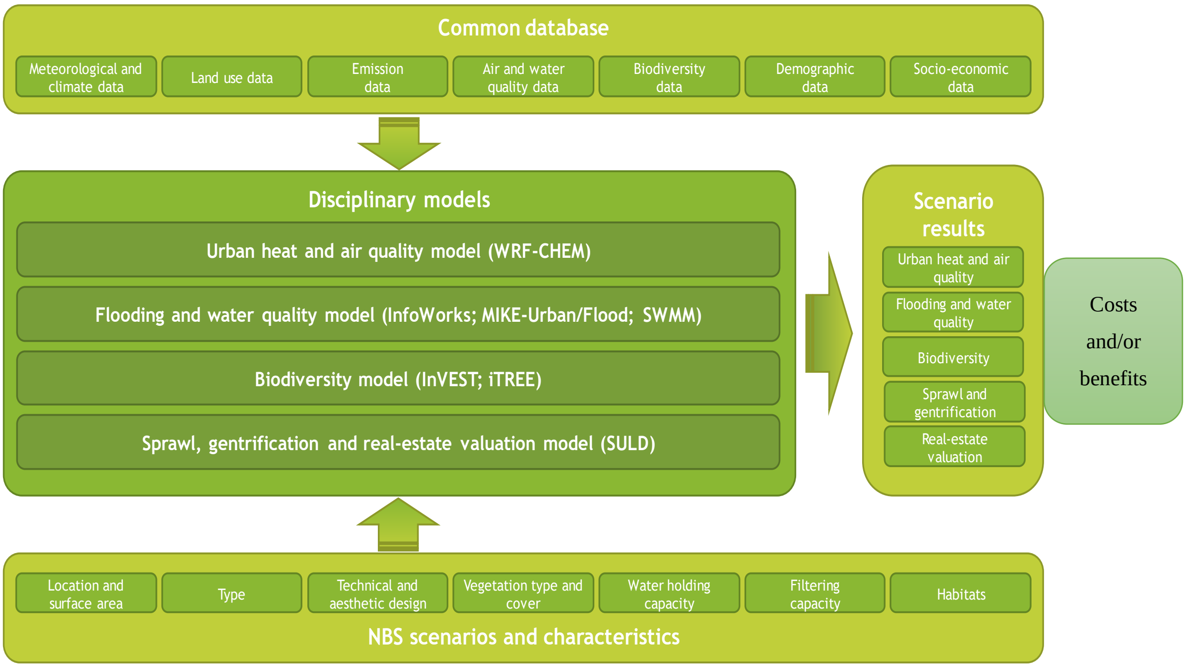

Figure 2- Schematic representation of the SDST in which will be included the quantification of the associated individual costs/benefits applied to four of the urban challenges addressed by the SDST (urban heat, air quality, flooding and water quality)individually and the total gains

To this end, the two models in the SDST will be used. The SDST integrates data and information from different disciplinary models into a spatially explicit system at the landscape scale, as well as NBS characteristics like the type, location and dimensions to assess the impacts, costs and (co-) benefits of NBSs on flooding (e.g. InfoWORKS) and real state valuation (SULD). The approach will be applied to the case of NBS scenarios proposed by the Municipality of Eindhoven in The Netherlands.

After achieving this objective, solid scientific information will be generated and integrated in a guideline manual for cities around the world, providing convincing arguments and allowing stakeholders and decisions makers to be more involved and take more conscious and informed decisions and actions about the implementations of NBS.

This study is developed within the UNaLab project framework (http://www.unalab.eu/). This project aims to develop "via co-creation with stakeholders" a reliable, "innovative, replicable and locally-attuned" EU reference framework for urban-based solutions implementation in order to address the challenges derived from climate change and ongoing urbanization that cities are facing worldwide and help built up and enhance their resilience to this problems.

UNaLab's three pilot cities, Tampere, Eindhoven and Genova**,** will serve as urban living labs, implementing different NBS within their areas, demonstrating and giving feedback about the benefits, co-benefits and costs, acting as guides for a larger scale replication in other cities.

1.4 Outline

This dissertation is divided in six sections including this one. The following section presents an overview of the literature on the impact, benefits and simultaneously co-benefits of nature-based solution implementation, through ecosystem services, and the evaluated socio-economic costs of the previous mentioned urban challenges (urban heat, air pollution, flooding and sprawl), associated with no intervention or lack of adapting measures such NBS. Keywords and search terms used to identify literature in search engines (*Scopus*, *Google Scholar* and *Science Direct*) were for example NBS, benefits, co-benefits, ecosystem services, air pollution, healthcare costs, costs, economic impact, etc.

In Section 3, the methods used to reach the initial objective are described such as i) environmental assessment – modelling the emissions (infoWORKS and SULD); ii) impact assessment – which damages are been caused and lastly iii) compilation of damage-cost or dose-response functions linking the physical impacts with the economic costs.

In Section 4, the case study for the city of Eindhoven is described – i) presentation of the current challenges that the city is dealing with, ii) city-based NBS scenarios to be applied in the simulations and iii) the relevant and useful data for the city (socio-economic and bio-physical characteristics) to be compiled in the working models (infoWORKS and SULD).

In Section 5 the outcome results from the different simulations performed in the two models integrated in the SDST is presented and simultaneously discussed through available literature, namely the real costs for the baseline situation and the comparison with the scenarios of NBS implementation for the several urban challenges.

The last two sections, conclusions and future recommendations represent, respectively the final considerations of the dissertation and improving suggestions for future research.

2. Literature review

This section provides an overview of partial NBS impacts studies, and its costs and co-benefits focussing on urban heating (Section 2.1), air pollution (Section 2.2), urban flooding (Section 2.3) and urban densification (Section 2.4).

2.1 Urban heating

2.1.1 Context

The lack of vegetation on urban areas, the input of anthropogenic heat as well as the cities' coverage and impermeabilization with artificial materials, among other factors leads to changes in the absorption and reflection of solar radiation resulting in alterations in surface albedo and in the surface energy balance, ensuing raised urban temperatures. This increased in air temperatures is specially noticed in urban areas and in most cases differences in temperature between these areas and the surrounding countryside are remarkable, being defined as "urban heat island effect". These changes in a micro scale environment lead to changes in the global macro climate (Bowler et al., 2010).

Retrofitting existing buildings and covering their envelope (walls and roofs) with vegetation and "greening the city" creates a potential to lower urban temperatures, in opposition with the traditional urban coverage materials like concrete which promptly absorb and retain heat from solar radiation (Bowler et al., 2010). According to Spronken-Smith & Oke (1998), Chen & Wong (2006) and Bowler et al. (2010) inside green spaces occurs a temperature reduction of about 1 ºC to 2 ºC (on average) and a reduction of 1 ºC to 3 ºC in water surfaces throughout an area of 30 to 35 m of extent (comparing with the surroundings during daytime) showed in studies by Hathway & Sharples (2012), Kleerekoper et al. (2012) and Žuvela-Aloise et al. (2016), being the temperature relationship with de-paved areas not clear yet.

Nastran et al. (2018) states that the cooling effect of urban green infrastructure presents a better efficiency in a range from 200 to 400m depending on their shape, type of vegetation, existence or not of irrigation, canopy cover structure, configuration, area and spatial distribution (Oliveira et al., 2011; Feyisa et al., 2014). In general aggregated and larger green spaces are preferential over small and distributed ones dealing with UHI effect (Nastran et al., 2018).

Hence green infrastructure in a form of as green walls, green roofs, urban forests, parks etc. can be incorporated onto cities urban fabric, providing as the main service the cooling of the urban environment. This type of infrastructure provides also other ecosystem services as co-benefits such as i) energy savings for cooling and outdoor / indoor thermal comfort, ii) improving air quality, iii) increasing human wellbeing and iv) health benefits as represented in Table 1.

Table 1 - Compilation of studies that prove the impact of NBS implementation on temperature and its respective co-benefits

NBS	***Study***	***Area***	***Impact***	***Co-Benefits***
Green Roofs and Green Walls Combination	(Alexandri & Jones, 2008)	Brasília (Brazil); Hong Kong (China)	Temperature reduction and mitigation of the "urban heat island"	Energy savings and Outdoor and indoor thermal comfort (1)
Green Roofs	(Ziogou et al., 2018)	Cyprus		Energy savings; Improving air quality (reduction of indirect CO2, NOx, and SO2 emissions) (2)
Urban Green Spaces	(Panno et al., 2017)	Milan (Italy)		Human Wellbeing (3)
Urban Green and Blue Spaces	(Kabisch et al., 2017)	-		Health Benefits (4) (specially for vulnerable groups as children and elderly)
Parks	(Feyisa et al., 2014)	Addis Ababa (Ethiopia)		Carbon storage, reduced air pollution; urban biodiversity hotspots; enhancing human well-being
Green Spaces	(Oliveira et al., 2011)	Lisbon (Portugal)		Reduction in energy consumption; CO_2 uptake; reduction of air pollution and noise levels and positive effects on human health

2.1.2 Impact Assessment

Cities are particularly sensitive and vulnerable to heat waves, having this increase in extern ambient temperature a repercussion on its own economies – in particular, in relation to: i) healthcare, ii) productivity and iii) energy consumption/thermal comfort.

Healthcare

As global climate change is continuously making itself noticed through the years (with temperatures well above historical normal ones), urban centres are being particularly affected by urban heat islands (UHI) effect (due to urbanization and industrialization processes), this phenomenon tends to enhance the warming status, consequently leading to an increase in the intensity, frequency and duration of heatwaves (extended periods of extreme temperatures) also, the setting of record high temperatures has being observed worldwide (Tan et al., 2010; Kenney et al., 2014).

Much information and several studies have been proving the heat impacts on human health and how temperatures above a certain threshold may negatively affect human body by thermal stress (Kovats & Hajat, 2008). Although humans have the capacity to adapt and survive through relatively small changes in mean ambient temperatures and even at extremely high temperatures for short periods of time, an extended exposure to these temperatures puts at a significantly pressure the cardiovascular system leading to concerning health damages, associated with thermoregulatory responses to heat stress. Elderly individuals (≥ 50years) are the most vulnerable age group for a range of physiological reasons with emphasis in their limited ability to thermoregulate their body temperature, and with a projected aged population rapidly growing the number of people at risk will be affected by an expected increase of heatwave frequency in the future (Kenney et al., 2014).

Vulnerability and sensitivity to heat is influenced by several factors in an urban context, such as i) build-up level of the area, ii) the age and sex group, iii) individual physiological status and iv) socio-economic status and living conditions (Kenney et al., 2014).

The mortality rate (all causes – particularly respiratory and cardiovascular system failure) substantially increases during a heat wave (exponentially with the maximum temperature). Heat-related mortality (all-cause deaths above the baseline temperature) is usually higher in inner part of urban areas (city centre) than the peripherical ones (sub-urban/rural areas). Due to the UHI witnessed in cities (which intensifies heat wave effects), urban population is more likely to suffer with this phenomenon, experiencing thermal stress both day and night due to the ability of build-up surfaces to easily heat up during the day and slowly releasing heat during the night, magnifying also night temperatures (Tan et al., 2010).

The August 2003 heat wave in Europe centred in France, where the greatest mortality impact occurred, accounted for an increase of mortality of 40% in France alone and 15000 excess deaths all over Europe, with 90% increase mortality in the elderly at some cases (see Table 2) (Kenney et al., 2014).

Table 2 - Excess mortality attributed to hot summer/heat waves period in Europe adapted from (Haines et al. (2006)

Heat Wave Event	***Excess Mortality (all-cause deaths above the baseline) [number of deaths/% increase]***
1981, Portugal	1906 deaths (406 deaths in Lisbon)
1983, Rome – Italy	35% in July
1987, Athens – Greece	>2000 deaths in heat wave period (21-31 July)
1991, Portugal	997 deaths in heat wave (12-21 July)
2003, France	14,802 deaths (60%) in heat wave (1-20 August)
2003, England and Wales	2091 deaths (17%) in heat wave period (4-13 August)
2003, Spain	4151 deaths (11%) in July and August
2003, Portugal	1854 deaths (40%) in August
2003, Switzerland	975 deaths (6,9%) in June-September period
2003, Italy	3134 deaths (15%) in all Italian capitals (1 June- 15 August)
2003, Germany	1410 deaths (heat wave 1-24 August)
2003, Netherlands	1400-2200 deaths (3-5%) in June- September period

Productivity

There are documented psychological and physical effects on the human body related to high temperatures exposure, which results in a reduced work capacity, thus in a lower productivity in several workplaces where a cooling system cannot be applied (Lundgren Kownacki, 2018).

In some countries (with low baseline temperatures), rising temperatures may increase labour productivity, but for the bigger part of them and at global scale a negative relationship is expected (Day et al., 2018).

Literature shows a clear decrease on labour productivity, as the temperature exposure rises above a certain limit (around 25 °C) and indicates a direct proportionality with the increase of temperature and the loss of productivity once the limit value is breached as showed in Figure 3 bellow.

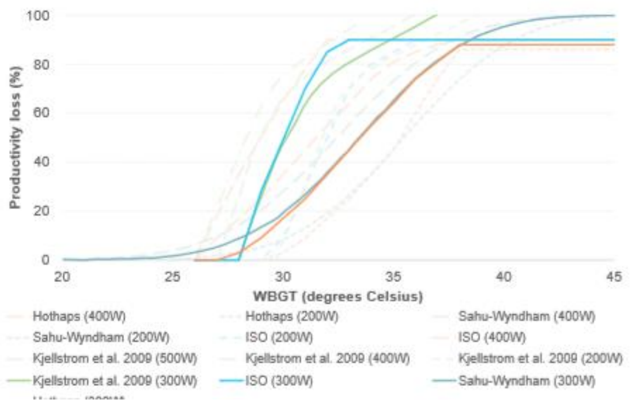

Figure 3- Relationship between temperature increasing and productivity loss (Vivid Economics, 2017)

With the permanent heat exposure, workers need either to reduce the working hours or to reduce their work intensity, which affects the hourly productivity and resulting "labour productivity loss" and having a significant impact on the economy (Dear, 2018).

According to the Climate Vulnerability Monitor Report (2012) "Labour productivity is estimated to result in the largest cost to the world economy", being the heat induced costs estimated to be approximately US$2 trillion in 2030. The costs for adapting are high and required a specific approach to each city circumstances, but the alternative of not acting on it results in higher costs related to the deteriorating health of workers, cooling costs and lower business competitiveness (DARA, 2012; Costa et al., 2016).

Energy consumption/Thermal Comfort

The temperature increases within the urban environment as well as the global temperature rise due to climate changes, creates a necessity to look for alternatives to face temperature changes. Power generation and in particular electricity, is one of the sectors that accounts for the largest greenhouse emissions, and as cooling beeing powered by electric devices, namely air conditioning devices, a warmer atmosphere may lead a shift in the energy demanding from heating devices (in winter/lower temperatures) to cooling ones (summer/higher temperatures).This energy shift has an impact on the intensification of the "urban heat island" effect on the urban medium but also at a global scale (Töglhofer et al., 2012).

Electricity demand and consumption have a relationship with meteorological variability and ongoing climate changes, being the air temperature factor the leading climate variable in this relationship. Higher temperatures involve an higher demand on energy for cooling in order to meet indoor thermal comfort requirements with likely increase of air conditioning systems use within the buidlings, expecting an increase in energy demand at a temperature around 22ºC (see Figure 4) (Lundgren & Kjellstrom, 2013). Temperature values ranging from 15ºC to 20ºC does not have a significative influence in electricity demands (Apadula et al., 2012).

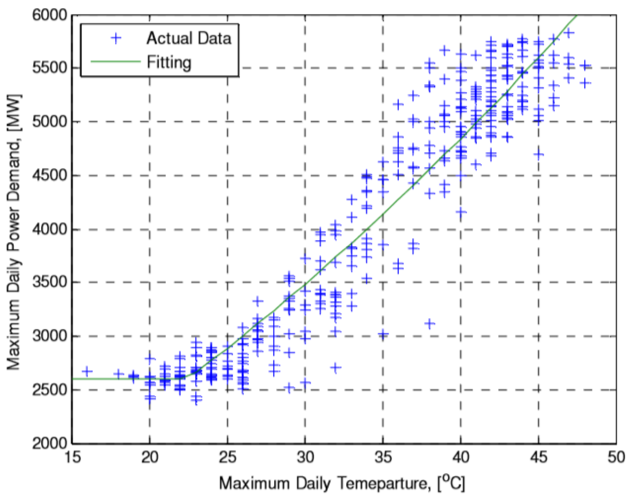

Figure 4– Relationship between temperature and energy demand in Qatar (Gastli et al., 2013)

Usually the type of energy used for heating in the winter (cold seasons) relies mostly on fossil fuels (e.g. wood) while the type of energy used for cooling in the summer (hot seasons) relies mostly on electricity (e.g. AC) (Fu et al., 2015). Urban heat islands seriously impact the energy consumption and corresponding energy peak demand through electrical devices used for indoor space cooling (Wang et al., 2016). Residential ACs are the number one link between temperature and electricity increases and may accounted for about 30% of the peak consumption during heat waves/periods as a study showed in the city of Madrid (Lundgren & Kjellstrom, 2013).

In order to in fact analyse the relation between excess cooling energy demand in summer due to UHI effect, the degree-hours calculation method was used to define this relation through the total number of cooling degree-hours (CDH) variables in linear form (Vardoulakis et al., 2013)

$$CDH = \sum_{j=1}^{N} (\overline{t_0} - t_{bal}) \tag{1}$$

Where, $\overline{t_0}$ is the hourly mean outdoor temperature of the station, *tbal* is the building base temperature and N the number of hours within a month.

Cooling-degree hours give the indication of days of building cooling energy consumption required according to the outside temperature within a month and for a specific location where outside temperature exceeds a site specified base temperature. The building base temperature depends on construction characteristics, use and type (Designing Buildings wiki, n.d).

2.2 Air pollution

2.2.1 Context

Industry growth and development has been accompanied by rapid economic growth followed by a rapid urbanization within cities with more people living in the same previous space. This generates an increase in human activities which release a wide range of emissions into the urban environment, causing a rise in the concentration of air pollutants in the outdoor ambient when comparing with the rural surrounding areas and other natural ecosystems (Han et al., 2014).

Air pollution in cities represent one of the biggest challenges of this century, posing its exposure risks and severe implications for human health besides having a negative impact on the environment, particular attention and concern has been given to ground level ozone (O3) and particulate matter with an aerodynamic diameter under 10 µm (PM 10) and 2,5 µm (PM 2.5) (Miranda et al., 2016).

Trees and vegetation play an important role concerning air quality, removing air pollutants mainly through the process of dry deposition and interception of particles and the uptake of gases by the stomata, thus reducing air pollution (Rocha et al., 2019). Vegetation can also influence air temperature, human health and well-being and building's energy costs among other additional benefits (see Table 3).

Table 3 - Compilation of studies that prove the impact of NBS implementation on air quality and its respective co-benefits

NBS	***Study***	***Area***	***Impact***	***Co-Benefits***
Green Spaces	(Rocha et al., 2019)	Lisbon, Portugal	Regulating Air Quality	Microclimate Regulation; noise reduction, flood risk reduction
Green Roofs and Living Walls	(Viecco et al., 2018)	Semiarid Climates		Building's energy savings, promoting biodiversity, controlling water run-off, mitigating urban heat island effect
Trees	(Selmi et al., 2016)	Strasbourg, France		Recreation, cultural, aesthetic, regulation of temperature; carbon sequestration
	(Nowak et al., 2018)	Canada		Air temperature reductions, human health improvements
Urban Forests	(Baró et al., 2014)	Barcelona, Spain		Global climate regulation, urban temperature regulation, noise reduction, runoff mitigation, and recreational opportunities

2.2.2 Impact assessment

The health impacts of outdoor air pollution are mainly expressed in two indicators (mortality and morbidity) derived from long-term and short-term exposure of air pollutants. Mortality refers to non-accidental premature deaths and reduction in life expectancy; morbidity refers to illness occurrence thus hospital admissions, years of life dealing with a disability/ year of life with limitations due to the disease, workdays and productivity loss, etc.

The harmful impacts of outdoor air pollution in human health have been described in several studies that link these air pollutants with respiratory and cardiovascular diseases, among these, lung cancer, acute lower respiratory infection, strokes, ischaemic heart disease and chronic obstructive pulmonary disease, etc. showing a relationship of outdoor air pollution with the increase morbidity (illness/hospital admissions) and premature mortality worldwide, being elderly people and children the most vulnerable groups to it (WHO, 2018). Health outcomes linked to air pollution that can be noticed after short exposure periods result in acute effects, while a long-term exposure results in chronic effects (Rafael et al., 2018). According to OECD a prediction of premature deaths caused by outdoor air pollution (specifically PM and ozone) is expected to triple until 2060 from 2010 values, being significantly higher in developing countries like India and China which are have high population density (see Figure 5) (OECD, 2016).

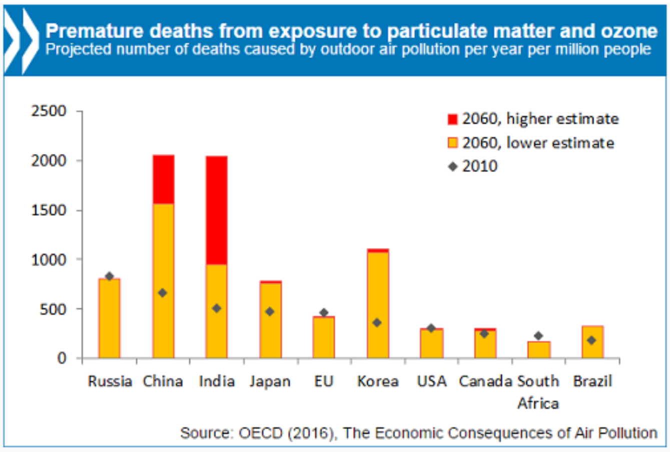

Figure 5- Number of premature deaths per year and per million people caused by outdoor air pollution (particulate matter and ozone) in 2010 and its estimation for 2060 for different countries (OECD, 2016)

The standard economic valuation methodology for morbidity is made based on "cost-of-illness" (COI) approach which estimates the costs of hospital admissions and medical and non-medical resources to treat a disease and productivity and production losses due to illness and does not consider non market values (e.g. pain and suffering) (Silveira et al., 2015) and for mortality, it is used the "value of a life year" (VOLY) monetary approach, (WHO, 2015).

Concentration-response functions (CRFs) linking PM_{10}, $PM_{2.5}$ and NO_2 concentrations exposure with health outcomes (morbidity and mortality indicators) at a population level given as relative risk (*RR*) are recommended in the HRAPIE project for those pollutant-outcome pairs where an evidence of an association of the pollutant with a health outcome previously concluded in the REVIHAAP project for an impact and cost assessment of outdoor air pollutants (PM_{10}, $PM_{2.5}$ and NO_2) considering specific conditions in the EU countries, concentrations expected by 2020 and the availability of baseline health data (Héroux et al., 2015).

The relative risk (*RR*) or risk ratio is based on epidemiological studies and it is the "ratio of the probability of an event occurring in the exposed group versus the probability of the event occurring in the non-exposed group", where if the risk is higher than 1 means that the risk of the outcome is increased by the exposure and defined at population level (Tenny & Hoffman, 2019).

The following equation (De Leeuw & Horálek, 2016) gives us the RR:

$$\boldsymbol{RR = exp[B(C - C0)]} \qquad \textbf{(2)}$$

Where *B* is the concentration-response factor, *C* is the estimated average concentration and *C0* is the reference concentration.

The formulation for the number of unfavourable implications (Silveira et al., 2015) is given:

$$\boldsymbol{\Delta R = IR_i \times CRF_{i,p} \times Cp \times pop} \qquad \textbf{(3)}$$

Where, ΔR is the the number of the unfavourable implications (cases, days or episodes) over all health indicators (e.g. number of premature deaths, days of hospital admissions, etc.) due to outdoor air pollution, IR is the annual baseline rate of the given health effect *i* (%) for both sex groups and for all ages (assumed to be constant over the country), *CRF* is the concentration-response function which is the correlation coefficient between the pollutant *p* concentration variation and the probability of experiencing a specific health indicator *i*. The

CRF is related with the Relative Risk (RR) (%). For example, *RR* for premature mortality due to $PM_{2.5}$ exposure within people above 30 years old is 1,062 per 10 μg/m^3, which means that, assuming linearity, for an increase in 10 μg/m^3 of $PM_{2.5}$, the total mortality increases by 6,2 % in the exposed population. Finally, *Cp* indicates the pollutant *p* concentration (μg/m^3) before and after the adoption of NBS, calculated using WRF-Chem and *pop* is the population units exposed to the pollutant *p*.

The concentration-response functions (CRF) are described in Tables 4, 5 and 6 for three outdoor air pollutants: PM10, PM2.5 and NO_2 respectively, recommended from the HRAPIE project (WHO, 2013).

Table 4 – Health effects related with PM10 exposure, concentration-response functions (CRF) and of respective economic valuation (base costs €2015)

Health Endpoint	***Age Group***	***Exposure Period***	***Relative Risk (95% CI) per 10μg/m³***	***Reference Costs (€/unit)***	***Unit***	***References***
Total mortality (all-causes)	< 1 year	Long-term	1.04 (1.02-1.07)	90 000 (2003)	VSL	(WHO, 2013) (Chiabai, Spadaro, & Neumann, 2018)
Asthma symptoms	5 - 19 years	Short-term	1.028 (1.006-1.051)	530 (2007) 42 (2005)	Case/year Day	(WHO, 2013) (Maurits & Hoogenveen, 2013) (Holland, 2014)
Chronic bronchitis (incidence)	>18 years	Long-term	1.117 (1.040–1.189)	53 600 (2005)	Case	(WHO, 2013) (Holland, 2014)

Notes:

- VSL: value of a statistical life

Table 5 - Health effects related with PM2.5 exposure, concentration-response functions (CRF) and of respective economic valuation (base costs €2015)

Health Endpoint	***Age Group***	***Exposure Period***	***Relative Risk (95% CI) per 10μg/m³***	***Reference Costs (€/unit)***	***Unit***	***References***
Total Mortality	All	Short-term	1.0123 (1.0045-1.0201)	90 000 (2003)	YOLL	(WHO, 2013) (Chiabai et al., 2018)
HA, Cardiovascular diseases	All	Short-term	1.0091 (1.0017–1.0166)	2220 (2005)	Hospital Admission	(WHO, 2013) (Holland, 2014)

Notes:
- HA: hospital admissions
- YOLL: years of life lost.

Table 6 - Health effects related with NO2 exposure, concentration-response functions (CRF) and of respective economic valuation (base costs €2015)

Health Endpoint	***Age Group***	***Exposure Period***	***Relative Risk (95% CI) per 10μg/m³***	***Reference Costs (€/unit)***	***Unit***	***Reference***
Mortality, all-cause (natural)	All	Short-term	1.0027 (1.0016–1.0038)	90 000 (2003)	YOLL	(WHO, 2013) (Chiabai et al., 2018)
HA, respiratory diseases	All	Short-term	1.0180 (1.0115–1.0245)	2220 (2005)	Case	(WHO, 2013) (Holland, 2014)

Notes:

- HA: hospital admissions.

- YOLL: years of life

2.3 Urban flooding

2.3.1 Context

The frequency and magnitude of flood events is expected to increase due to the effects of climate change, socio-economic key drivers, land-use change patterns, and soil sealing (Svetlana et al., 2015). One of the characteristics associated with urbanization is the conversion of pervious terrain into impervious surfaces to accommodate the urban expansion and development, causing a reduction in the natural system to infiltrate water which results in an increase of surface runoff (Brody et al., 2007). Frequently engineered solutions, such as dredging or diverting natural streams, are thought to mitigate flood effects. In most cities the conventional method to address excess water is to convey the water away from the city area, in the shortest time possible, through a conduit-based drainage system and discharge it to the nearest stream resulting in increasing flood peaks and a smaller groundwater recharge (Lashford, 2016).

Instead of moving the problem and possibly creating floods downstream, Sustainable Urban Drainage Systems (SuDS) - a concept enclosed by NBS - focus on recreating the natural hydrological conditions and thus re-establish the natural infiltration capacity of the soil and boosting groundwater recharge. Usually it is implemented using green solutions such as vegetation or permeable areas. Some examples of SuDS may include green roofs, retention basins and bioretention ponds, which provide areas for water to be stored and infiltrate into the soil and also allows that the water be either evaporated or transpired by vegetation (evapotranspiration) (Lashford, 2016). Besides providing a water storage and thus reducing the flood risk and peak runoff flow, these infrastructures also ensure other benefits such as enhancing water quality, temperature regulation, environment aesthetics and habitat for wildlife (see Table 7).

Table 7 - Examples of studies that quantify the impact of NBS implementation on flood risk and its respective co-benefits

NBS	***Study***	***Area***	***Impact***	***Co-Benefits***
Combined urban parks and retention basins	(Roebeling et al., 2011)	Aveiro (Portugal)	Flood risk reduction	Appreciation of real estate values
"Sponge City" Concept	(Chan et al., 2018)	China		Enhancement of ecological functions; aesthetics benefits; Additional Amenity space; urban water body preservation; storage, infiltration and purification of stormwater; grey-water reuse
Green Roof-Trees Combination	(Zölch et al., 2017)	Munich, Germany		Sequestering and storing carbon emissions, biodiversity benefits by providing habitat, and social and health benefits by providing areas of recreation filtering air pollutants and reducing noise pollution
SuDS combination	(Lashford, 2016)	Leicester, United Kingdom		Carbon sequestration, urban cooling, and energy reduction, water quality increasing

2.3.2 Impact Assessment

Flood damage can be divided in tangible and intangible damage. The first one is directly evaluated in monetary terms, while the latter cannot be assessed in monetary terms (Romali & Sulaiman, 2015). Tangible damage can also be divided in direct damage caused by the contact or submersion in water (destruction of infrastructures like buildings, roads and railroads for example) and indirect damage caused by the interruption of physical and economic networks (disruption of public services, business interruption on the flooded area, damage to livestock, etc). Intangible damage refers to assets that do not possess a market value such as injuries, trauma, loss of life, phycological distress, etc. (Merz et al., 2010).

Assessing the expected damage caused by flood events is conventionally done using damage-functions, by considering the relation between floodwater depth and percent damage for a variety of sectors. This methodology represents the economic loss (as absolute or relative values) as a function of the maximum water depth. Nonetheless other factors may influence the amount of damage caused by a flood event such as flow velocity, duration of flood, effectiveness of the emergency response, etc. (Middelmann-Fernandes, 2010). A common approach is to define the damage percentage as “the ratio of the total cost to replace the damaged components of a flood-affected property to the pre-disaster market value of the property” and with the costs of the repair and the market value referring to the same period (Pistrika et al., 2014). Figure 6 shows an example of the depth damage curve for the German economy. With an increase of population and services localised in vulnerable flood risk areas, the damage on infrastructure might increase and consequently the related costs will be higher (Svetlana et al., 2015).

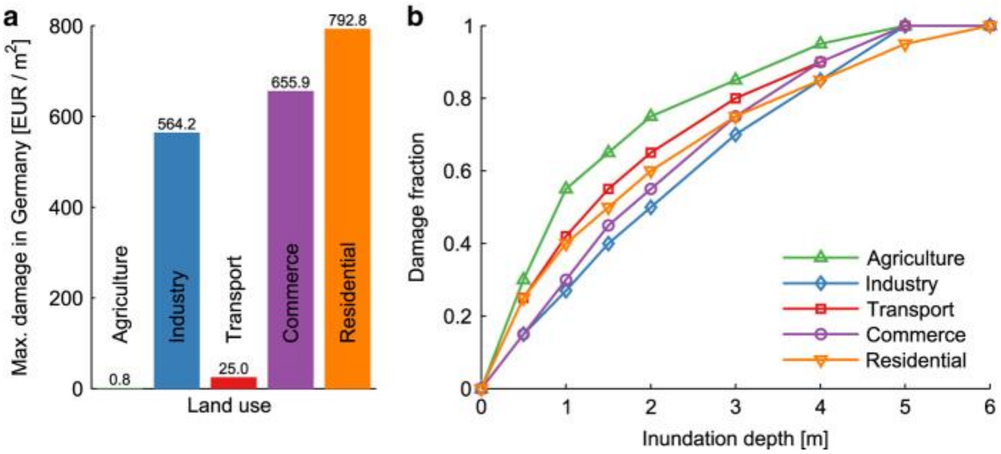

Figure 6- Depth Damage function for the different sectors in Germany's economy (Prahl et al., 2018)

2.4 Sprawl, gentrification and real estate valuation

The migration of the population for sub-urban, undeveloped and peripherical areas (exponentiated by urban population and economic growth and limited available area within the city) with low-density dwellings and segregated land-use creates a process of urban sprawl. This type of population distribution leads to a conversion of natural and agriculture areas for mainly residential and commercial sector construction, resulting in cities' expansion. Urban sprawl comes along with problems at social and economic levels, among them: non-efficient use of resources, less transportation alternatives (private transportation dependency), loss of biodiversity, etc. (Broitman & Koomen, 2015; Haaland & van den Bosch, 2015).

The urbanization phenomenon and cities' expansion lead decision-makers and planners to make policies to adapt cities to these changes, often requiring the conversion of green infrastructure into residential and commercial properties to accommodate and make room for the increasing population (Mayor et al., 2009; Poudyal et al., 2009; Kabisch & Haase, 2014; Roebeling et al., 2017). These urbanization changes leave the remaining green open spaces to be shared by a growing number of residents, being the existing available areas insufficient to respond and supply the necessary benefits and recreational potential to its users. The loss, intensive use and degradation of these spaces may have an undesirable and opposite effect to its users (Poudyal et al., 2009).

The lack of a reasonable amount of green/blue spaces in cities makes them more valuable for residents that recognise their recreational, aesthetic and physical benefits (Mayor et al., 2009; Xiaoyun, 2015). There is a supply-demand shift in the real estate market linked to the deficiency of a fair availability and quality of green areas within the urban medium.

Although many studies prove the health and well-being benefits of green/blue urban areas (besides the environmental amenities) there is still a challenge to properly quantify them in monetary gains since the access to these spaces is usually free. In order to provide its value, a non-market method is usually used – the hedonic pricing method.

The hedonic pricing method decomposes the total price of a good in the monetary value of each one of the characteristics/benefits that comprises that good. The price of a house can be divided into its attributes: number of rooms, age of the building, garage space, living area, etc. Besides its physical characteristics, neighbourhood and surrounding characteristics have also a significative weight for homebuyers when it comes to choosing a property: distance to work, proximity to schools, hospitals, public transportation/ road access availability, proximity to environmental amenities, etc. (Morancho, 2003; Mayor et al., 2009; Roebeling et al., 2017). From all the factors that can influence housing preference and thus the prices and real estate market, environmental amenities pose as one of the top (Trojanek et al., 2018). Using regression techniques, the method can identify the fraction attributable to environmental amenities (green/blue spaces).

As the competition and demand for these attractive areas rise, so does the real estate values, and property values may boost from 6-8% in the Netherlands, to 17% in China and 20% in the USA when close to parks (ATCC, 2014), leading to environmental gentrification in which higher income households are mainly benefited, accentuating the income inequalities within a city, and displacing lower income households, resulting in a change in demographic distribution patterns. With an increased added value of environmental amenities of green/blue spaces, households with a higher purchasing power are willing to pay more for less living space when living close to these type of areas. (Roebeling et al., 2017; Augusto, 2018). Several studies show that housing market prices are influenced by proximity, size and view of this areas, being proximity the most significative and impactful factor (Mayor et al., 2009; Lin et al., 2015).

Green/blue spaces (e.g. parks, ponds, lakes, etc.) as well as the integration of greenery and vegetation on buildings (green roofs/green façades/green walls) in the urban medium represent a solution to promote urban densification in build-up central areas, as it will create a favourable, attractive, recreational, aesthetically beautiful and restorative local environment (ATCC, 2014; Roebeling et al., 2017). Moreover, it provides important ecosystem services like carbon sequestration, temperature regulation and noise pollution reduction (see Table 8), adding not only value to the house itself but also to the urban environment, creating natural and green landscapes.

Table 8 - Compilation of studies that prove the impact of NBS implementation on urban densification and its respective co-benefits

NBS	***Study***	***Area***	***Impact***	***Co-Benefits***
Urban Forest	(Tyrväinen, 1997)	North Carelia (Finland)		Balanced microclimate; pleasant landscape, clear air, peace and quiet, recreation, improved aesthetics; erosion control
Urban Green Spaces	(Trojanek et al., 2018)	Warsaw (Poland)	Real estate valuation	Human health and wellbeing, social cohesion, tourism, biodiversity, air quality improvement and carbon sequestration, water management, cooling of urban areas.
Urban Green Spaces	(Morancho, 2003)	Castellón (Spain)		Carbon sequestration; regulation of humidity; temperature and rainfall, soil erosion restraining; form the basis for the conservation of fauna and flora
Urban Green Spaces	(Kolbe & Wüstemann, 2014)	Cologne (Germany)		Recreational and aesthetic benefits; carbon sequestration and storage; wellbeing; biodiversity and habitats protection;

3.Methodology

In this Section an economic evaluation is performed for the different endpoints (flood depth and real estate values) in each of the urban challenges (flood risk and urban sprawl) for the quantification of the external costs building on the Impact Pathway Approach (IPA; Merz et al., 2010; Silveira et al., 2015; see Figure 7). This approach has several steps: i) quantifying the impact in terms of influencing factors (precipitation and urbanization), for this part an environmental assessment is performed in which the several disciplinary models described in this study are used (see Section 3.1), ii) linking the influencing factors with a bio-physical impact (damaged buildings and changes in the real estate market) based on literature (i.e. exposure-response functions); and iii) attributing a monetary value to the answer about the corresponding impact (see Section 3.2).

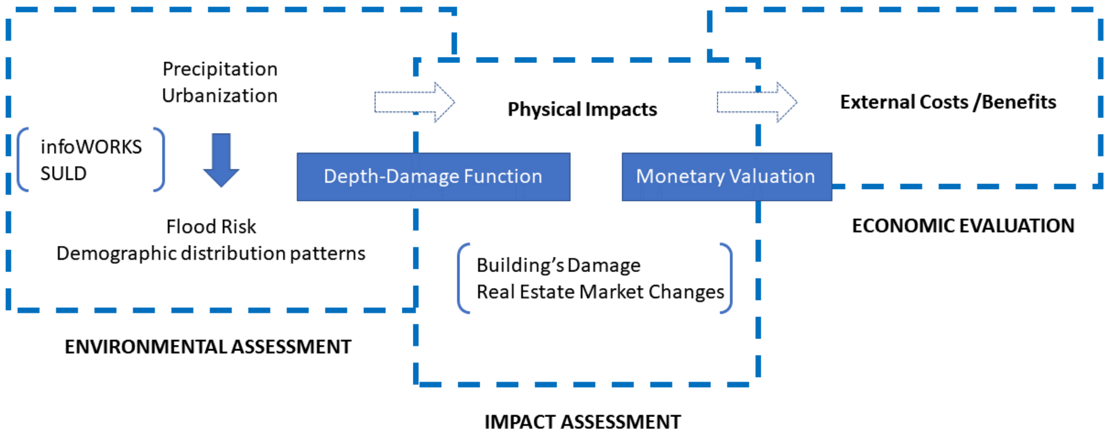

Figure 7 - Schematic Representation of the Impact Pathway Approach (adapted)

In this study the focus will be on flood risk mitigation and sprawl, gentrification and real estate valuation. Urban heating and air pollution were not considered as there was a lack of information on temperature and air pollution (PM_{10}, $PM_{2.5}$ and NO_2) at a spatial scale (1km * 1km) relevant for this study.

3.1 Environmental assessment

In this section we described the models (InfoWORKS, Section 3.1.1; SULD, Section 3.1.2) used in this study to assess the changes in environmental states (flood risk; sprawl, gentrification and real estate valuation) due to the implementation of NBS.

3.1.1 InfoWORKS

This section describes the InfoWORKS ICM (Integrated Catchment Management) model used to assess the impacts of NBS implementation on urban flood adaptation.

Included in the pre-processing is the calculation of synthetic hyetographs to be used as an input to the model. Instead of the traditional IDF curves (Intensity-duration-frequency curves) were used DDF curves (Depth-duration-frequency curves), which relates the rainfall depth with the duration and frequency of occurrence.

InfoWORKS ICM will model rainfall, surface and subsurface processes separately for the sub-catchments comprising therefore three major steps. The first step is the calculation of surface runoff conveyed into the pipes. This is done using the Unit hydrograph model and the Desbordes time of concentration (Desbordes, 1978). The second step is running the hydraulic model inside the pipes and conveying the flow using Mass and Momentum conservation equations such as Saint Venant. The third step is the calculation of 2D flow and the interaction between the surface and sub-surface model when the conduits surcharge using the 2D model MULFLOOD (Innovyze, 2018).

InfoWORKS ICM (Innovyze, 2018) model comprises two models and the linkage between both: a sub-surface network (1D model), an overland surface network (2D model) and the interaction between sub-surface and surface flow (1D/2D linkage).

1D sub-surface flow model

The sub-surface network flood wave can be described by solving the 1D Saint-Venant equations in the pipe network:

$$\frac{\partial}{\partial t}A + \frac{\partial}{\partial x}Q = 0 \tag{4}$$

$$\frac{\partial}{\partial t}Q + \frac{\partial}{\partial x}\frac{Q^2}{A} + gA\left(\cos\theta\frac{\partial y}{\partial x} - S_0 + \frac{Q|Q|}{K^2}\right) = 0 \quad (5)$$

where Q is the discharge (m^3/s), A is the cross-sectional area (m^2), g is the acceleration due to gravity (m/s^2),θ is the angle of bed to horizontal (degrees),S_0 is the bed slope and K is conveyance.

These equations are solved implicitly using the Preissmann four-point scheme, in which functions and derivatives are replaced by weighted averages over the four corners of a box in (x,t) space.

2D surface flow model

The 2D surface flood wave can be described by the Shallow Water Equations:

$$\frac{\partial}{\partial t}h + \frac{\partial}{\partial x}(uh) + \frac{\partial}{\partial y}(vh) = \sum_{i=1}^{n} q_i \quad (6)$$

$$\frac{\partial}{\partial t}uh + \frac{\partial}{\partial x}u^2h + \frac{1}{2}\frac{\partial}{\partial x}gh^2 + \frac{\partial}{\partial y}uvh = -gh\frac{\partial}{\partial x}B - \tau_{bx} + \sum_{i=1}^{n} q_i u_i \quad (7)$$

$$\frac{\partial}{\partial t}vh + \frac{\partial}{\partial x}uvh + \frac{\partial}{\partial y}v^2h + \frac{1}{2}\frac{\partial}{\partial y}gh^2 = -gh\frac{\partial}{\partial y}B - \tau_{by} + \sum_{i=1}^{n} q_i v_i \quad (8)$$

Equation 6 is the mass conservation equation and Equations 7 and 8 are the two momentum conservation equations. Where *h* represents the water depth, *u* and *v* the velocity components in the x and y orthogonal directions respectively, q_i is the *i* th net source discharge per area , u_i and v_i are the velocities in the x and y directions of the ith net source discharge, respectively, *g* is the gravitational acceleration, *B* is the bed elevation and *n* the Manning's Roughness coefficient.

1D/2D interaction

The sub-surface system (conduits and manholes) becomes surcharged and the pipes become completely full due to a rainfall event posing a pressure increase in the pipe network thus forcing water to flow out from the drainage system through manholes to the surface system (streets) - pressurized flow (see Figure 8) .

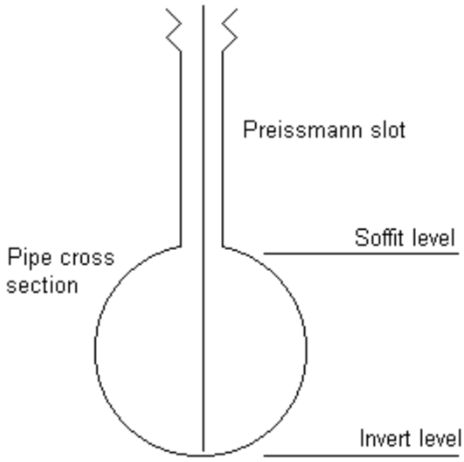

Figure 8 – "Preissmann Slot"- conceptual vertical and narrow slot providing a conceptual free surface condition for the flow when the water level is above the top of a closed conduit

The overflow running out from manholes (linkage element) causing street flooding uses vertical *Weir/Orifice Equation* in order to determine the exchange flow between the sewer and surface network.

The data applied to the model is acquired through stakeholders and open source databases: precipitation patterns through time, historical floods, physical characteristics of the city, streams/water bodies nearby, NBS to be applied to the case study, etc. InfoWORKS ICM (Innovyze, 2018) model simulations results are available in the form of tables and maps, graphs, raw data, GIS compatible formats or images. Depth-damage curves will be applied to the outputs obtained from the 1D/2D interaction in order to allow subsequently assess the flood damage by sector (residential, infrastructure, commercial, etc.) and in total.

3.1.2 SULD

This section describes the Sustainable Urbanizing Landscape Development (SULD) model developed by Roebeling et al. (2017) used in this study to assess the impacts of NBS implementation on urban densification adaptation.

This decision support tool is an economic and hedonic pricing simulation, spatially explicit Geographic Information System (GIS) based model that helps and provides information for stakeholders in the decision-making process regarding a sustainable urban and peri-urban planning, development and management including environmental amenities (green/blue spaces) through the application of the hedonic pricing simulation method (Roebeling et al., 2017). The hedonic price method determines housing location choices and decomposes the total value of the house into every constituent that has a contribution for its price, linking the building value and structural characteristics (number of rooms, number of bathrooms, size, age, garage space, etc.) with the surrounding characteristics of the neighbourhood/ amenities characteristics (location, proximity to the city centre, access to transportation, proximity to environmental amenities, dimension and views or access to the green space, less noise spaces) (Mayor et al., 2009).

In this study the model will be used to determine the impact and influence of location-specific environmental amenities (aesthetics, recreational, etc.) on house prices for the city centre of Eindhoven, Netherlands.

The demand side (Equation 9) is represented by households, considering their preferences regarding certain goods and services, as residential space S, other goods and services Z, and environmental amenities e. The utility obtained by households in each location depends on their preferences, distance to environmental amenities and income y. Hence, households aim to maximize their utility U at a certain location i, subject to the budget constraint y, that is spent on housing ($p_i^h S_i$), other goods and services (Z), and transportation between the residential area and the urban centre ($p_x x_i$):

$$\max_{S_i, Z_i} U_i(S_i, Z_i) = S_i^{\mu} Z_i^{1-\mu} e_i^{\varepsilon} \quad subject\ to\!: \quad y = p_i^h S_i + Z_i + p_x x_i \tag{9}$$

where p_i^h is the rental price of housing (€/m^2), p_x the commuting cost (€/km) and x_i the road-network distance to the closest urban centre (km). Moreover, μ is the elasticity of demand for residential space (S_i) and ε is the elasticity of utility with respect to environmental amenities (e_i). The household's bid-rent price for housing p_i^{h*} (maximum household willingness to pay for housing at location i – demand side of the real estate market) which optimized their residential location by trading off trading off utility from environmental amenities (e_i), residential space (S_i) and other goods and services (Z_i) versus land rent ($p_i^h S_i$) and commuting costs ($p_x x_i$), subject to a budget constraint (y) and is now given by:

$$p_i^{h*} = \left(\frac{\mu^\mu(1-\mu)^{1-\mu} e_i^\varepsilon (y - p_x x_i)}{u}\right)^{\frac{1}{\mu}} \tag{10}$$

where u is the utility level U.

The supply side (Equation 11) is represented by real estate developers which aim to maximize their profit (π) at location i by trading off returns from housing construction revenue($p^h D$) and associated development costs (l+D^η), that are subject to households' willingness to pay for housing:

$$\max_{D_i} \pi_i(D_i) = p_i^h D_i - \left(l_i + D_i^\eta\right) \quad with\text{:} \quad D_i = n_i S_i \tag{11}$$

where p_i^h is the rental price of housing, l_i the opportunity cost of land, D_i^η the construction cost function (with η the ratio of housing value to non-construction costs), n_i the household density and S_i the residential space. The developer's bid-price for land r_i^{**} is now given by:

$$r_i^{**} = \left(m p_i^{h**}\right)^{\frac{\eta}{\eta-1}} \tag{12}$$

where $m = [(\eta-1)^{\eta-1}/\eta]/\eta$. This equation determines the minimum rental price for housing the developer is willing to accept $\left(p_i^{h**}\right)$, thus representing the supply side of the housing market. This means that developers will only develop when residential land rents ($p_i^h D_i$) are larger than the opportunity cost of development ($l_i + D_i^\eta$), which corresponds to the foregone land rents (l_i) and investments in land conversion (D_i^η).

The equilibrium is where the housing supply equals the demand (i.e. $p_i^{h*} = p_i^{h**}$). The land rent price r_i can now be derived using Eq. 10 and 11, and is given by:

$$r_i = \left(\frac{k e_i^\varepsilon (y - p_x x_i)}{u}\right)^{\frac{\eta}{\mu(\eta-1)}} \tag{13}$$

where $k = \mu m^\mu (1-\mu)^{1-\mu}$. The corresponding optimal household density n_i is given by:

$$n_i = \frac{D_i}{S_i} \tag{14}$$

with $S_i = \mu(y - p_x x_i)/p_i^{hx}$ the necessary condition for optimality U_i and with $D_i = (\eta - 1)^{1/n}(r_i)^{1/n}$ the necessary condition for optimality of π_i, and where p_i^{h*} and r_i are given in Equations (10) and (13), respectively.

The equilibrium land rent price r_i and household density n_i are then derived, providing development patterns for a certain population size and composition and given the location of urban centres and environmental amenities location. SULD builds on a numerical application of the above-described model, using the General Algebraic Modelling System. The objective function maximizes, for a given household population Q_t, the difference between benefits B from residential (L_i^{res}) and non-residential (L_i^{nres}) land uses and development costs ($l_i + D_i^{\eta}$), so that:

$$\max_{L_i} B(L_i) = \sum_i (l_i L_i^{nres} + \left(r_i - l_i - D_i^{\eta}\right) L_i^{res}) \tag{15}$$

with $Q_t = \sum_i n_i$ and $L_i^{res} + L_i^{nres} = \mathrm{a_i}$, and where l_i represents the opportunity cost of land, r_i is the land rent price and a_i corresponds to the grid-cell area. Land use conversion can happen between residential and non-residential land uses – all other land uses are fixed.

The data inputted in the model is spatial data – land use, road network, environmental amenities, urban centres and population densities and non-spatial data - household types, property value, transport costs and construction costs relative to the current situation (2015) and the NBS implementation scenarios, this data is obtained from stakeholders' databases and open source databases.

SULD gives the outputted data in a form of maps, tables and graphs containing information on housing price – annual rental value (€/m2/yr) per household type (low income households – type 1; middle income households – type 2; high income households- type 3), residential development density (m2/cell), household density (hh/cell), showing the display of households in 22x22m cells.

3.2 Compilation and synthesis of the relationship between physical and economic impacts

Compilation of data and information (based on literature and report review) for the development of damage-functions as well as associated cost and willingness-to-pay functions and connecting the alterations (i.e. precipitation) and the physical impacts (i.e. damage to buildings) and, at last, to its economic impact (cost). This will result in generic dose-cost and depth-damage functions that can be used to determine the impacts, costs and/or benefits related to the baseline and NBS scenarios.

The urban flooding will be quantified in terms of flood depth damage on several sectors (residential, agriculture, commerce, etc.) and its corresponding economic valuation. In this study we will only consider one of the parameters to assess the flood damage, which is the flood water depth, being this not only the most important in cost estimation studies but also the easier to quantify and the one that causes greater damages (main factor of direct damage) (Genovese, 2006).

The depth damage curves are a common methodology used to calculate flood damage and are a function of: i) the different type of land uses (damaged sector) coupled with the orography of the city, ii) flood depth , iii) damaged fraction of the and iv) monetary value per unit of area. The generic formulation is:

$$Damage\ (€) = A \times df \times P \tag{16}$$

Where A is the area (m^2) of the corresponding land use, *df* is the water depth damage factor (as a function of the flood depth and the damaged fraction) and P is the average price or value per m^2. All prices and values are given in Euros for the year 2015.

The depth damage curves are usually presented as a set of points rather than an expression. These curves were converted to functions by fitting a third-degree polynomial. The maximum depth is usually an established depth for which the building might suffer catastrophically failure and therefore considered totally lost. These values are usually systematically obtained from regression analysis of damage values identified in literature (Huizinga et al., 2017). For built-up areas the land use class is expressed per unit area (land-use based).

Residential buildings

An average of the local values for housing prices (€/m^2/year) within the study area provided by SULD (baseline scenario) were converted to their total real estate value (€/m^2) (considering an interest rate of 5%). The maximum damage values for the residential sector are based on full construction costs, referring to building's structural costs. The damage percentage for each flood depth is bellow represented in Figure 9. The damage for the residential sector was 1301€/m^2.

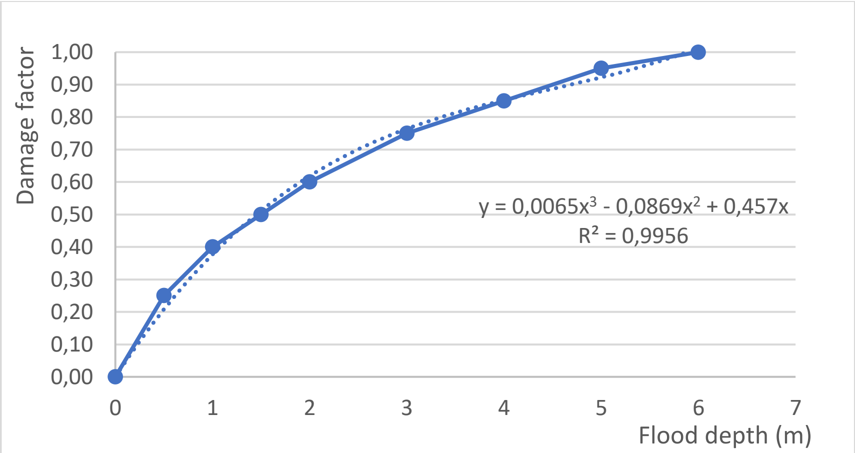

Figure 9 – Percentage of damage for residential buildings according to flood depth

Commercial and Industrial buildings

For commercial and industrial buildings an average of values provided by (Huizinga et al., 2017) was calculated, since the GIS file obtained has these two sectors aggregated. The values used were land-used based, since there is not enough information in order to do the calculations building-based (with structural and content damages). The values obtained €2010 were converted into €2015 values using consumer price index (CPI) from World Bank (https://data.worldbank.org). The damage percentage associated with flood depth is represented in Figure 10. The maximum damage for commercial and industrial buildings was 380 (€2015/ m^2).

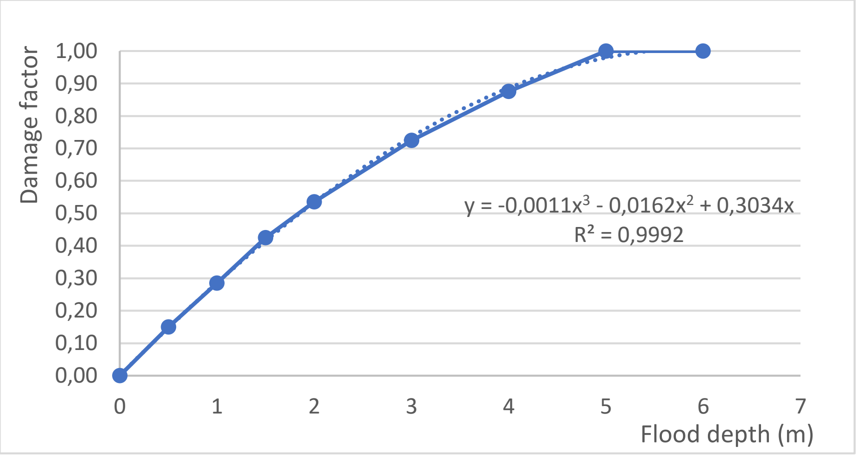

Figure 10 - Percentage of damage for commercial and industrial buildings according to flood depth

Infrastructure (roads)

The calculation procedure for infrastructure damage was the same as described for commercial and industrial damage. The damage percentage associated with flood depth is bellow represented in Figure 11. The maximum damage for infrastructure was 32 (€2015/ m^2).

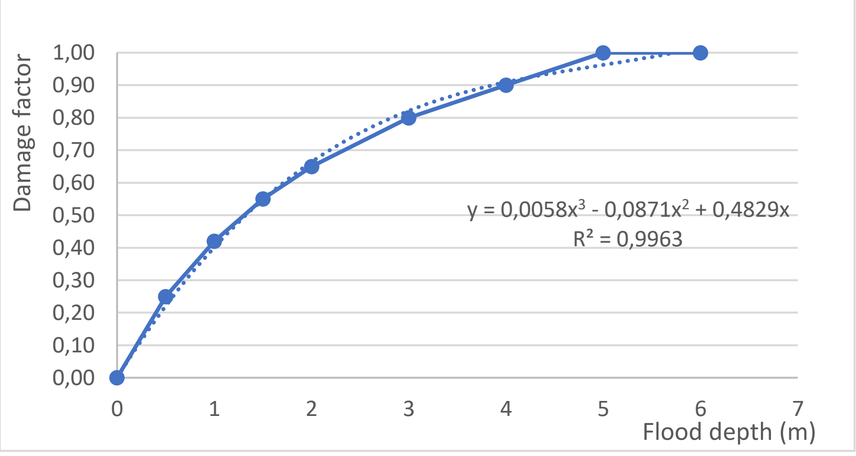

Figure 11 - Percentage of damage for infrastructure according to flood depth

4. Case study description

4.1 Eindhoven

The case study area is the city of Eindhoven, the fifth largest city in the Netherlands, located in the south-east part of the country in the province of North Brabant, close to the Belgian and German borders of the Netherlands with a population of about 224 900 inhabitants in 2015 and an area of approximately 78 km^2 (Population.City ,n.d), thus an average population density of 2883 inhabitants/km^2. The city was originally located in the confluence of the Dommel and Gender streams, nowadays the Gender is covered and invisible in the city centre, however the Dommel stills flow through the city openly (Zetcijen, 2016).

In 1890 Philips Company settled in the city and was the main responsible for the industrial development (largely dependent on fossil fuels) and demographic growth, influencing not only the economy but also the social part of the society, having the city grown over the years from an agriculture region to a technological and modern one we know today with a build-up area mainly of residential and commercial character. In 1920 Eindhoven was merged with the 5 surrounding villages Stratum, Strijp, Woensel, Tongelre and Gestel, growing from 8,000 to 45,000 inhabitants, separating these parts with green infrastructure, remaining to this day. During Philips expansion and peak, Eindhoven population grew to 100,000 inhabitants in 1930 (Zumelzu Scheel et al., 2015; UnaLab, 2016).

The expected tendency these days is that the population continues to increase rapidly within the next years (see Figure 12), having experienced a growth of about 13000 inhabitants from 2006 to 2015 (Zetcijen, 2016) and possibly growing to an estimated 300 000 inhabitants by 2030 (UNaLab, 2016).

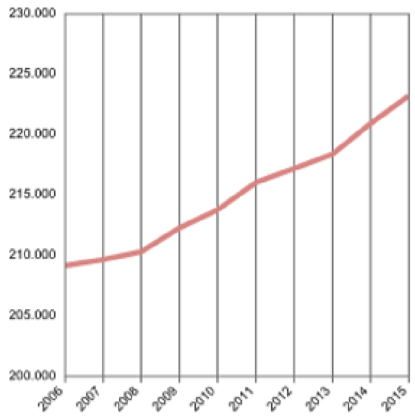

Figure 12 - Population trend in Eindhoven

The Eindhoven case study focusses on the inner-ring of the city of Eindhoven, which comprises 23 neighbourhoods, serviced by 4 highways, an international airport and 21 environmental amenities among them parks and water canals and ponds (UNaLab, 2016). As many other cities in the world Eindhoven is facing urbanization and climate change challenges, with Eindhoven focus on flooding problems and urban sprawl. With groundwaters just below the surface most of the year and with mainly loam and loamy sand soil which makes it harder for rainwater to quickly infiltrate in some places making flooding problems the main challenge to deal with in the city (UNaLab, 2016).

The current land use in Eindhoven is mainly residential and industrial/commerce buildings, with some agriculture areas in the periphery and urban parks surrounding the city centre (see Figure 13).

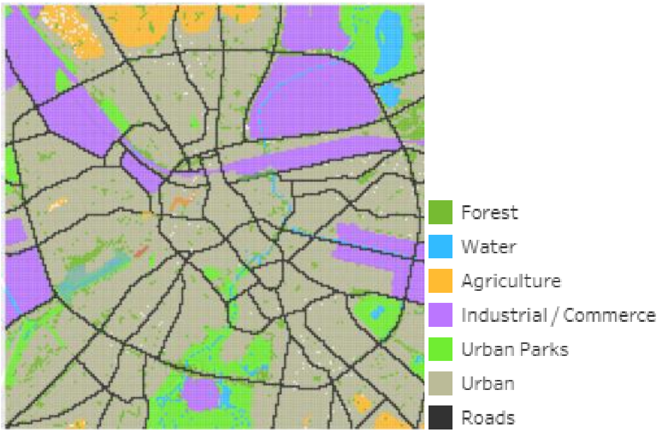

Figure 13 - Land Use for the inner-ring of Eindhoven

4.2 Scenario description

Several scenarios will be applied to the SDST for the year 2015 without (Baseline scenario) and with NBS implementation for the study area.

4.2.1 NBS scenario

The scenarios simulated for this case study were the same as the ones implemented in the work of Bodilis (2018) and Augusto (2018) and are geographically represented (see Figure 14) and described below (see Table 10).

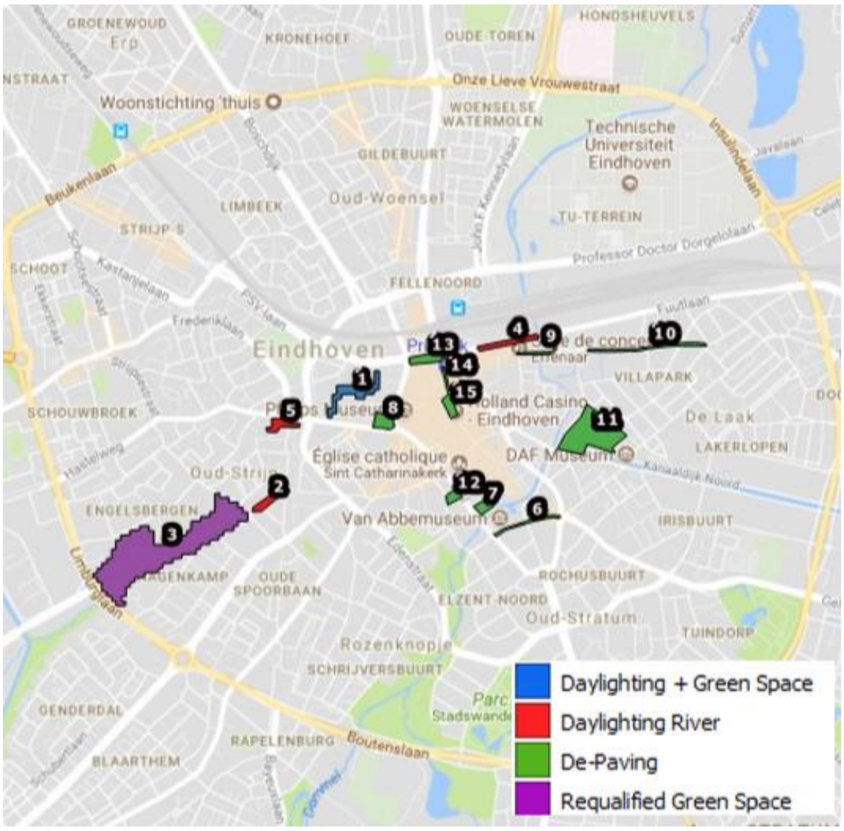

Figure 14 - Multiple NBS implementation scenarios in the city centre of Eindhoven, Netherlands

Table 9 - Description of the NBS implementation scenarios

NBS	***Type of NBS***	***Description***	***infoWORKS***	***SULD***
1	River Daylighting + Green Space	Implementation the daylighting of a section of the Gender river, restoring it to its previous natural condition, with the addition of a green space surrounding it.	☑	☑
2	River Daylighting	Gender river daylighting on the Frederika van Pruisenweg street	☑	☑
3	Requalification of Green Spaces	Improving ecological status of the Gendervijver pond and enhancing the environmental amenities of the park	☑	☑
4	River Daylighting	Daylighting of the Gender river near the train station (Stationsweg)	☑	☑
5	River Daylighting	Daylighting of the Gender river on Willemstraat	☑	☑
6-15	De-paving	Removing of impervious surfaces like asphalt and concrete ones and the replacement by new permeable ones (vegetated surfaces) that allow water infiltration and creating new useful and pleasant ones (e.g. bicycle lanes)	☑	☒

5. Results and discussion

By implementing the methodology and data derived from the disciplinary models mentioned in Section 3 and the scenarios described in Section 4 for Eindhoven, results presented in the following section are obtained in a form of risk maps and/or tables.

The SDST integrates data and information from different disciplinary models into a spatially explicit system at the landscape scale, to assess the impacts, costs and (co-) benefits of NBS on urban flooding and real estate market. Urban flooding is assessed using InfoWORKS ICM model and the real estate market is assessed using SULD model (see Section 3).

Information and data are applied in the different disciplinary models *a priori* as well as the baseline and NBS implementation scenarios and will integrate the systemic decision tool (SDST) for the case study of the city of Eindhoven (Netherlands). The SDST will generate detailed scenario simulation results for each of the physical impacts (such as exposed population, flooded areas and affected elements) without (baseline scenario) and with NBS implementation (see Section 4.2).

5.1 Flooding

The baseline scenario for the current situation (2015) shows a situation of flooding areas for a return period of 20 years (1 in every 20 years flood). The flooding areas in this case study are mainly roads since the model simulates the overcharged manholes, being the floods originated from it.

Four main flooding areas (see Figure 15) were identified for the city centre of Eindhoven.

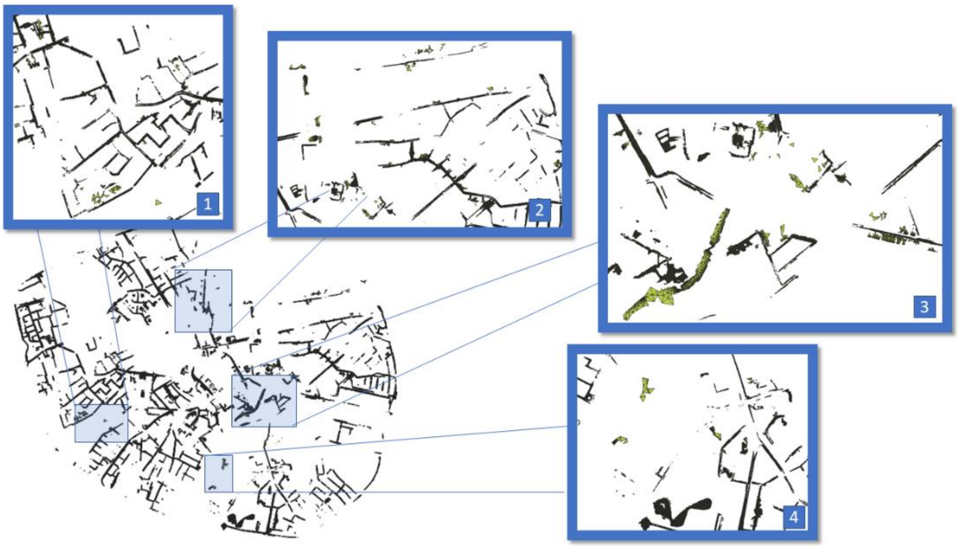

Figure 15 – Current situation (2015) – flood depth in Eindhoven (city centre) for a rain event of return period of 20 years where the main flood areas are highlighted

Using the *QGIS* field calculator it was possible to calculate the damage (€) through the Equations integrating the several polynomial regressions for each damage sector (see Section 3.3.3) – continuous and discontinuous urban fabric (residential area), commercial and industrial areas and infrastructure (roads), for both baseline and NBS scenarios by creating a conditional statement for the flood damage calculation (see Figure 16).

*Sem título - Bloco de notas

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```
CASE
WHEN  "CODE2012"= 12220 THEN "AREA2D" *(0.0058* ("DEPTH2D" ^3) - 0.0871* ("DEPTH2D" ^2 )+ 0.4829* "DEPTH2D" )*32
WHEN "CODE2012" = 11210 THEN "AREA2D" *(0.0065* ("DEPTH2D" ^3 )- 0.0869* ("DEPTH2D" ^2 )+ 0.457* "DEPTH2D" )*1301
WHEN "CODE2012" = 11100 THEN "AREA2D" *(0.0065* ("DEPTH2D" ^3) - 0.0869* ("DEPTH2D" ^2 )+ 0.457* "DEPTH2D" )*1301
WHEN "CODE2012" = 12100 THEN "AREA2D" *(-0.0011* ("DEPTH2D" ^3) - 0.0162* ("DEPTH2D" ^2 )+ 0.3034* "DEPTH2D" )*380
ELSE 0
END
```

Figure 16 - Creation of a conditional statement in QGIS field calculator for flood damage calculation

After that by installing the module "Dissolve with stats" in QGIS it was possible to calculate the summation of the damage (€) for each of the sectors. The costs are represented in Table 10 by sector for each scenario and in total.

Table 10- Flood damage costs for a return period of 20 years: Baseline and NBS implementation scenario for Eindhoven (2015)

Sector		*Costs Baseline (€)*	*Costs NBS (€)*
Residential	Continuous urban fabric	7 601 253.3	7 311 604.9
	Discontinuous urban fabric	1 535 063.3	1 422 602.1
Infrastructure (roads)		367 042.3	349 901.6
Commercial and Industrial		973 541.3	844 274.1
Total costs		10 476 900.2	9 928 382.7
Total annual costs (M€/yr)		523 845.0	496 419.1

The costs in Table 10 are being represented for a flood with a 20-year return period, which makes them seem significantly higher than what they are when compared to the annual costs associated to it, so the representation of the annual costs of the damages associated with the mentioned flood gives a better understanding and perspective of the costs. Since there is only a return period simulation, the annual costs are calculated dividing the total by 20 years.

Applying the baseline and NBS shapefile on Google Earth it was possible to do the spatial observation of the flood range in each of the scenarios (Figure 17; see Annex II).

Figure 17 - Baseline (blue) and NBS (green) flood streams in a part of the city

Later a spatial distribution of the different types of NBS in Google Earth allow the linkage of the impact with the NBS type (Figure 18).

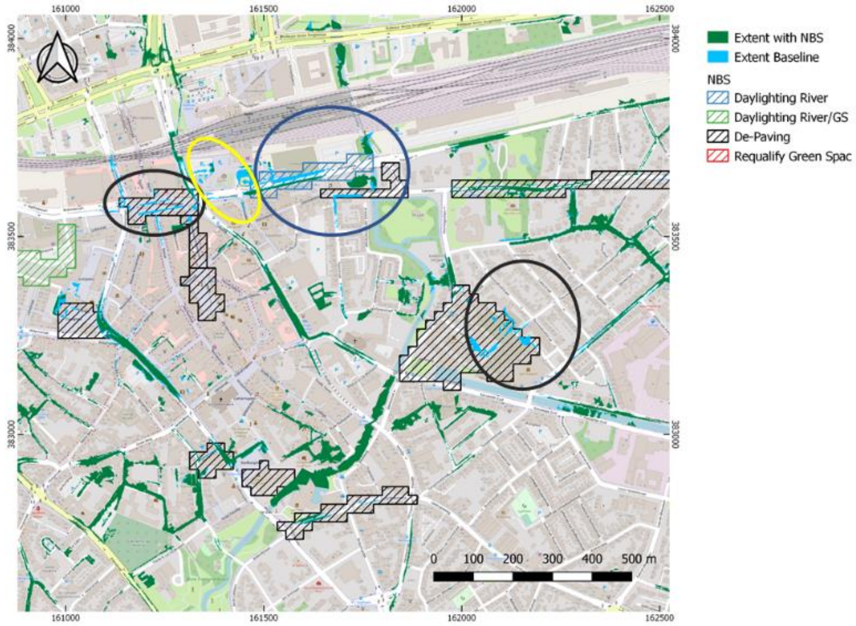

Figure 18 – NBS spatial distribution with the main flood mitigation areas identified

The higher impacts produced by the different NBSs are marked in Figure 18: black line identify the areas where there was an impact caused by the de-paving; blue lines identify the daylighting of the river; yellow lines identify both.

Most of the initial runoff in the baseline scenario is attenuated by the de-paved areas implementation. These high porosity permeable pavements allows rainwater to infiltrate and be naturally stored, releasing it into the drainage system at a slower pass than a conventional pavement (non-porous), thus reducing the runoff volume and peak discharges (Gonçalves et al., 2017). Even though after a long period it is prone to clog due to debris and litter, thus reducing its efficiency.

The river daylighting also plays a big part in the reduction of the flood stream. The previously buried channel provides additional storage of the excess water volume during rainfall events helping reduce the runoff volume which in the baseline scenario relied mostly on the drainage system capacity which was not enough to deal with the current needs. However, the section now open may, in a situation of an extreme rainfall to overflow, increasing the flooded area comparing with the baseline scenario in which the excess water was accounted only for the surcharged manholes.

Through the observation of Figure 17 and Figure 18 it is possible to conclude that the flooded area is smaller in the NBS implementation scenario than in the baseline one, hence it's associated costs (Table 10).

Generally NBS show a higher efficiency when used as short-term measures (for events up to 10-years return period) (Sörensen, 2018), unless there is a significantly large area covered by them that can contribute for a sufficient water storage capacity (Zölch et al., 2017). When it comes to economic benefits its more convenient to mitigate small intensity- high frequency flooding events than high-intensity-small frequency ones, even though the last ones pose a higher risk (Borges Batista, 2013). Since our analysis return period is higher (20-years return period), the suggested NBS may have a high efficiency on short-term, although in a long-term period fail to cope efficiently with high-intensity floods.

5.2 Sprawl, gentrification and real estate valuation

The results obtained from SULD for the inner ring of the city were observed using *Tableau*, making possible an analysis of how NBS implementation influenced population dynamics and the real estate market. Figure 19 shows the household density changes after the NBS implementation, screening a significative household density decrease in the peripherical areas of the city – outside the inner-ring (decrease from -1.43 household/cell to -1.75 household /cell) and, in turn a significative increase in the central part (increase from +0.04 household /cell to +0.48 household /cell) close to where the different NBS scenarios were implemented.

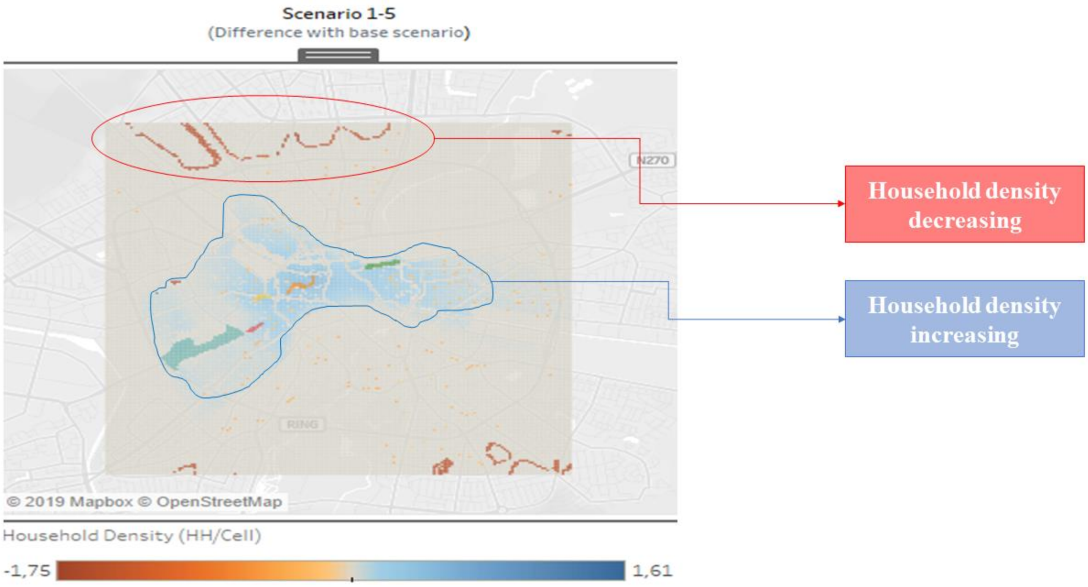

Figure 19 - Difference between NBS and baseline scenario for household density (scenario 1-5)

Despite the remarkable household increase near the NBS scenarios implementation location, some disperse decreasing in household density points are also present within the central area of Eindhoven, been probably attributed to gentrification and displacement of poorer households due to price rise in the properties in more attractive areas along with the re-location of high-income households to near these areas (Roebeling et al., 2017; Augusto, 2018).

Likewise, the distance to largest and more attractive green/blue spaces (scenarios 1, 2 and 3) (see Figure 20) was smaller (decrease of 8.4m to 64.7m), followed by a housing price and real estate market rise (increase of 10.7€/m^2 to 109.1€/m^2) (see Figure 21) in the area. When keeping all the properties characteristics constant, households are willing to pay up to 2.9% more for an equivalent property when this is situated near an environmental amenity. Households with different income and purchase power levels make this price increase lead to an environmental gentrification process in which higher income households are benefited over lower income households, which are taken to peripherical areas, accentuating the income inequalities within a city (Xiaoyun, 2015).

The higher difference in prices is shown in the Witte Dame Neighbourhood, where the scenario 1 was implemented, consisting in the daylighting of a section of Gender river and a new park creation in the city centre.

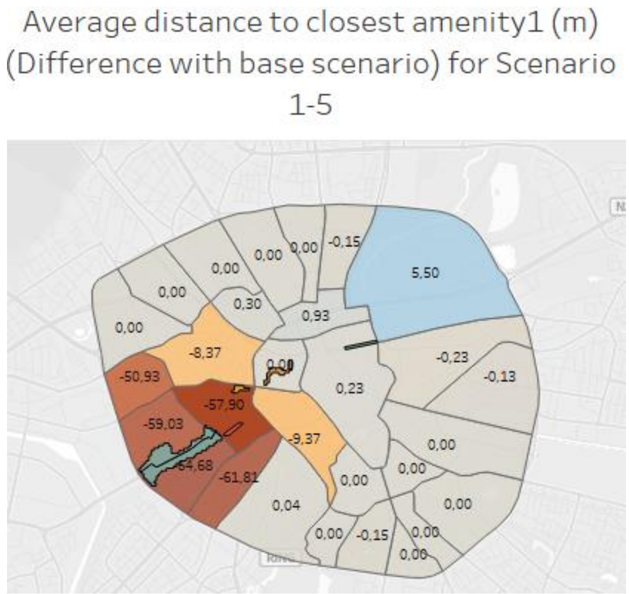

Figure 20 - Difference between NBS and baseline scenario for distance to higher value green/blue spaces (m)

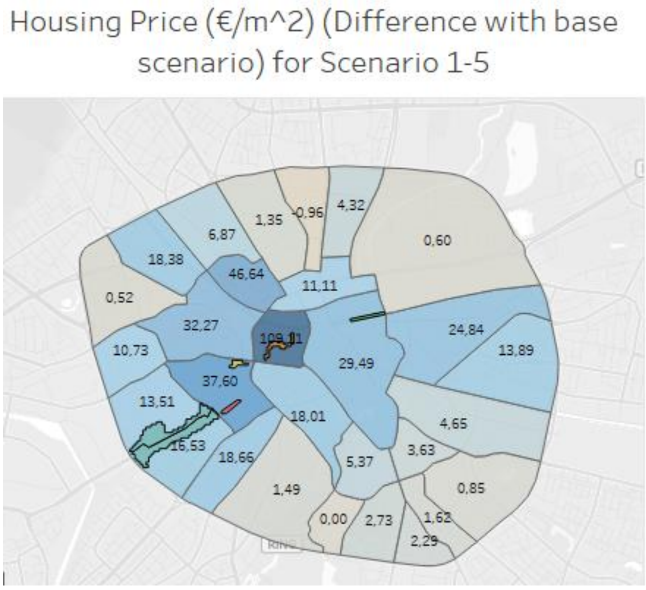

Figure 21 - Difference between NBS and baseline scenario for house price (€/m^2)

Through *SULD* it was possible to calculate the housing price (€) attending the square meters in the residential sector for each grill cell (22x22m) for the inner ring of Eindhoven, both for the baseline and NBS scenario (see Table 11).

Table 11- Real estate: annual rental value (M€/yr) for baseline and NBS implementation scenario for Eindhoven

	Baseline	***NBS***
Housing prices (M€/yr)	205.3	211.3

The results are in line with Xiaoyun (2015) and Roebeling et al. (2017) that show that green/blue spaces and environmental amenities have the capacity to attract more people near them in order to enjoy them.

These areas generally have a more positive response in people when comparing to build-up ones, being favourable for buyers to consider those aspects when it comes to choosing a property thus stimulating higher real estate market prices (White & Gatersleben, 2011). This added appeal near the NBS tends to favour processes of urban densification over urban sprawl within the city.

These amenities influence the real estate market by boosting prices in properties near them; however, the higher rise in property prices is not near the largest green/blue space, since it is a renovation of a previous existing park, but near the other smaller NBS distributed in the area. This indicates that although these type of amenities are an important factor in the choice of property location, people value being close to them but a closer proximity does not add up more value (Mayor et al., 2009). Other type of amenities and location attributes are taken into account in the buyers' willingness-to-pay (Mayor et al., 2009 ; Xiaoyun, 2015) like the closeness to the city centre, distance to work, accessibility to public transport and main roads, etc. In general it is more important and significant the provision of sufficient green/blue areas with a moderate size throughout the city than fewer and larger green areas, being distance more relevant than size when with comes to choosing a property (Morancho, 2003).

5.3 Total economic impacts of NBS

The total economic avoided costs related with NBS implementation - difference between NBS and Baseline scenario, are described in Table 12.

Table 12 - Total Avoided costs and benefits from NBS implementation

Economic Impact	***Costs(*** $C_{Bas} - C_{NBS}$ ***) (€/yr)***
Avoided flooding damages	27 425.9
Real estate valuation (housing prices)	6 084 018.7
Total benefits /avoided costs (M€/yr)	6.1

According to our results the NBS implemented in this case study two main ecosystem services were identified: a regulation service through flood regulation and a cultural one with an aesthetical and recreational value. NBS implementation besides reduce long-term costs while coping with urban challenges (flood risk) have also an effect on the real estate market, changing the population distribution patterns in Eindhoven and favouring a creation of a more compact city. Considering the NBS multiple long-term added benefits (well-being, air quality improvements, urban heat island mitigation, etc.) its avoided costs are expected to be even bigger.

An ideal urban densification process should develop itself in a controlled and supervised way in order to maintain a minimum green/grey ratio (increasing the potential of the NBS effects) within the city as well as keeping the standards of life quality for its citizens.

6. Conclusions

This dissertation aims to quantify the economic impact of nature-based solutions implementation to cope with urban challenges. So far, the majority of the studies partly assess the impacts, costs and/or (co-benefits) of NBS implementation, focusing individually on one or two of these such as Borges Batista (2013), existing few or no studies doing a simultaneous and integrated analysis which assesses the multiple impacts, costs and/or benefits, enhancing the relevance of this study. By using modelling simulations in a real case study, it is possible to provide convincing arguments and additional information to stakeholders and decision makers leading them to take more conscious and informed decisions and actions about the implementations of NBS.

Flood damages were calculated based on the flood depth inundation, using depth-damage functions to estimate the damage factor per sector (residential, commercial and industrial and infrastructures) and the value per unit area associated to each one. To this end InfoWORKS was used to estimate the impact of the NBS implementation on flood risk in the inner ring of the city.

Real estate values were evaluated through the hedonic pricing method, which decomposes the total price of the property per the items that add value to it, including in this case the environmental amenities in the surroundings of that property. To this end, SULD was used to assess the impacts of the NBS implementation in sprawl, gentrification and real estate valuation.

Results show that the implementation of nature-based solutions leads to an increase in real estate values (+6.1 M€/yr) due to upgraded aesthetics and has an impact on flood damages acting on flood mitigation and reducing damage costs (-27.4 k€/yr). Besides its main functions, NBS also show an effect on population distribution patterns – favouring urban densification over urban sprawl processes.

An urban climate adaptation strategy should address and include socioeconomical aspects besides the environmental ones in order to be effective and beneficial for all stakeholders. Nature-based solutions come as an alternative that can act in several levels, being more than just an aesthetical improvement to the urban medium; for example, green infrastructure besides allowing a local temperature drop and filtering air particles, shows positive effects on health and well-being, thus helping reduce healthcare costs.

The hazards addressed in this study are a consequence of climate change, anthropogenic dynamics and land-use change patterns combined with an unthoughtful planning strategy which together increase the exposure risk for urban populations. NBS integration and its multifunctionality should be considered in the planning strategy and decision-making processes of every city as an essential part of urban dynamics and infrastructure. However, it may be a challenge to provide an adequate grey/green ration in highly build-up and compact urban areas due to lack of open space. Other solutions/scenarios should be considered in these cases: for instance, implementing green roofs in all the flat-roof building thus increasing the green areas without any land requirements or even boost the number of street trees and integrating them with rain gardens which may help coping with water storage/retention problems at the same time that acts on temperate regulation and air particles filtration.

7. Future recommendations

The results may present an under-estimation of costs since it is focused on one time interval for flooding events (1 in every 20 years) as well as evaluating of only the direct impacts for real estate market based on NBS implementation. Having this said some recommendations for strengthening the conclusions that can be drawn from this study for future research are:

- A wider set of flooding events (1/5 years; 1/10 years; 1/50 years;1/100 years; etc.) for the simulations;
- The study of indirect impacts, costs and benefits in the real estate market associated with urban densification;
- The study of indirect impacts, costs and benefits of the implementation of NBS in a larger scale with the integration of a significative number of small NBS throughout the area of study;
- To consider implementation and maintenance costs of NBS implementation;

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Annex

Annex I

Damage functions

Flood depth, [m]	Damage class									
	Damage function									
	EUROPE									
	Residential buildings		Commercial buildings		Industrial buildings		Industrial & commercial buildings		Infrastructure - roads	
0,0000001		0,00		0,00		0,00		0,00		0,00
0,5		0,25		0,15		0,15		0,15		0,25
1		0,40		0,30		0,27		0,29		0,42
1,5		0,50		0,45		0,40		0,43		0,55
2		0,60		0,55		0,52		0,54		0,65
3		0,75		0,75		0,70		0,73		0,80
4		0,85		0,90		0,85		0,88		0,90
5		0,95		1,00		1,00		1,00		1,00
6		1,00		1,00		1,00		1,00		1,00

Annex II

Baseline and NBS flood streams representation and NBS location