URBAN GreenUP

D6.2: Characterization of front-runner and follower cities from the perspective of the implementation of NBS

WP 6 , T 6.1

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Abstract

By implementing demo NBS at the front runners (Valladolid, Liverpool and Izmir), the URBAN GreenUp project showcases large scale and replicable actions of NBS, accompanied by key performance indicators (KPIs) and rigorous evaluation procedures for monitoring and evaluation. The implementation of NBS in front runner cities will be further considered and corroborated by a set of other European cities, which act as followers to strengthen the replication potential of the results (Ludwigsburg and Mantova), and finally by non-European cities (Medellín and Quy Nhon) which allows further testing of the replication potential and validation of the renaturing methodology applied in the project.

Through the replication methodology, the characterization and analysis of the front runner and follower cities will support the cities in their effort to develop Renaturing Urban Plans (RUP), which incorporate the urban planning aspects directly related with nature-based solutions as a strategy to mitigate against climate change, improve water management and address other challenges. A driver-pressure-state-impact-response analysis framework, therefore has been developed and carried out in an effort to characterize cities regarding their current multiple challenges, pressures and its appropriate responses to the challenges.

The characterization process links the current challenges faced by different cities with different anthropogenic and natural processes/activities happening within the city (for example, different transportation and noise issues, air pollution, typical microclimatic weather condition of the city). From identified pressures and states of the cities, different NBSs have been identified as possible to be implemented to counter the effect of these challenges to the communities.

The characterization process and DPSIR analysis for Liverpool show the primary challenges and impacts of climate change and urbanization processes at the city are the local flooding, losses of biodiversity and air pollution. At the lesser extent and severity, the impacts on the city from primary challenges including the local regeneration potential and quality of green space. Following the analysis framework, different responses from city has been revealed and characterized (on infrastructure and policy) for each of the impact such as the Liverpool Green Infrastructure Strategy and Biodiversity policies as a few examples of the city's actions to counter the negative impacts as the result of climate change, urbanization processes.

The Valladolid municipality including the city of Valladolid is characterized by flat terrain on the flood plain of the Pisuerga and Esgueva rivers. The urban Valladolid is currently facing challenges including the urban regeneration issue where there is a shift in demographic distribution towards the suburban areas hollowing the city center. Besides, the city is also facing serious challenges regarding the flood water management, air quality due to increasing traffic. Through the DPSIR analysis of the Valladolid urban area, it shows that the drivers for the challenges that currently city is facing are from urbanization process on the flood plain with increasing traffic and shifting in demographic distribution. The city has developed responses in its planning for the double green belt surrounding the city area together with different policies on urban trees, green corridor development, integrated sustainable development strategy and Comprehensive Urban, Sustainable and Safe Mobility Plan of the

city of Valladolid. The NBS planning thus also contribute to the overall planning of the city toward its regeneration of city center, and clean transportation with some mitigation on the green wall and green filter, green noise barriers among other NBS implementation.

Izmir is characterized as the big metropolitan area with strong linkage with the Izmir bay (as the existential relationship) with dynamic dependency of the urban area and the provisioning service from the bay area for ecosystem and economic activities. Due to different climate change and meteorological impacts the air quality of the urban area is deteriorating (industry is the most polluting sector for SO2 in the study area, contributing about 88 % of total emissions), rapid population growth together with economic activities rendering the degradation to the coastal wetland and ecosystem (replacement of natural lands by mostly high-density built-up areas threatens coastal resilience by exposing coastal communities to extreme events such as intense run-off with pollution. DPSIR analysis framework shows that the changing in flood plain of Peynircioğlu stream coupling the climate change impact as the cause for local flooding and wash off pollutant from inland to coastal area beside air pollution due to the increase transportation and economic activities as the main drivers for the current challenges facing the urban area of Izmir. Izmir has thus developed different policy and NBS application response for such challenges such as the Izmir Green Infrastructure Strategy where ecological corridors has planned as the primary element connecting main areas of the city to reverse the fragmentation of the green space in urban landscape and develop of permeable surface to reduce the runoff and filtering the storm water among other proposed water retentions ponds around Bio-Boulevard and Smart soil, green shady structures and parklets.

Mantova is characterized as the mixture of ancient central town with great landscape and architecture value next the Lago di Mezzo lake. The municipal territory is influenced by the low terrain of Po Valley and closed by the Alps and Apennines mountains that block the wind flow to disperse pollutant and natural circulation. The main challenges that currently facing Mantova including heat island effect and air pollution from landscape features, urbanization process and increasing industry and economic activities. The secondary challenges with the city are the loss of biodiversity, local flooding and disconnection among urban green areas. Through the DPSIR analysis, it shows that the city has adopted the policy such as Sustainable Mobility Urban Plan and possible renaturing parking, cool pavement, green façade and urban garden. However, it is also worth noting that the old center of Mantova is protected under a UNESCO management plan, any implementation of NBS intervention has to be undertaken in a manner sympathetic to World Heritage requirements.

Ludwigsburg is one of the most prosperous economic centres in the Stuttgart Region of Germany, spreading over 7 suburbs, home to many global corporations, small businesses, industrial, craft enterprises, service providers and suppliers, representing a dynamic business activities. The landscape of Ludwigsburg including part of the Neckar catchment. Ludwigsburg has a relatively high percentage of green cover with 40 m2 of green space per inhabitant and about 29,000 trees on public ground. Currently the city is facing with challenges including the urban heat island effect from high density of building, noise and air pollution from traffic in addition to flood risk from Neckar river. DPSIR analysis reveals that with the current drivers of urbanization processes and economic activities had induced different impact on the human

and environment, the city has thus approved several key policies and strategies including Integrated Urban Development Strategy, Strategic Concept for Open Space and Green Areas together with other consideration of the NBS implementation like Green shady structure, green facades, green noise barrier, Floodable parks, green pavements, SUDs to mitigate the current challenges the city is facing.

Medellín is located in the region known as Valle de Aburrá, an inland valley of the Central Cordillera of the Colombian Andes, crossed by the Medellín River. Medellín is conceived as a compact city in the centre of the valley, where the Aburrá River or the Medellín River is consolidated as a natural structuring axis. The city is characterized with a phenomenal expansion of the urban population and urban area from 12.31 km^2 to 201.86 km^2, which corresponds to an increase of 1540% from 1948 to 2019. Due to the way in which the urban territory of the Aburrá Valley has evolved, the hydrology of the basin has been altered considerably, the natural drainage network has been modified, the increasing urbanization have altered the microclimatic dynamics generating phenomena of thermal inversion and heat islands affecting the quality of the air and life of the citizens. Through the DPSIR analysis for Medellín, it shows that the drivers for current challenges are the rapid economic development and demand of urban housing has put pressure on the landscape features and the self-regulating climatic condition of the valley which cause widespread challenges on human and environment, on the urban regeneration, renaturing and loss of biodiversity. The city has adopted different plans and policy including Municipal Territorial Ordinance Plan together with NBS such as green corridor, Urban Garden BioFilter; Green Façade with climbing plant, Green shady structures Pollinator's modules (compact and natural designs).

Quy Nhon is characterized as a coastal city in Binh Dinh Province, Vietnam with diverse landscape features from mountainous areas to a river delta, with aquatic systems including: coral reefs, seagrass and the Thi Nai coastal lagoon. The city is the key economic area of the province. The urban form of Quy Nhon city was strongly influenced by the French colonial period when the colonial left to create a unique architecture of the city with urban center's structure spatial arrangement is in the shape of a fan along an east-west axis. Quy Nhon is currently facing with multiple challenges from economic development and climate change such as urban flooding, coastal erosion, loss of biodiversity. The city therefore has adopted Green Growth Urban Development Plan by 2030 to contribute to improving people's material and spiritual life, improving resilience and responding to climate change of the urban system beside some consideration for NBS implementation such as Grassed swales, Sustainable Urban Drainage, Wetland regeneration, Rain garden, floodable park for water purification.

Carrying out the characterization for cities will further help each city to characterize different pressures and identify appropriate responses, while also serving as the foundation for the future replication analysis and assisting cities in developing Renaturing Urban Plans of their own.

1. Background and Objectives

The Urban GreenUp project, under the funding of EU's Horizon 2020 Research and Innovation Programme, aims to support the co-development of Renaturing Urban Plans and assist in the implementation of Nature-Based Solutions (NBS) in an effective way. The main concept of the project focused on the demonstration and promotion of innovative, best practices in implementing NBS for urban environment combating adverse impacts of climate, urban development and anthropogenic activities and ultimately integrate the NBS in the city strategic plans.

URBAN GreenUP project by implementing demo NBS at the front runners (Valladolid, Liverpool and Izmir) showcases large scale and fully replicable action of NBS accompanying key performance indicators (KPIs) and rigorous evaluation procedures for the monitoring and evaluation in replication processes. The implementation of NBS in front runner cities will be further considered and corroborated by a set of other European cities, which act as followers to strengthen the replication potential of the results (Ludwigsburg and Mantova), and finally by non-European cities (Medellín and Quy Nhon) which allows further testing of the replication potential and validation of the renaturing methodology applied in the project.

Along with the demos at front-runner cities and the verification and replication at the follower cities, the project also seeks to develop the replication methodology (considering technical, managerial, financial, cultural and institutional aspects) to allow the follower cities in the project and other easy deployment of NBS in (NBS catalogues) for the challenges at their cities. Furthermore, through the replication methodology, the characterization and analysis of the front runner and follower cities will support the cities in their effort to develop the Renaturing Urban Planning (RUP), which incorporates the urban planning aspects directly related with nature-based solutions as major strategy to fight against climate change, water management and other challenges.

This deliverable (D6.2) aims to develop a synthesis characterization report for (front-runner and follower cities) on their current urban environment challenges, drivers, and pressures due to anthropogenic activities, climate change and water management to help guide forward the development, selection of suitable NBS. According to the structure of the Urban GreenUp project, this deliverable is part of the WP 6 and built up on the city characterization report prepared by front-runner and follower cities in Task 6.1 and closely link with WP 1 – Renaturing City Methodology and its deliverable (D 1.1 NBS catalogue, D 1.2 Climate change challenge catalogue). Those task and deliverable serve as the basis for the characterization analysis of front-runner and follower cities which in turn forms part of the basis for Renaturing Urban Plan (RUP) at the participated cities. Within this deliverable, the following objectives are addressed:

- Conceptualize, analyse and qualitatively characterize the typical drivers, pressures, environmental states of the cities across the project in relation to complex social-

economic and institutional systems that entails certain NBS implementation and integration;

- Identify the suitable NBS applications relevant to the context of the city.

2. Characterization framework for NBS applications and replication

The characterization framework for NBS applications and replication refers to a process of identifying the driving factors behind the transition pathways to a final envisioned target (linkage). Examples might include transitioning from green development community practices and initiatives to the formulation of a strategic policy or from the characterization of multiple benefit of nature-based solutions to the design optimization of the NBS application and finally the design decision of the developer. Previous work has established a holistic characterisation framework of NBS in built environments (Xing, Jones et al. 2017), which links a comprehensive classification of green infrastructure from topology to design options, benefits and policies for the greening of spaces around buildings. However, that characterization process focusses on the built environment, particularly around buildings. Applying the framework to a wider range of NBS applications for urban environment requires a widening of the scope to include the social-economic and ecological impacts of NBS.

From the stand view and analysis of the urban ecologist, urban development and urbanization process accompanying with human activities has transformed the land use management societal and economical arrangement of the city in general (Scott, Lennon et al. 2016). The ever evolving development of urban environment can be perceived as an complex and engineered ecosystem formed through the interconnection of natural system at (terrestrial, freshwater, forestry, coastal) which partly preserved or adjusted at the needs of urban process through the designed system (industry, transportation, human services) and the social-institutional (activist groups, industry groups, strategic urban planning, climate change adaptation, urban greening policy). In short, the interaction of partly natural systems and engineered systems generates a need for another holistic approach to extract meaningful connection between elements of the urban environment to support policy development, guiding those interventions.

Looking at the urban landscape through the lenses of ecosystem services, there are two dominant classification systems to describe. The most widely recognised framework comes from the report from Millennium Ecosystem Assessment (MEA 2005) which identified and characterized four distinct categories of ecosystem services (applied in any environment) including the provisioning services (the products obtained from ecosystems), the regulating services (the benefits obtained from regulation of ecosystem services like water, and climate regulations), the cultural services (which is nonmaterial benefits obtained from ecosystems such as educational, aesthetic, recreational and spiritual benefits) and finally the supporting

services (which include services necessary for the production of all other ecosystem services such as soil, nutrient and primary production). There are, however, extensions to the framework which modifies the concepts to suggested that ecosystem services to defined the "actively" or "passively" processes to produce or derive benefits for human well-being to include the process of society to extract the benefits from the ecosystem (built capital, human capital, physical capital)(Fisher, Turner et al. 2009). Thus making it for the purposes of re-defining the provisioning services and the benefit extracting services, thus encompassing both ecosystem and society structure (Boyd and Banzhaf 2007).

The second classification system looks into a conceptual framework describing a causal chain between the origins and consequences of environmental problems in anthropogenic interventions in nature, Westing (1989) initially propose a driving force and pressure framework to capture and characterize that causal relationship (Westing 1989). Following the initial conceptual framework of interaction between nature and human activities, regarding the maintenance of functional integrity of ecosystem and its services, others have applied the so-called "DPSIR" framework to explore and explain the underlying relationship and responses of ecosystem processes with various human interventions in nature from marine environment management (Elliott 2002) to risk communication on biodiversity (Maxim, Spangenberg et al. 2009) and water resources sustainability assessment (Sun, Wang et al. 2016) and green infrastructure planning in urban environments (Spanò, Gentile et al. 2017).

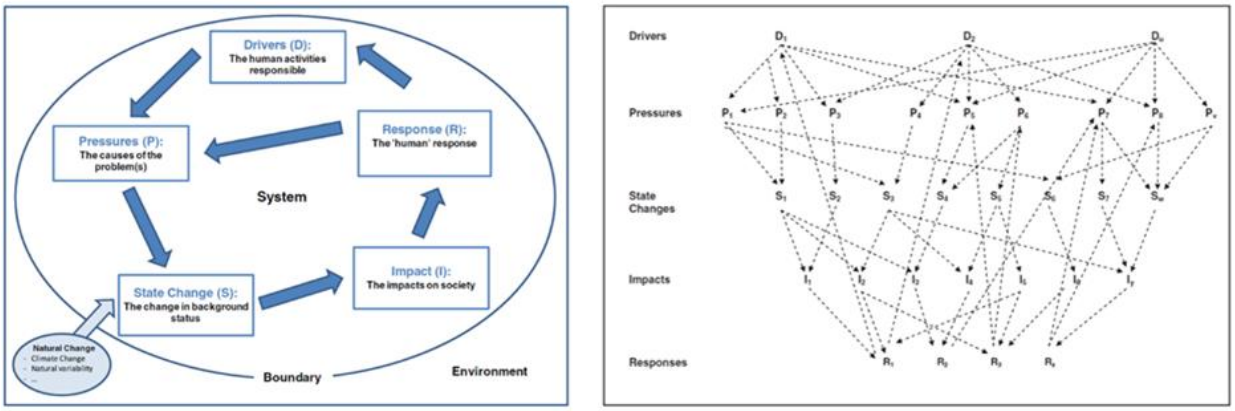

Figure 1: DPSIR framework and illustration of multiple interactions within the framework - adapted from (Atkins, Burdon et al. 2011)

Since 1995, the DPSIR has officially been used by the European Environment Agency and by EUROSTAT, for the organization of environmental indicators and statistics (Jesinghaus 1999) to assess the causes, consequences and responses to change for environmental processes. In any context, as showed in Fig. 1, the conceptual framework of DPSIR covers the overarching driving forces of the social economic development (through space for living, food, recreation etc.). Those drivers create several or many overlapping pressures on the system,

such as the exploitation of natural resources, demands for nature products, modifying land use and landscape, discharge of contaminated water. As a result, a change in the state of the system is happening (in inherent environment components such as the water resources availability, balance of the ecosystem, clean air and soil as well as the aesthetic quality of the environment) resulting in impacts on society such as the loss of biodiversity, degraded environment and recurrence of adverse health conditions or human welfare for human being. Societal responses to these changes will follow (Atkins, Burdon et al. 2011). Other derivations of the framework were developed looking at different angles combining certain elements in the framework such as DPS, DSR, PSIR (Patrício, Elliott et al. 2016) or DPSWR (Driver–Pressure–State–Welfare–Response) (Cooper 2013).

Driving forces (or **Drivers**) have been defined as the social, demographic and economic developments in societies with the primary force of population growth that drives the overall production and consumption (Smeets and Weterings 1999). Some authors have suggested that driving forces should be divided into two classes: internal and external driving forces; where the internal driving forces refer to nature itself such as the environmental conditions, climatic conditions and natural resources and the external driving forces are related to economic and social activities (Cooper 2013, Liu, Sun et al. 2019). The other elements in the DPSIR framework were also presented in the report in which **Pressure** indicators were defined as the exertion of the driving processes or the use of the natural resources such as the release of biological and physical substances, exploitation of raw materials and the land use change. The **State** was defined as a description of the status of the nature and environment (quantity and quality) such as the air and noise pollution level, the present resources of the presenting system boundary. As the result of the pressure on the environment that changes the state of the environment that cause **Impacts** on the social, natural and economic functions such as loss of biodiversity, and adequate conditions for health. Finally, the **Response** elements including the technological and institutional actions that ameliorate or compensate for the changes in the state of the environment such as increase protection of natural area, and implementation of policy to enhance adaptation or mitigation elements.

After two decades of development, the DPSIR framework has received some criticism from researchers and practitioners regarding shortcomings of the framework including oversimplification of mechanics, linearity of the scheme and the lack of spatial, temporal and quantitative consideration of the framework for assessment (Ness, Anderberg et al. 2010, Gari, Newton et al. 2015). Suggested improvements include integrating a spatial element where legal, technological limits, challenges at the higher scale or extent (at meso- and macro level) guiding those small actions on the landscape (at micro-level). That assessment framework would be able to capture the dynamic interaction between upper level administrative challenges and the actions taking place at the landscape level, thus allowing the incorporation of multilevel perspective of particular nature-based solutions or interventions (Ness, Anderberg et al. 2010).

This deliverable aims at characterizing front-runner and follower cities from the perspective of the implementation of NBS, building upon the DPSIR assessment framework with the consideration of the spatial extent of the challenges as well as the impact of different pressures on the urban environment of participating cities in the project. Therefore, the following definitions or classification will be used to describe different elements in the DPSIR framework applied for the characterization report.

Drivers

Drivers can be either anthropogenic or natural factors that directly or indirectly cause a change in the environment. In this report, the drivers for the challenges faced by cities or urban areas include the following: the demand for new urban housing and services, economic and population growth rate, demand for natural products, increase in tourism or recreation services near natural areas or coastlines and increase of transportation infrastructure (roads, railways, harbors, mobility). Internal driving forces include environmental conditions, topography and climatic conditions (including climate change).

Pressures

'Pressures' are the factors reflecting driving forces on the social, local, and ecological environment, which include changes in land-use and land consumption, urbanization of water courses and the coastline, the narrowing or culverting of natural watercourses, the pollution of watercourses and air and creating impervious surfaces in urban areas.

State

The condition of natural resources used in this deliverable include landscape features, water flow regulation and flood mitigation, habitat quality, ecological processes and the integrity of coastal area, water supply coverage and availability.

Impact

The impact components can include loss of vegetation cover, loss of water and soil quality, decline of biodiversity, fragmentation of habitat, loss of connectivity of green space or landscape, reduction in hydraulic efficiency, flooding, the degradation of natural stream, and increase in temperature of the urban environment and degradation in the quality of life (or wellness and life expectancy).

Response

The indicators for the response component (actions/policies) relate to the application of NBS to increase the protection of natural areas (lake, forest, coastline), protection of natural vegetation and hydraulic conductivity along water courses, increase in ecological connectivity in high residential areas, increase landscape permeability and continuity, implementing mitigation element for enhancing landscape connectivity – corridors, enhance adaptation practices and policies to mitigate/adapt to climate change and prevent floods.

Spatial Extent and severity classification (extra elements in the analysis framework)

In characterizing the various interactions in the DPSIR framework, as mentioned, the missing elements in the framework weaken the policy advice if simply looking at the original DPSIR only. Since the spatial and multi-level interactions were left out of the analysis thus do not reflect whether an action at micro-scale has certain influence or mitigate a challenge at higher spatial level, or whether an NBS intervention at a larger scale would render mitigation for a challenge at smaller extent in the urban environment. Therefore, it is helpful to include the spatial limitations in the characterization framework to sufficiently address the challenges faced by cities in the project. The spatial scale used in the analysis will reflect different levels of the challenges (for example, a localized challenge with air quality or noise as the impact and pressure of urban transportation would require localized NBS intervention such as green wall or mixing of local intervention with higher scale policy intervention of limiting the transportation in certain vulnerable areas).

In analysing the spatial extent of the challenges facing by cities in the project, the spatial definition such as site, local, patchy or widespread will be used to describe whether the challenges are localized in certain sites or restricted to the environment or widespread over a large area of the city. The extent then will be accompanied by the frequency and severity of the challenges, such as low (does not cause a noticeable effect on the ecosystem or city environment or wellness), chronic (impact that occurs often enough and will have potential cause severe consequences such as recurring flooding or tidal flooding of coastal city), acute (a short duration impact with high severity such as a heat wave or local heat island).

3. City characterization results

i. Liverpool

Main facts about city's social, natural and economic status, as well as the legal and institutional guidelines on NBS application

The city is a vibrant port and logistics hub in the North of England with a young population. The city covers an area of 113 square kilometres and has a population of more than 491,500 (45.4% of the population are aged between 16-44 years old compared with 23.9% nationally) reflecting the popularity of the city among students and young professionals. The main occupations in the city are professional and followed by associate professional and technical jobs. Publicly available data shows around 6,400 Full Time Equivalent (FTE) green infrastructure related jobs in the Liverpool City Region with 9% of these connected with water transport. The legacy of the city's historic long-term economic and population decline is that Liverpool suffers from economic and social deprivation and is ranked fourth in the English Indices of Deprivation (i.e. it has the highest level of income deprivation among England's core cities with gross value added £24,396 per capita, lower than other UK and UK core cities (which have a GVA of £28,407 per capita))

Today Liverpool has 1,400 low carbon businesses that employ 22,000 staff and contribute £2.7 billion GVA towards the sector economy and the city is recognized as a principle investment

hub for offshore wind and tidal with a designation as a Centre for Offshore Renewable Engineering (CORE). The city region is characterized as a major port and logistics hub for the North of England and has a highly developed transport and logistics infrastructure with expertise in ship building, fabrication, manufacturing and engineering; employing 28,000 people across 1,700 businesses and contributing £3.4bn to the city region's GDP.

The city's current streetscape is dominated by high rise buildings in the city centre, which are flanked by small terraced housing out towards the city suburbs (with a dominance of smaller properties). In this area, the most common and abundant form of GI are domestic gardens and there is a lot of potential to use these spaces more creatively for climate change adaptation. With regard to general green space, the city has an abundance of parks and a mosaic of green spaces across the city, which are a legacy from the Victorians, and much of the city centre and waterfront is recognised as a UNESCO World Heritage Site. The city has good provision of city and district parks, with smaller amounts of neighbourhood parks and amenity space at a local level and around the busy port. Parks, amenity spaces, scrubland and woodland are usually under local authority control and all make key contributions to opportunities for new or improved green infrastructure.

Whilst Liverpool has a number of existing Nature Based Solutions (NBS), they have not to date been installed for this purpose; for example, some of the landscape improvement works have been carried out to assist with local flooding and although Nature Based Solutions have in part been applied, it has not been the primary focus of the scheme. The distribution of NBS assets across the city varies considerably. The north of the city, traditionally the more industrial and more deprived area, has lower levels of accessible green infrastructure than the more affluent central and southern areas. The city centre, due largely to its built-up nature, has less than 5% green infrastructure. There are many initiatives aimed at enhancing these areas such as the 'One tree per child' initiative and the recent Northern Forest proposal which aims to plant 50 million new trees in a band across the north of England and is being led by the Community Forest Trusts.

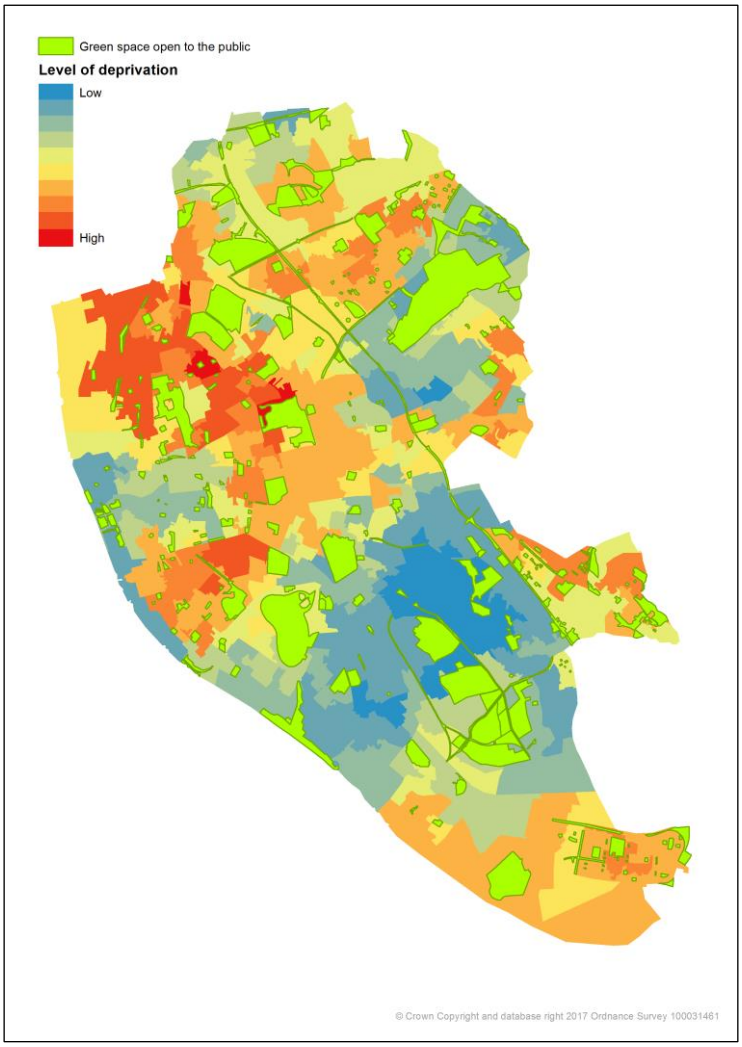

Figure 2: Level of deprivation and green space provision in Liverpool (Source: The Mersey Forest)

The UK is a highly centralised system, wherein authority rests with the British Government, and a significant proportion of financial resources flow from the central government. At the same time, a great deal of responsibility rests with local government, who do not always have commensurate resources, which is a well-known challenge for effective natural resource management. A democratically elected local government represents the views of local communities, voicing local concerns and responding to local needs. Local authorities promote the interests of local communities, including the social, economic, environmental, recreational, cultural, community or general development of an area.

Liverpool is also part of the Liverpool City Region Combined Authority. Along with five other authorities (Sefton, Knowsley, Wirral, Halton and St Helens), Liverpool has chosen to work collaboratively on issues related to housing, planning, regeneration and transport. In May 2017, Liverpool City Region elected its first Metro Mayor, to lead the Combined Authority. The Metro Mayor's manifesto includes a goal for a zero-carbon city region by 2040, protection of

green spaces and encouraging young people to become more involved in environmental projects and programmes.

The Liverpool city council administrative responsibility for green space is broken down as follows:

Regeneration and Economy

- Planning issues for green space
- Assets/disposals in the green space

Community Services

- Capital projects and development of green space/NBS
- Community engagement in green space/NBS
- Small scale green space events

Liverpool Streetscene Services Limited

- Operational maintenance of green space/NBS
- Cleansing of green space

Culture (from 2019 onwards)

- Large events and animation of key greenspaces
- Concessions/leases/licences in the greenspace

Important legislation that affect the implementation of NBS nationally and locally

Nationally

The UK Climate Change Act (2008) has: a legally binding target of at least an 80% cut in greenhouse gas emissions by 2050 and a reduction in emissions of at least 34% by 2020 (both against 1990 baseline); a carbon budgeting system that caps emissions over five-year periods; creation of the Committee on Climate Change; further measures to reduce emissions, including measures on biofuels; and the Act also introduces powers for the UK government to require public bodies and statutory undertakers to carry out their own risk assessment and make plans to address those risks.

The Flood and Water Management Act (2010) introduced legislation to address the threat of flooding and water scarcity, both of which are predicted to increase with climate change. The act requires the use of sustainable drainage systems in certain new developments. The Flood Risk Regulations 2009 require Lead Local Flood Authorities to identify areas which are at risk of flooding from surface water flooding, groundwater flooding, ordinary watercourse flooding and flooding from canals with significant consequences, and to produce a Preliminary Flood Risk Assessment (PFRA) based on those areas.

The Environment Act 1995 requires the UK government to prepare a National Air Quality Strategy. The Air Quality Standards Regulations 2010 set legally binding limits for concentrations in outdoor air of major air pollutants that impact public health such as particulate matter (PM10 and PM2.5) and nitrogen dioxide (NO2).

The Natural Environment and Rural Communities Act 2006 (in England and Wales) imposes a duty to conserve biodiversity and applies to all local authorities and extends beyond just conserving what is already there to carrying out, supporting and requiring actions that may also restore or enhance biodiversity. The Secretary of State is required to publish a list of habitats and species that are of principal importance for the conservation of biodiversity in England.

Locally

Liverpool City Council's Climate Change Strategic Framework (2009) and Adaptation Framework Report (2009) form the backbone of the City's Climate Change Framework. Together they address climate change impacts and projections and identify a number of priority and supporting actions for a low carbon city. In addition, Liverpool City Council is the lead Local Flood Authority for Liverpool and has to comply with the Flood and Water Management Act (2010) to develop strategies to address all flood risk management matters.

Most importantly, at the local level are Liverpool Green Infrastructure Strategy (commissioned by Liverpool City Council Planning Service in partnership with Liverpool Primary Care Trust (PCT) in 2010) and the Liverpool Open Space (Assessment and Standards Report) Study 2017 which underpin the development of the Liverpool Local Plan in assessment of existing open space and planning of green infrastructure to improve public health. The Strategic Green and Open Space Review, 2014-2016 provided a series of recommendations for the future management of the city's green spaces and the Green Infrastructure Strategy of the city plays an instrumental role in setting out the direction for the future of NBS in the city and implementation of Green Infrastructure project.

Current urban challenges for Liverpool

Flooding

Liverpool is at risk from flooding from multiple sources, including the Mersey and 10 streams, which are mostly culverted. Many of the earlier streams in the city are now lost or hidden in undersized pipes because of culverting during periods of earlier construction boom when former greenery was literally paved over. These culverted streams introduce surface water flood risks when culverts are blocked, exceeded by flood-flows or where overland flow struggles to reach its original channel. In many instances, flood vulnerability in Liverpool is archetypical of the problems associated with the unintended consequences of mass construction and poor drainage, with as much as 4% (4.57km^2) of Liverpool being at fluvial flood risk from the city's watercourses from the 1% and 0.1% events. As many as 510 properties are at risk from a 1% tidal event such as a storm surge along the Mersey Estuary.

Poor air quality

Poor air quality is associated most often with the busiest parts of the road transport network, where the key processes of dilution, dispersion and deposition are most inhibited. The risk of air quality standards breach is highest during times of heavy traffic and static air conditions, for instance blocked high pressure and persistent humidity. In 2010, the attributable deaths due to air pollution (age 25+) were 239 and the associated life-years lost were 2440, making Liverpool the 6th highest ranking city to live for poor air quality outside of London (UK government report). Although poor air quality emanates from both domestic and industrial sources the majority of the air pollution, especially in relation to NO_2 and particulate matter in Liverpool is associated with transport sources in particular buses, heavy goods vehicles and taxi fleets. Monitoring reveals that, at times, Liverpool's air exceeds statutory NO_2 emission targets and that air quality is poorest in the north of the city and around the airport.

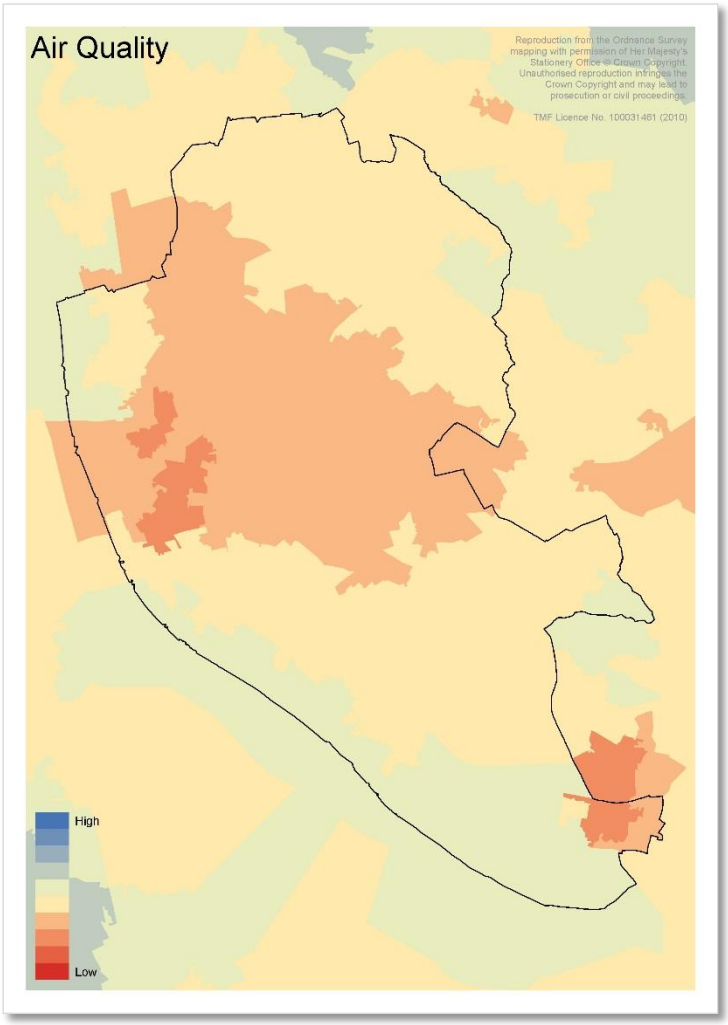

Figure 3: Air quality status of Liverpool (source: the Strategic Green Infrastructure Strategy)

Biodiversity

Liverpool, was identified by Natural England as an area with natural environment that has high vulnerability to climate change. In October 2015 as part of a Strategic Green and Open Space review of the city the Merseyside Environmental Advisory Service carried out a review of biodiversity value in Liverpool which investigated data sets and reviewed historic reports. The review found an average of 7 species per hectare which was classified as very low and probably under representative of the presence of biodiversity – for many areas there were simply no records and absence of evidence is not evidence of absence.

The report also made a number of recommendations that were focused on:

- Protection of priority habitat other than woodland
- Improved biodiversity management
- Creation of connecting corridors
- Finalising a list of Local Wildlife Sites
- Encouraging community engagement for species recording

Institutional and legal barriers

The biggest legal barriers relating to NBS installation probably relate to land ownership, land owner permissions, risk and future liability. The UK has comprehensive planning and legal systems which together govern the installation of NBS. As with any other installation, especially one on/in/over/under a pedestrian or publicly accessible walkway there will be issues of risk and liability that will need to be considered and addressed. The process of assessing the risk of an NBS is no different to risk assessing any other highways structure, be that underground pipe work or erecting advertising boarding.

DPSIR analysis framework for Liverpool: current challenges.

According to the analysis framework of DPSIR to characterize the city with its current challenges, pressures and impacts in the perspective of implementing NBS, the following table shows the connection between different driving forces for the city and the corresponding actions/policies to counter the pressure and negative impacts. This analysis will form the foundation for the planned city Renaturing Urban Plan (RUP) and serve as the guiding framework for the selected interventions in the city.

Driving force (human demand)	**Pressure** Use of natural resources (Pressure) Exogenous, Unmanaged Pressure (e.g., due to climate change)	**State** (Condition of natural resources)	**Impact** (Change in natural resources)	**Spatial extent of impact** (Widespread, local, site) **Additional component to the DPSIR framework**	**Responses** (actions/policies) **NBS development referring to the NBS catalogue in WP1**
Primary					
Urbanization with increasing culverting of natural streams	Narrowing of watercourses Loss of open green space from city Climate change with rainfall and storm surge	Regulated Water flow and lack of naturalness of stream through engineered channels	Flooding Loss of biodiversity	Local	**Infrastructure** Rain gardens Open water SUDS Permeable paving Tree SuDS **Policy** Urban Development Strategy Liverpool Green Infrastructure Strategy Local flood and water management policies Biodiversity policies
Increased transportation system	Air pollution, Noise	Air circulation, dispersion and trapping of pollutants	Human and environmental health	Patchy-widespread	**Infrastructure** Tree planting Green screens Green wall Green roofs

Driving force (human demand)	**Pressure** Use of natural resources (Pressure) Exogenous, Unmanaged Pressure (e.g., due to climate change)	**State** (Condition of natural resources)	**Impact** (Change in natural resources)	**Spatial extent of impact** (Widespread, local, site) **Additional component to the DPSIR framework**	**Responses** (actions/policies) **NBS development referring to the NBS catalogue in WP1**
					Policy Sustainable Energy Action Plan (SEAP)/ A Transport Plan for Growth/ Sustainable Urban Development Strategy/ Low Carbon Economy Action Plan/ Joint Recycling and Waste Management Strategy Climate change policies
Secondary					
Demand for urban development and economic activities	Land-use change Energy supply Waste generation	Ecological processes and balance Landscape features	Loss of biodiversity Loss of green space for flood control and other NBS function	Patchy-widespread	Increase the ecological connectivity (green corridor) Pollinator walls Pollinator planting Insect hotels Aquatic planting Tree Planting

Driving force (human demand)	**Pressure** Use of natural resources (Pressure) Exogenous, Unmanaged Pressure (e.g., due to climate change)	**State** (Condition of natural resources)	**Impact** (Change in natural resources)	**Spatial extent of impact** (Widespread, local, site) **Additional component to the DPSIR framework**	**Responses** (actions/policies) **NBS development referring to the NBS catalogue in WP1**
		Habitat quality			Floating island Green roofs **Policy** Sustainable Urban Development Strategy Liverpool Green Infrastructure Strategy Waste policies SEAP
Tertiary					
Development and economic activities	Economic depression	Landscape features are lost	Local regeneration Low quality green space Unemployment Low educational attainment Chronic health problems	Local	Accessible green route Location, linkages and connectivity **Policy** Community resilience work Climate change policies Distribution planning of NBS facilities to promote local business and properties and

Driving force (human demand)	**Pressure** Use of natural resources (Pressure) Exogenous, Unmanaged Pressure (e.g., due to climate change)	**State** (Condition of natural resources)	**Impact** (Change in natural resources)	**Spatial extent of impact** (Widespread, local, site) **Additional component to the DPSIR framework**	**Responses** (actions/policies) **NBS development referring to the NBS catalogue in WP1**
					wellbeing of residents

Table 1: DPSIR framework for the characterization of Liverpool toward NBS applications

The analysis presented in Table 1 highlights the most important features when considering NBS development for Liverpool, including: economic development (economic depression) with the uneven access to NBS in some City areas, the highly culverted streams across the City, the considerable lack of biodiversity because of the current lack of green space connectivity and green corridor provision, together with air pollution due to traffic and industrial development around the City. Along with the current physical, natural pressures and challenges, the City in its legal framework has also been proactively engaged with enabling policy to advance the implementation of Nature Based Solutions such as the Liverpool Green Infrastructure Strategy It is worth noting that some of the NBS schemes already implemented in the City were not originally intended to focus on NBS, such as the SUD at the Estuary Business Park.

ii. Valladolid

Social, natural, and economic conditions and legal/institutional frameworks related to NBS application

The municipality of Valladolid is divided into five unique population entities: Valladolid (1), Pinar de Antequera (2), Puente Duero (3), Navabuena (4) and El Rebollar (5). The municipality of Valladolid is located in a flat area with little variation in elevation. The natural landscape of the municipality and the Valladolid city is integrated by valley vegetation and river terraces, as well as different agricultural crops in rural area of the municipality. Hydrographically, Valladolid is located in the River Duero Basin. The Pisuerga and Esgueva rivers run through the municipality. The Pisuerga River divides the city into two parts, with several communication bridges between them. The River Esgueva, which formerly crossed the city in two branches, at the end of the nineteenth century was channelled and only affects and divides suburbs east of the municipality.

The City of Valladolid has a population of 301,876 inhabitants (INE, 2016) and area of 197.5 km^2. It is located in the centre of the 23 municipalities of the province of Valladolid, which has a surface of a 1000 km^2 and a population of 410,000 inhabitants. The City has approximately 500 hectares of green areas, which means a ratio of 16 m^2 per capita (2017, Environment and Sustainability report). It is the largest city in the North-West of Spain. The economic characterization of Valladolid is divided between 4 main sectors (services 80.7%, construction 3.4%, industry 13.9% and agriculture 2%).

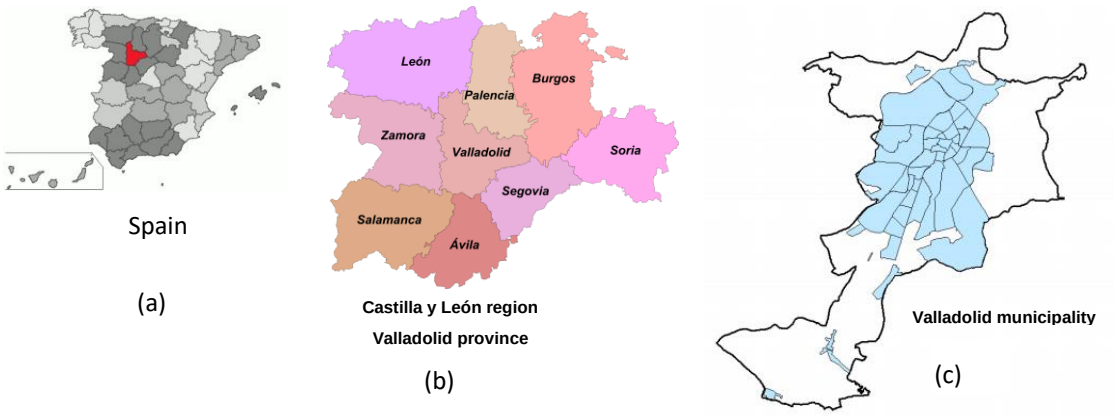

Figure 4: Location of Valladolid municipality in a national (a), regional (b) and local (c) context (Source: Valladolid General Plan of Urban Planning of 2017)

The buildings of Valladolid present a multitude of constructive typologies, containing areas of terraced houses with a maximum of two storeys, and areas in which most of the buildings exceed 12 storeys. Similarly, in the municipality there are both narrow streets with little traffic, and large avenues of up to three lanes with a high traffic flow.

The urban growth model for the city of Valladolid predicts a fragmented city type; the city is growing in the peri-urban area, towards the nearby municipalities. The urban population has been decreasing since the 1980's with the demographic restructuring with the economic sector shifting towards service, thus the City Centre is becoming less populated, with an ageing population.

Institutional settings related to NBS implementation

NBS are managed and implement through cooperation between several departments inside the City council, namely the Public Space and Infrastructures Service, The Architecture and Housing Service, the Environment Service, the Service of Parks and Gardens, The Urban Cleansing Service, and Urban Mobility Centre. The Competent Authority for the public bidding processes for the construction of the NBS is Valladolid City Council, promoted by the Innovation Agency. Written approval is required from other departments, such as Urban Planning or Environment. Other public bodies can also be involved, depending on the context of the NBS, including the River Duero Basin (for relevant water-based NBS) and, private companies who may rely on the public licenses provided by the municipality.

Legal systems related to NBS

In Valladolid municipality there are no specific regulations for Nature-based solutions. Valladolid has a Sustainable and Integrated Urban Development Strategy (EDUSI) called INNOLID 2020+, which is the current framework guiding NBS implementation. The EDUSI identifies climate change, transport and environmental challenges for the city of Valladolid, among others, that could be tackled by the implementation of NBS.

Every urban planning project in Valladolid should be implemented with the specifications of the Urban General Urban Plan of Valladolid (PGOU 2004, which is currently on revision, pending approval, expected in 2019). The General Plan of Urban Planning (PGOU) is a general planning instrument defined in the urban planning regulations of Spain as a basic instrument of integral management of the territory of one or several municipalities. The PGOU classifies the land uses and the fundamental elements of the municipality equipment system are defined. The PGOU of Valladolid includes the urban planning of the city, integrating sustainability principles and criteria. Two other planning strategies are relevant to the implementation of NBS in Valladolid: Local Agenda 21 (www.valladolidagendalocal21.es) V Action Plan (2016-2020) and the Comprehensive Urban, Sustainable and Safe Mobility Plan of the city of Valladolid (PIMUSSVA) (www.pimussva.es), 2015.

Locally, Valladolid is developing a systemic project for urban parks and green corridors; a dual strategy for the protection of local environmental resources and their sustainable recovery. It has been developing a new double green ring that will be an "equipped urban parks system" to provide key services to citizens.

Figure 5: Open space strategy for Valladolid municipality, with the creation of a double system of parks founded on a double road ring by the river Pisuerga and its banks (PGOU, 2017)

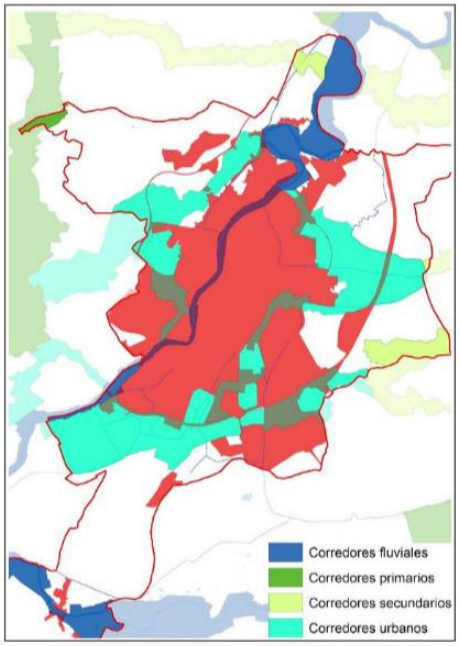

Figure 6: Ecological corridors and connectivity for the city of Valladolid. Green ring proposal (PGOU, 2017)

The Inner Green Ring is an urban parks system where there are several existing parks, and others new parks to be added. Pisuerga and Esgueva Rivers, as well as Canal de Castilla and Duero river, are the main waterways in this inner green system.

Urban challenges for Valladolid

Since the 1980s, Valladolid has faced a significant demographic problem: the urban population has decreased in size, the City centre is becoming empty, the average age is increasing, and citizens are moving to the surrounding municipalities looking for better prices and more family-friendly accommodation. Furthermore, social inequality between neighbourhoods is increasing. The unemployment rate is not a real threat but it is a risk that the city is reviewing carefully.

The City is built on the flood plain of the Pisuerga river, thus there is expected hydrological risks in the municipality of Valladolid associated with natural flooding processes. Big rivers

suffer sheet flows, due to persistent rainfall in low slope basins like the Pisuerga river. The risk of flooding increases with intense precipitation (Spring) and thawing (Winter). Valladolid municipality approved the 1st Action Plan for floods in October 2018, qualifying as a city with "high" risk of flooding for the population.

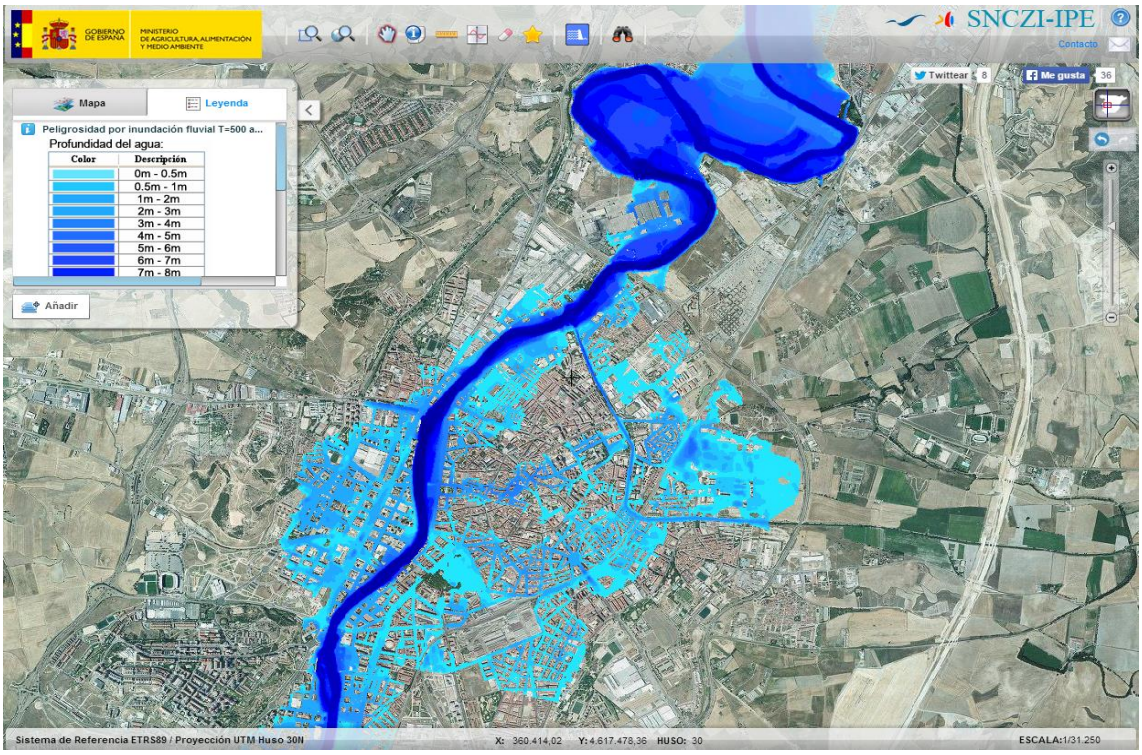

Figure 7: Hazard map by river flood for T=500 years (Source: *www.chduero.es* River Duero Basin)

Water quality - The general quality of the water of the Pisuerga River in the provincial limit of Palencia is gradually degrading as the catchment is incorporated into the urban and industrial zones of the municipality of Valladolid.

Along with the water quality and flooding during the high flow season, there are also periods of very low flow due to water extraction for agriculture in the area during the dry season. This also causes challenges for the City regarding the maintenance of environmental water flows sufficient to sustain the River ecosystem. Poor water quality typically coincides with periods of low water flow of the River.

Air quality – The Valladolid metropolitan area suffers from atmospheric chemical emissions from urban traffic due to the many highways, roads and bypasses, as the area serve as the axis of transport for the region and nation; more than 250,000 vehicles on average drive on these roads on a daily basis. Air quality is also affected to a lesser extent by industrial activity around the urban area.

In the city of Valladolid there is an Atmospheric Pollution Control Network (RCCAVA) composed by five stations that continuously measure NO_x, PM_{10}-$PM_{2.5}$, O_3, SO2, CO and/or BTX. The Action Plan for Alert Situations in Urban Air Pollution in Valladolid, framed in the

Action Plan against Pollution (Department of Environment, 2017) identified warning situations due to ozone and particulate matter pollution. In June, October and November 2017 the alert threshold was reached.

During 2016 alert threshold of 'Preventative' was reached 11 times, 7/11 by Ozone, 2/11 NO2, 2/11 PM and the 'Warning' situation was reached 8 times, 3/8 by Ozone, 2/8 NO2 and 3/8 PM. The protocol to respond to 'Warning' situations is limiting vehicle velocity to 30 km/h and closing the city centre to motor traffic.

DPSIR analysis framework for Valladolid: current challenges.

Following is the result of the analysis framework carried out for Valladolid, recognizing the city's multiple challenges and mapping the challenges with relevant social economic activities that contribute to the challenges. From the analysis, the framework together with the available catalogue on the NBS applications and the selection of the city has presented the relevant responses of the cities corresponding with the current challenges and the pressures that Valladolid city environment is facing. The city has identified main challenges are: local flooding; the air pollution and noise from transportation, industry source; the heat island effect; the loss of biodiversity and lack of connectivity in public and green space; the urban regeneration issue with city centre getting empty due to economic hardship.

Driving force (human demand)	**Pressure** Use of natural resources (Pressure) Exogenous, Unmanaged Pressure (e.g., due to climate change)	**State** (Condition of natural resources)	**Impact** (Change in natural resources)	**Spatial extent of impact** (Widespread, local, site) **Additional component to the DPSIR framework**	**Responses** (actions/policies) **NBS development referring to the NBS catalogue in WP1**
Primary					
Urbanization with development on flood plain of Pisuerga and	Narrowing of watercourses Climate change with increased	Natural overflow to flood plain in rainy season	Flooding	Local	**Infrastructure** Floodable park; SUDs; rain garden.

Driving force (human demand)	**Pressure** Use of natural resources (Pressure) Exogenous, Unmanaged Pressure (e.g., due to climate change)	**State** (Condition of natural resources)	**Impact** (Change in natural resources)	**Spatial extent of impact** (Widespread, local, site) **Additional component to the DPSIR framework**	**Responses** (actions/policies) **NBS development referring to the NBS catalogue in WP1**
Esgueva Rivers	rainfall				**Policy** ▪ Local Action Plan for flood risk, 2018. ▪ Flood Risk Maps, River Duero Basin.
Increase transportation system	Air pollution, Noise	Air circulation and self-cleaning process	Human and environmental health	Patchy-widespread	**Infrastructure** Green noise barriers Urban Trees (Planting and renewal of urban trees; Shade Trees; Cooling trees); Urban Garden BioFilter; Green infrastructure (Green Façade, Green shady structures, mobile gardens, etc.); Electro wetland; Smarts soils as substrate. **Policy** ▪ Local Ordinance of Noises and vibrations

Driving force (human demand)	**Pressure** Use of natural resources (Pressure) Exogenous, Unmanaged Pressure (e.g., due to climate change)	**State** (Condition of natural resources)	**Impact** (Change in natural resources)	**Spatial extent of impact** (Widespread, local, site) **Additional component to the DPSIR framework**	**Responses** (actions/policies) **NBS development referring to the NBS catalogue in WP1**
					▪ Air Pollution Control Network of the Valladolid City Council (RCCAVA) provides daily air quality data ▪ Comprehensive Urban, Sustainable and Safe Mobility Plan of the city of Valladolid (PIMUSSVA) (www.pimussva.es), 2015 ▪ Clean vehicles agenda (PVL) 2012-2015, for the development of an electric vehicles system for the city of Valladolid
Secondary					
Demand for new urban housing	Land-use change	Landscape features	Heat island effect	Local (city center)	**Infrastructure** ▪ Urban Trees (Planting and renewal; Shade & Cooling trees ▪ Urban garden

Driving force (human demand)	**Pressure** Use of natural resources (Pressure) Exogenous, Unmanaged Pressure (e.g., due to climate change)	**State** (Condition of natural resources)	**Impact** (Change in natural resources)	**Spatial extent of impact** (Widespread, local, site) **Additional component to the DPSIR framework**	**Responses** (actions/policies) **NBS development referring to the NBS catalogue in WP1**
					biofilter ▪ Green corridor: New cycle lane and renaturing current cycle lane **Policy** ▪ Integrated Sustainable Urban Development Strategy (EDUSI), 2016 - REE4: Decrease in emissions of CO2 and rationalization of mobility in the urban area. ▪ Plan for integral urban mobility, PIMUSSVA, 2015.
Human economic activities	Land use change Pollution of watercourses	Natural process of water system self-purification	Loss of water quality for purpose of using	Pisuerga river/ seasonally (in drought season)	**Infrastructure** ▪ Natural Wastewater Treatment Plant (NWTP); Green filter; Electro wetland. **Policy** ▪ Integrated

Driving force (human demand)	**Pressure** Use of natural resources (Pressure) Exogenous, Unmanaged Pressure (e.g., due to climate change)	**State** (Condition of natural resources)	**Impact** (Change in natural resources)	**Spatial extent of impact** (Widespread, local, site) **Additional component to the DPSIR framework**	**Responses** (actions/policies) **NBS development referring to the NBS catalogue in WP1**
					Sustainable Urban Development Strategy (EDUSI), 2016 - Challenge: Efficiency in water use.
Tertiary					
Demand for urban development and economic activities	Land-use change	Ecological processes and balance Landscape features Habitat quality	Loss of biodiversity	Patchy-widespread	**Infrastructure** Urban Trees (Planting and renewal of urban trees; Shade Trees; Cooling trees; Trees for re-naturing parking); Pollinator's modules (compact and natural designs); Urban farming activities (small-scale urban livestock, urban orchard, composting, etc.) **Policy** Sustainable Urban Development Strategy

Driving force (human demand)	**Pressure** Use of natural resources (Pressure) Exogenous, Unmanaged Pressure (e.g., due to climate change)	**State** (Condition of natural resources)	**Impact** (Change in natural resources)	**Spatial extent of impact** (Widespread, local, site) **Additional component to the DPSIR framework**	**Responses** (actions/policies) **NBS development referring to the NBS catalogue in WP1**
					Liverpool Green Infrastructure Strategy
Development and economic activities	Economic depression	Landscape features	Local regeneration City centre is getting empty	Local	Accessible green corridor Location, linkages and connectivity **Policy** ▪ Integrated Sustainable Urban Development Strategy (EDUSI), 2016. ▪ Valladolid Smart City (RECI and INNPULSO networks).

Table 2: DPSIR framework for the characterization of Valladolid toward NBS applications

Table 2 highlights the highest level of challenges Valladolid is facing is the flooding (which affects locally) and the noise and air pollution due to high economic activities and transportation which the city has proactively respond with several policy to reduce its impact. At the same time, the city is also looking at several NBSs offer by Urban GreenUp project to tackle the issue with air and noise pollution and its replication. Of lesser concern, however also are the heat island effect, the loss of biodiversity and the local regeneration as the impact of urbanization process, land use change and the economic depression which has been identified

through the DPSIR framework to offer the city with different infrastructure in combination with its already issued policy to respond to these challenges.

iii. Izmir

Social, natural, and economic conditions and legal/institutional frameworks related to NBS application

Izmir is located in the west of Turkey and midway on the coastline of the Aegean Region. It is surrounded by the province of Balıkesir in the north, province of Manisa in the east and province of Aydın in the south. The area of Izmir is 1.201.477,55 ha, with the metropolitan area extending along the outlying waters of the gulf of Izmir and inland to the north across the delta of the Gediz River, to the east along an alluvial plain created by several small streams and to a slightly more rugged terrain in the south.

Izmir is a metropolitan city with a population of 4.2 million, making it the third largest city in Turkey. The city maintains this rank also regarding national economic indicators. Izmir owes this situation to being a population attraction centre at Aegean Region and on a national scale as the large metropolis of its region. Central part of Izmir around the Izmir Bay covers most of the inhabitants (2.9 million) and peripheral regions largely characterized with rural population. Considering the distribution of population according to location, percentage of those living in urban areas is 91% while those living in rural areas is 9%. Density of population is 333 per square km and İzmir is the third city in Turkey in terms population density

The most notable feature of the city is its İzmir Bay that covers an entire aquatic ecology, consisting of streams, wetlands and fisheries. The relationship between Izmir and its 972 square kilometre Bay is profound and existential. The city of Izmir receives its economic dynamism as much from its magnificent Bay opening to the Mediterranean as its hinterland that sweeps over the Aegean region. The Alsancak Port, situated at the innermost part of the Inner Bay is one of the most important channels of the bustling trade of the city. Those who live in Izmir, a city that surrounds the Inner Bay like an amphitheatre, increase their life satisfaction by looking at the sea day in day out and by travelling on the sea.

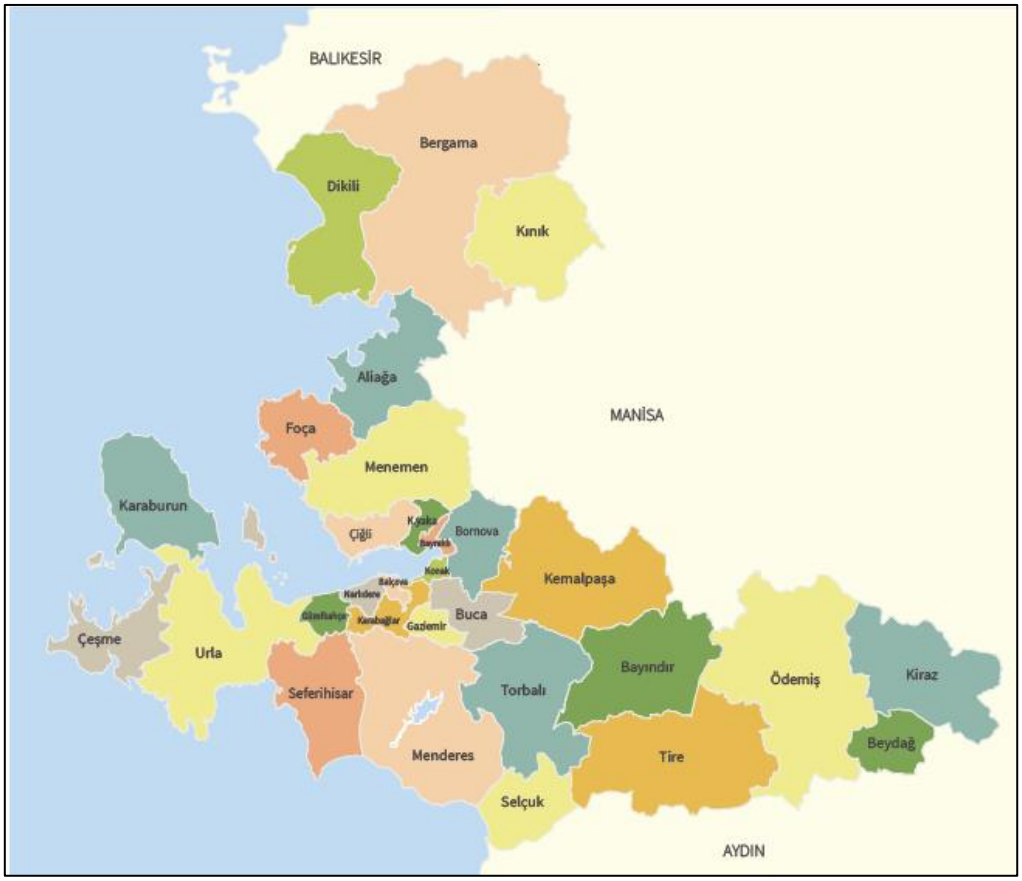

Figure 8: Izmir districts map (source: Izmir Strategic plan 2015-2019)

In Izmir, most of the buildings are multi-storey, generally up to 9 floors. In the 1950s, many detached houses were converted to apartments, with the emergence of concrete technology. However, recent years have seen a derease in the production of new multi-storey housing due to the decrease in the number of empty parcels in the city center and the maximum number of apartments allowed in city.

Izmir is economic powerhouse of its region (40 % of total population), due to the city offering multifaceted production opportunities, rich natural resources and high quality of living. Manufacturing is diverse, ranging from agribusiness, textiles, clothing, shoe production, chemicals, iron and steel, all the way to the automotive industry and a service industry required by this large aggregation of population and conglomeration of manufacturing industry. The city is among the 130 largest cities of the world.

Strategies and plans related to NBS

The Izmir Green Infrastructure Strategy (IGS)[2] outlines strategies to tackle different issues such as preserving and improving biodiversity in a systematic way within the boundaries of the

[2] İzmir Büyükşehir Belediyesi, 2018. İzmir Doğa - Yeşil Alt Yapı Stratejisi, accessed 18 January 2019, <http://izmirdoga.izmir.bel.tr/tr/yesilAltyapiHakkinda/1/8.>

central city. It also shows the commitment of the local government to make a comprehensive green infrastructure plan that would establish planning guidelines for other spatial plans in the city.

- According to the IGS, ecological corridors and linkages are the primary elements or connectors that can be used to reverse fragmentation of natural and/or green spaces in urban landscapes. They act as conduits providing opportunities for species movement to maintain and/or increase biodiversity. At the same time, they are multifunctional elements that serve recreational and cultural demands of city dwellers such as walking and bike paths. In IGS, watercourses such as urban rivers and streams are considered natural blue linkages that connect the green belt in the periphery of Izmir with the city centre and are also recreational corridors to serve pedestrian and bike routes.
- According to the IGS, creating more permeable surfaces (sponge like surfaces) should be a priory in provision and/or improvement of green and blue corridors throughout the city. That would also be helpful in abating the urban heat island effect as well as serving to filter storm water.
- The IGS also suggests establishing ecological/natural zones or pockets with an unmaintained native vegetation in urban parks and green areas. In this way, it is hoped to attract more wildlife, including pollinator insects. Both in the Sasali region and along the Peynircioğlu Stream, plant species from native communities are dominant. Pollinator houses or modules are recommended by the IGS to increase and support biodiversity in urban green areas besides providing shelter, highlighting the importance of pollinator friendly green areas and vegetation cover to the city. Creating pollinator friendly green areas and vegetation cover are the main principles of almost all the NBS in the project.

Current challenges in Izmir

Air Quality

In Izmir, poor meteorological conditions especially inversions can lead to serious air quality issues. Air pollution due to inversion (temperature reversal) is affected by industrial pollutions and the use of low-quality fossil fuels. As a result, both air temperature and air pollution increase. Additionally, northerly winds blowing through Bornova lowland bring additional air pollution to the city of Izmir from the industrial facilities located both in Bornova and Kemalpaşa lowlands.

Carbon dioxide (CO_2) emissions per capita (person) in Izmir is 5.31 tones/year[3]. A proper emission inventory is very important for planning pollution control programs, particularly in coastal sites like Izmir, where environmental quality is of growing concern owing to their typical meteorological conditions. Industry is the most polluting sector for SO_2 in the study

[3] İzmir Metropolitan Municipality. (2016). *Sustainable Energy Action Plan.* İzmir

area, contributing about 88 % of total emissions. Domestic heating is the most polluting sector contributing about 56 % of total PM emissions while traffic has the highest portion for NOX emissions. Industries located around the Izmir metropolitan centre contribute to the industrial SO_2 emissions by 93 %, PM emissions by 59 % and NOX emissions by 80 % of the total.

Rapid population growth, economic activity, tourism and fishery activities coupled with climate change impacts has led to degradation and loss of coastal wetlands in Izmir and increasing vulnerability and decreasing climate resilience of coastal area. In the coastal districts of Izmir, replacement of agricultural lands and natural areas by mostly high-density built-up areas threatens coastal resilience by exposing coastal communities to extreme events such as intense precipitation and flooding. The loss of coastal wetlands has many negative consequences including loss of habitat and loss of protection of the city against ocean swell.

DPSIR analysis framework for Izmir: current challenges.

Following are results of the analysis framework carried out for Izmir, recognizing the city's multiple challenges and mapping the challenges with relevant social economic activities that contribute to the challenges. The main challenges identified for the city are: local flooding; air pollution and noise from transportation and industry coupling with microclimatic condition of temperature inversion; heat island effect; loss of biodiversity (of both inland and coastal environment) and lack of connectivity in public and green space.

Driving force (human demand)	**Pressure** Use of natural resources (Pressure) Exogenous, Unmanaged Pressure (e.g., due to climate change)	**State** (Condition of natural resources)	**Impact** (Change in natural resources)	**Spatial extent of impact** (Widespread, local, site) **Additional component to the DPSIR framework**	**Responses** (actions/policies) **NBS development referring to the NBS catalogue in WP1**
Primary					
Urbanization with development on flood plain	Narrowing of watercourses	Natural overflow to flood plain in	Flooding	Local	**Infrastructure** Grassed swales and Water retentions

Driving force (human demand)	**Pressure** Use of natural resources (Pressure) Exogenous, Unmanaged Pressure (e.g., due to climate change)	**State** (Condition of natural resources)	**Impact** (Change in natural resources)	**Spatial extent of impact** (Widespread, local, site) **Additional component to the DPSIR framework**	**Responses** (actions/policies) **NBS development referring to the NBS catalogue in WP1**
of Peynircioğlu stream	Climate change with rainfall	rainy season			ponds around Bio-Boulevard **Policy** Izmir Green Infrastructure Strategy
Increase transportation system Economic activities	Air pollution, Noise Temperature reversal	Air circulation and self-cleaning process	Human and environmental health	Widespread	**Infrastructure** Smart soil into green shady structures, Parklets, Biofuel production unit
Demand for new urban housing, rapid urbanization	Land-use change	Landscape features	Heat island effect	Widespread-patchy	**Infrastructure** Green covering shelter on car parking areas, Cool pavements around selected car parking areas, Shade and cooling trees alongside parking lots

Driving force (human demand)	**Pressure** Use of natural resources (Pressure) Exogenous, Unmanaged Pressure (e.g., due to climate change)	**State** (Condition of natural resources)	**Impact** (Change in natural resources)	**Spatial extent of impact** (Widespread, local, site) **Additional component to the DPSIR framework**	**Responses** (actions/policies) **NBS development referring to the NBS catalogue in WP1**
Demand for urban development and economic activities	Land-use change	Ecological processes and balance Landscape features Habitat quality	Loss of biodiversity	Patchy-widespread, coastal and inner-city area	**Infrastructure** Pollinator house, green walls, fruit walls Coastal wetland regeneration (Restoration of southern Gediz delta and its valuable wetlands ecosystems)
Secondary					
Rapid urbanisation	Land use change	Connectedness of greenspace	Disconnection among urban green areas	Widespread	**Infrastructure** Green Corridor

Table 3: DPSIR framework for the characterization of Izmir toward NBS applications

Table 3 shows the linkage between some of the drivers, and pressures leading to the current challenges Izmir facing which prioritize the responses to local flooding, the heat island effect due to rapid urbanization, the loss of biodiversity and green space connectivity (from widespread patchy to widespread) due to land use change. Most importantly, the development of policy to foster the NBS infrastructure to respond to the challenges is largely missing in the current context which should be strengthen in tandem with the green infrastructure development.

iv. Mantova

Social, natural, and economic conditions and legal/institutional frameworks related to NBS application

Mantova is located in the south-east sector of the Lombardy Region, along the course of the Mincio River, on the Po Valley. The territory, in its history as well as in its morphology, is characterized by a wide-spread and sprawling water presence; about 8% of its territory is occupied by three lakes: the Lago Superiore (Lake Superior), the Lago di Mezzo (Middle Lake) and the Lago Inferiore (Lower Lake), and a wide wetland. In 2007, Mantua's centro storico (old town) and Sabbioneta were declared by UNESCO to be a World Heritage Site.

The historic center is composed of an ancient central town of great landscape and architectural value, lying very close to the lakes, including the areas from the settlements of the Gonzagas' time to the compact expansions built until the first half of the 20th Century. This most area of the city is particularly sensitive, in relation to real estate interventions (subject to landscape or monument protection law), dealing with public space management (as cobble stones are subject to World Heritage controls) and traffic and parking management, and because the area hosts most of administrative public services, hotel-restaurant-casino and commercial activities, and attracts tourism.

The municipal territory is crossed by an important surface water network, including man-made canals and wetlands. The water management system of the Lakes of Mantua is regulated under a reclamation and navigation plan named Adige-Garda-Mincio-Tartaro-Canalbianco, that, in addiction to keeping the lake at a fixed level through a series of hydraulic tools, led to the construction of two great completely covered man-made canals: the Canale Diversivo Mincio (Diversion Canal of Mincio) and the Canalbianco (White Canal). The riverbanks of Mincio have been subject to renewal efforts in recent years to ensure that they are accessible to citizens, through the construction of a network of bike lanes linking the lakes to the city.

Figure 9: Mantova city, situated on Mincio River (source Wikipedia)

Between 2005 and 2017 the population of Mantua grew by 1738 people with an influx of immigrants of 6865. Over this period, the number of families grew by 1635 units, up to 23905 family units at the end of 2017. The GDP per capita of €2 8.000 is relatively high and the productive system is strong (with 1 enterprise per 10 inhabitants) and is strongly export oriented (47% of GDP). The economic sector of the city is divided between agriculture 4.2%, industry 6.8%, building construction 15.1%, trade 24.3%, others 49.5%. The Hotel Restaurant Casino sector is strongly connected with the tourist function of the city. Among the different companies, in addition to the ones located in the chemical hub, there are two important companies which are large manufacturers of menswear (Lubiam SpA and Corneliani SpA). The commercial sector includes small and medium sized businesses, including a large shopping mall.

Existing city plans

The municipal administration's strategies include the Sustainable Mobility Urban Plan, establishing policies for strengthening the park and ride systems at the entrances of the city, through providing new structures serving the Old Town, in order to help to gain access to it, promoting in the meantime the soft mobility. The concurrent review of the Plan Document and upgrade of the Management Plan of the UNESCO World Heritage Site, both currently in progress, become thus an occasion for coordination and specific analysis with common targets such as cultural, touristic and commercial promotion of the city. The plan ensures the protection of cultural heritage, in order to guarantee the maintenance for next generation of the heritage

General Urban Plan: it represents the main management territory instrument. It is composed by three documents, a general cognitive frame, a Utilities Plan and a Rules Plan which describes the transformation of the following five years and the adaptation plan guidelines (after approval). The Utilities plan, which describes green public areas and ecological local grid. Adaptation Plan Guidelines: the document show data linked with climate change effects, such as green areas, heat weaves, winds etc. It suggests some technical and nature-based solutions.

Mantua and its Municipality are located in ZONE A - dense urbanized lowland. The City developed Noise Zoning Plan defines the characteristics of the municipal territory for applying the noise pollution prevention rules and for drawing up a recovery plan based on the existing noise levels and on the causes that have led to this level.

Mantova urban present challenges

The physical condition of the city with continental weather condition influenced by the low land configuration of Po Valley, completely closed by the mountains, Alps and Apennines, that block the wind flow from Northern Europe. Thus, does not create favorable climate condition favor the dispersion of pollutant and natural circulation leading to hot summer with storms and frequent hail. Heat island has been identified as seriously affect people lives that entail responses. As shown in the heat waves vulnerability graph, most of the dense urban area of the cities are under high risk of heat island effect and affected by recent heat waves.

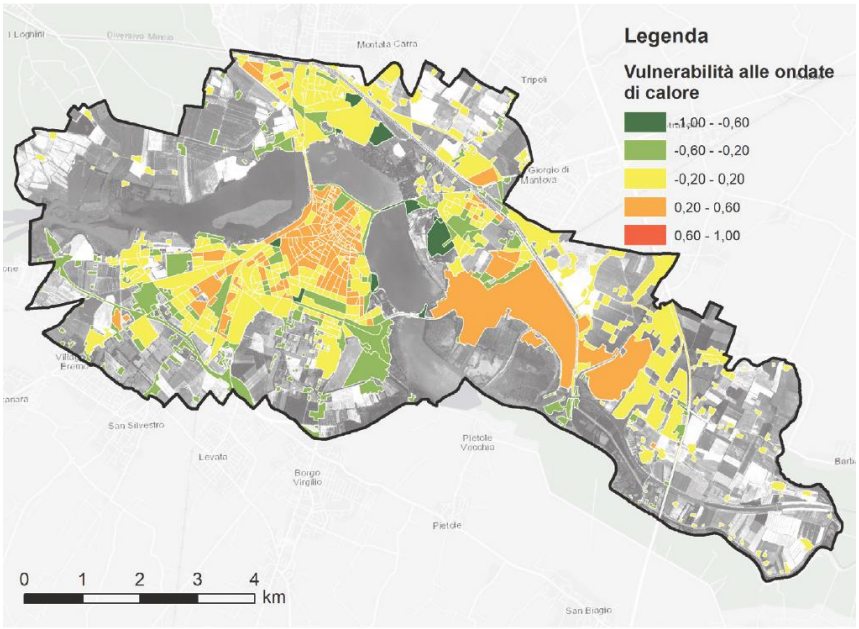

Figure 10: Heat weaves vulnerability – Values are obtained by the sum of morphologic indicators related with weak inhabitants. (Source: Mantova General Urban Plan)

As the City has a strong connection with the surrounding river and lakes in the area, the city also identified management of this ecosystem as a key challenges in its development. Crossed by Mincio River, forming 3 lakes surrounding the historical Centre, and included in the Mincio Natural Park, Mantova is a Nature 2000 natural reserve. On the other side, the City comprises a polluted area of national relevance (mainly due to the chemical industrial activity by the lakeside), posing a key threat to the ecosystem.

With the old center protected under a UNESCO management plan, any implementation of NBS intervention has to be undertaken in a manner sympathetic to World Heritage requirements.

DPSIR analysis framework for Mantova: current challenges.

Following are the results of the analysis framework carried out for Mantova, recognizing the city's multiple challenges and mapping the challenges with relevant social economic activities that contribute to the challenges. The city has identified several key challenges including: heat island effect; air and noise pollution due to traffic and industry coupled with the unfavourable microclimatic condition of temperature inversion; local flooding; loss of biodiversity of the green space in the city and the wetland ecosystem surrounding the city; and lack of connectivity in public and green spaces. Besides the various requirement of the existing Urban plan, the city also needs to follow an UNESCO management plan that restricts many of the NBS options for the city.

Driving force (human demand)	**Pressure** Use of natural resources (Pressure) Exogenous, Unmanaged Pressure (e.g., due to climate change)	**State** (Condition of natural resources)	**Impact** (Change in natural resources)	**Spatial extent of impact** (Widespread, local, site) **Additional component to the DPSIR framework**	**Responses** (actions/policies) **NBS development referring to the NBS catalogue in WP1**
Primary					
Urbanization processes	Land-use change Typical microclimatic condition of the area (restricted air circulation)	Landscape features	Heat island effect	Widespread-patchy	**Infrastructure** -Greening -Shade trees -Planting and renewal urban trees, Urban Carbon Sink -Trees re-naturing parking -Cool pavements -Green Covering Structures (shelters, roofs, shady structures) **Known barrier** Legal barriers connected with UNESCO site
Increase	Air pollution,	Air circulation	Human and	Widespread	**Infrastructure**

Driving force (human demand)	**Pressure** Use of natural resources (Pressure) Exogenous, Unmanaged Pressure (e.g., due to climate change)	**State** (Condition of natural resources)	**Impact** (Change in natural resources)	**Spatial extent of impact** (Widespread, local, site) **Additional component to the DPSIR framework**	**Responses** (actions/policies) **NBS development referring to the NBS catalogue in WP1**
transportation system Economic activities	Noise Temperature reversal	and self-cleaning process	environmental health		- Urban Garden BioFilter - Green Façade - Cycle and pedestrian green routes - Planting and renewal of urban trees; Shade Trees; Cooling trees; Trees re-naturing parking and Arboreal areas around urban areas **Policy** Sustainable Mobility Urban Plan
Urbanization with development on flood plain of Mincio river	Narrowing of watercourses Climate change with rainfall	Natural overflow to flood plain in rainy season	Flooding	Local	**Infrastructure** Grassed swales and Water retentions ponds around Bio-Boulevard

Driving force (human demand)	**Pressure** Use of natural resources (Pressure) Exogenous, Unmanaged Pressure (e.g., due to climate change)	**State** (Condition of natural resources)	**Impact** (Change in natural resources)	**Spatial extent of impact** (Widespread, local, site) **Additional component to the DPSIR framework**	**Responses** (actions/policies) **NBS development referring to the NBS catalogue in WP1**
Secondary					
Demand for urban development and economic activities	Land-use change	Ecological processes and balance habitat quality (fragile ecosystem of the wetland and lake)	Loss of biodiversity	Local	**Infrastructure** Wetland regeneration Sustainable urban drainages, floatable park
Rapid urbanisation	Land use change	Urban renewal process	Disconnection among urban green areas	Widespread	**Infrastructure** - Planting and renewal of urban trees; Shade Trees; Cooling trees; Trees re-naturing parking - Arboreal areas around urban areas, urban catchment forestry - Green Filters, Natural wastewater treatment, biofilters,

Driving force (human demand)	**Pressure** Use of natural resources (Pressure) Exogenous, Unmanaged Pressure (e.g., due to climate change)	**State** (Condition of natural resources)	**Impact** (Change in natural resources)	**Spatial extent of impact** (Widespread, local, site) **Additional component to the DPSIR framework**	**Responses** (actions/policies) **NBS development referring to the NBS catalogue in WP1**
					community composting

Table 4: DPSIR framework for the characterization of Izmir toward NBS applications

Table 4 highlights the pressures of urbanization process as well as the local climatic condition give rise to the main impacts currently faced by Mantova are the heat island effect, air pollution and local flooding. The secondary impacts are the loss of biodiversity and the connectivity of the urban green area that draw the interest of the city to apply several NBS schemes. Noteworthy though is that the city center which requires NBS application to tackle the current impacts however is restricted in the NBS options can be applied due to its UNESCO recognition status. Besides, the current policy to foster the application of NBS to respond to the current challenges is limited which should be address along the infrastructure considered for the implementation.

v. Ludwigsburg

Social, natural, and economic conditions and legal/institutional frameworks related to NBS application

Ludwigsburg is located within the Stuttgart Region, and the district is part of the administrative region (Regierungsbezirk) of Stuttgart. Ludwigsburg houses about 93,000 inhabitants spread over 7 suburbs and is one of the most prosperous economic centres in the region. Within the City there are 50 factories, 1200 craft-oriented and commercial companies and over 2000 wholesale and retail outlets. Companies of all sizes, many of which operate worldwide, have their headquarters located in Ludwigsburg. Global corporations and small businesses, industrial and craft enterprises, service providers and suppliers are equally represented. The business park Weststadt is the largest and most dynamic business park in Ludwigsburg. It built a solid base for the economy of Ludwigsburg with around 10,000 jobs and well-known companies such as Mann + Hummel and Hahn + Kolb, as well as emerging start-ups such as Porsche Digital.

The river Neckar flows through Ludwigsburg. There are only a few municipal areas (Neckarweihingen and Poppenweiler) in which catchment water flow can present a problem. However, in those areas there is little dense development near the River.

Ludwigsburg has a relatively high percentage of green cover; approximately 24% of the area is covered by vegetation (Figure 11). The publicly owned forest (36%) is PEFC-certified. Ludwigsburg is a green city, with 40 m^2 of green space per inhabitant and about 29,000 trees on public ground.

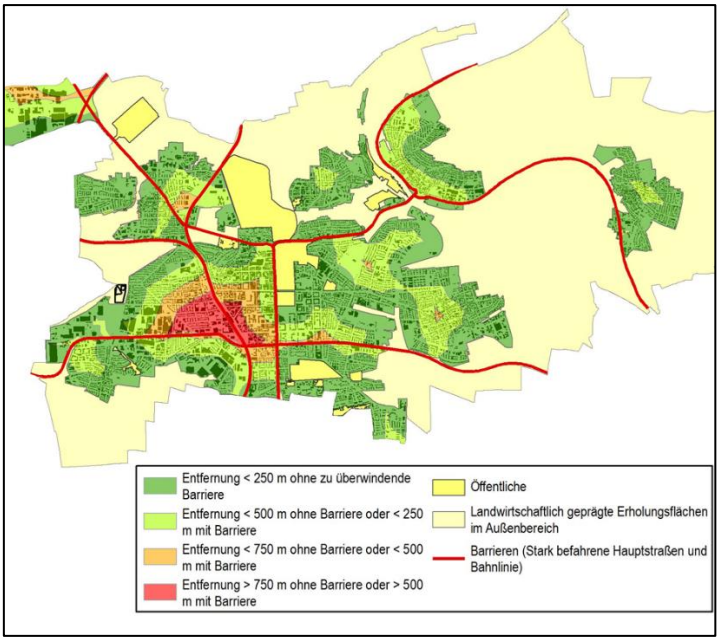

Figure 11: Average distance to green areas and barriers for residents of the city (source: Strategic Concept on Climate Adaptation - KliK 2016, S. 126)

In Ludwigsburg there are three offices that are involved in planning, design, construction and maintenance of NBS: Urban Planning & Surveying; Civil Engineering and Green Spaces; Europe & Energy. The Lord Mayor is responsible for the general management of the City administration, which is divided over 3 departments:

- Economy, culture, administration (led by the Mayor)
- Education, sports and social affairs (led by the first Deputy Mayor)
- Building, technology and environment (led by the Deputy Mayor with responsibility for building)

In addition, a new interdepartmental unit was established in 2008 under the direct supervision of the Mayor's office – the Department for Sustainable Development. This interdepartmental structure was created to transform the traditional linear structure of administration. It is involved in all decision-making processes related to sustainable urban development.

On the basis of an integrated Urban Development Strategy (Stadtentwicklungskonzept SeK), Ludwigsburg developed a municipal energy and climate protection plan (citywide energy Strategy – Gesamtenergiekonzept GeK), which is implemented via numerous projects. For the realization of the SeK, the entire municipal administration was reorganized. An interdepartmental unit for sustainable urban development (referat Nachhaltige Stadtentwicklung) was founded and put under the control of the Lord Mayor, and energetikom, a "competence centre for energy, climate protection and eco-design" was created. Moreover, several national and European research projects on energy and climate protection are conducted. In the following, the numerous activities in the course of the Urban Development Strategy are briefly introduced. The Quality of Air and the Acoustic environment are essential parts of the integrated urban development concept (Stadtentwicklungskonzept, SEK), further elaborated in the master plans "Mobility" and "Green in Town".

The Strategic Concept for Open Space and Green Areas (Freiflächenentwicklungskonzept, FEK) was developed in 2014. The FEK delivers an analysis of the current state of open space and green areas within the City, recommending further measures for improvement. The FEK sets guidelines such as dual development of the inner city (urban densification, while extension and preservation of green areas) and integration of FEK planning principles into the development plan. The FEK also recommends the development of a continuous network of green shaded areas for pedestrians and cyclists. This "green ring" connects the districts of West, South, East and inner city on the border to the outdoor area of the city; e.g. the city concluded recently on a greening concept for the street Comburgstraße, providing the planting of trees and the establishment of grass verges.

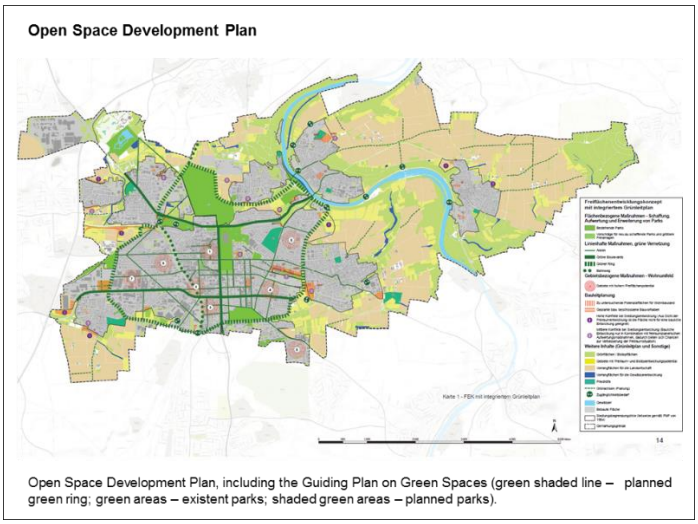

Figure 12: Open space development plan (Source: Ludwigsburg Strategic Concept for Open Space and Green Areas, FEK)

Ludwigsburg urban challenges

Ludwigsburg is highly affected by rail noise as the city is linked to Stuttgart's urban railway and the larger region's rail network. Therefore, from 2007 – 2012 the German Rail set up a funding scheme for noise prevention, including protection measures such as the installation of sound proof windows and speed limits.

Ludwigsburg's climatic challenges in urbanised areas are mainly in the inner city, including mitigating the heat island effect from the high density of buildings and bituminised streetscapes.

DPSIR analysis framework for Ludwigsburg: current challenges.

Following are the results of the analysis framework carried out for Ludwigsburg, recognizing the city's multiple challenges and mapping the challenges with relevant social economic activities. The main challenges identified include: high temperatures in summer; air and noise pollution due to increased traffic and industry coupled with the unfavourable microclimatic condition of temperature inversions; local flooding.

Driving force (human demand)	**Pressure** Use of natural resources (Pressure) Exogenous, Unmanaged Pressure (e.g., due to climate change)	**State** (Condition of natural resources)	**Impact** (Change in natural resources)	**Spatial extent of impact** (Widespread, local, site) **Additional component to the DPSIR framework**	**Responses** (actions/policies) **NBS development referring to the NBS catalogue in WP1**
Primary					
Urbanization processes	Land-use change Typical microclimatic condition of the area	Landscape features	Heat island effect (increased number of hot days)	Widespread-patchy	**Infrastructure** cool pavements, green covering structures **Policy** Ludwigsburg Strategic Concept for Open Space and Green Areas
Increase Economic activities, transportation system	Air pollution, Noise	Air circulation and self-cleaning process	Human and environmental health	Widespread	**Infrastructure** Green shady structure, green facades, green noise barrier
Secondary					
Urbanization with development on flood plain	Narrowing of watercourses Climate change with rainfall	Natural overflow to flood plain in rainy season Increased impermeable surface	Flooding	Local	**Infrastructure** Floodable parks, green pavements, SUDs

Table 5: DPSIR framework for the characterization of Ludwigsburg toward NBS applications

Ludwigsburg as characterized in the framework is facing several impacts mainly local heat island (due to the local climatic condition) and the noise pollution (mainly due to the transportation hub) and local flooding effect due to the urbanization leading to narrowing of water courses. Nevertheless, the city with high per capita green space offers the city with high resilience with the current impacts, together with the active engagement of open space planning process put the city in a good position with adopting some innovative NBS schemes to mitigate current impacts rather than large build-up of NBS.

vi. Medellín

Social, natural, and economic conditions and legal/institutional frameworks related to NBS application

Medellín is located in the region known as Valle de Aburrá, an inland valley of the Central Cordillera of the Colombian Andes, crossed by the Medellín River. Medellín is the capital of Antioquia and is Colombia's second most important city and a well-positioned dynamic centre for commerce, industry and technology. The Metropolitan Area is spatially characterized by its linear development: the ten municipalities that comprise it have been settled along the Medellin River, forming a structured urban agglomeration out from the urban centre. This spatial arrangement makes the river the main articulating axis of the valley's urbanization process.

Medellín is conceived as a compact city in the centre of the valley, where the Aburrá River or the Medellín River is consolidated as a natural structuring axis. The River is seen as a system that is integrated, through transverse water connectors, with the parks and natural reserves located on its rural topographic edges. Through these hydrographic axes, the municipality has an integrated system of public and private parks, which are natural reserves within the urban system.

From 1948 to the present, the territory of the Aburrá Valley has experienced a trend of growth within urban areas and reduction in the population of rural areas. The phenomenon has been of such magnitude that from 1948 to the present urban areas have increased from 12.31 km^2 to 201.86 km^2, which corresponds to an increase of 1540%.

Medellín and the Aburrá Valley produce close to 14% of the national GDP (Alcaldía de Medellín-Metropolitan Area of the Aburrá-EAFIT Valley, 2011). In recent decades, the region has undergone a process of productive transformation oriented to six economic clusters (medicine and dentistry, ICT, construction, electrical energy, business tourism, and textiles and fashion) considered strategic to enhance the development of the city. It is estimated that Medellin's GDP growth rate is of 7.3% and exports at 17% annual average (Mayor's Office of Medellín-Metropolitan Area of the Aburrá Valley -EAFIT, 2011) and GDP per capita is at USD 11,466 as of 2018[4].

[4] https://data.colombiareports.com/medellin-economy-statistics/

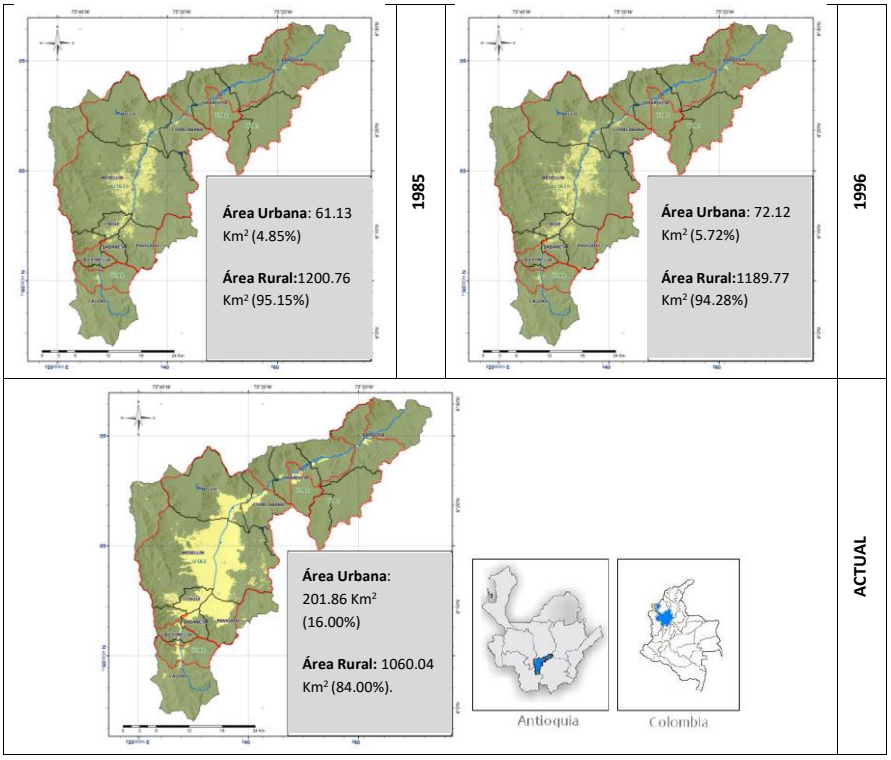

Figure 13: Map of Aburrá Valle and the municipalities that comprise it (Source: City´s Drainage Plan)

Due to the way in which the urban and rural territory of the Aburrá Valley has evolved, the hydrology of the basin has been altered considerably, since the natural drainage network has been modified as a consequence of the increase in impervious areas. The City has been designed to ensure that rainwater is evacuated as quickly as possible, which reduces the possibility of retention and infiltration, and increases the speed of arrival in the lower part of the basin. This has involved the construction of large infrastructures that are able to evacuate flows, but exponential growth has challenged the capacity of this infrastructure. This is why using NBS the City can both control urban expansion, and repair damage to natural landscapes while protecting citizens from flooding, flash flooding and fire.

The Secretariat of the Environment of the Municipality of Medellin, as the entity responsible for the maintenance of urban forestry and the landscaping of the city, will be responsible for defining and implementing environmental policies, as well as the planning, design, coordination, execution and evaluation of strategies related to the conservation, recovery and protection of renewable natural resources and environmental sustainability. This means that the Secretariat of Environment should carry out actions that guarantee the conservation of natural resources in the Municipality of Medellín, oriented to the protection of flora and fauna, isolation and reforestation of protective areas and other actions that so require, lead and manage the necessary actions for the protection, conservation and promotion of green public spaces, landscaping and forestry.

The City´s Environmental Management System, SIGAM, is defined as an organizational scheme in which environmental management is planned, developed and monitored in the territory. The plan identifies the elements and components of the organization and public management to fulfil the environmental policy outlined for the municipality of Medellín. Relevant matters include all aspects, impacts and externalities that potentially result in environmental problems.

Additionally, the National Ministry of the Environment oversees the management and planning of green infrastructure and urban forestry. The green infrastructure of the city is classified into three scales: Macro, Meso and micro scale, formed respectively by the ecological structure (main and complementary), the Ecological Connectivity Network and green areas designed on a small scale.

Medellín urban challenges

The physical characteristics of the basin where the second most populated urban conglomeration in Colombia is located, are not conducive to the dispersion of pollutants. The Aburrá Valley is located in the centre of the Department of Antioquia, in the middle of the Central Cordillera of the Andes, in the basin of the Aburrá River or Medellín. The Valley is characterized by being a prolonged and narrow concavity of 60 km in length in total and a maximum width of 7 km in the central part at the height of the municipality of Medellín. The topography is irregular and with steep slopes; the floor of the valley is at an elevation of 1,300 meters above sea level and is bordered by mountains that reach heights of up to 2,800 meters above sea level (Atlas Metropolitan Area of the Aburrá Valley, 2010). The mountain ranges surrounding the Aburrá Valley give rise to different microclimates by adding a greater number of variables and processes, making the atmospheric dynamics related to the dispersion of pollutants and air quality significantly more complex (Herrera Mejía, 2015). The influence of local meteorological phenomena and the increasing urbanization have altered the microclimatic dynamics generating phenomena of thermal inversion and heat islands which influence in the quality of the air and life of the citizens.

Other of the great riches of the Aburrá Valley are, without a doubt, its water sources, represented in numerous streams and streams that come down from the mountains and feed the river. This water network, due to its wide coverage, is perhaps the main common denominator of the valley: wherever it passes, there is always a stream. In spite of this, the relation of the inhabitants with the water resource has not been very respectful and the planning processes have not been able to capitalize on their ecological and landscape values, in favour of the environmental quality of the city and its social development. The loss of supply relationships associated with the construction of aqueducts with distant catchments turned the water sources into wastewater tanks. When deteriorating, by sewer systems discharges, the ravines also lost their amenity and scenic value, and as annoying elements, they were covered or left in the back areas of the houses instead of integrating to the roads and the public space. The tendency has been to marginalize, hide and degrade water courses as a constant in urban occupation. Additionally, to the waste water issue, the soil permeability has being disrupted by layers of pavement placed while the city urban, reason why the ground

water sources are actually losing their volume and quality. This has been caused by a model of urbanism focused on the conformation of "hard" surfaces (asphalt, paved, etc.) that limit the permeability of the soil and the recharge and purification capacity of the aquifer.

Further challenges confronting the City of Medellín include:

a. Social and functional segregation of the territory

The production and employment generation areas are mainly located in the centre and south of the city with a "dormitory city" in the north. The population located in the north of the city and the Aburrá Valley has lower than average income and resources are distributed inequitably.

b. Underutilization and disarticulation of the river axis

Due to its strategic location, the River has strengthened over the last fifty years as the structuring axis of metropolitan mobility, but its potential as a public and environmental hub and as the heart of the metropolis is underdeveloped. New projects, such as the Parque Vial del Río, aspire to transform this current dynamic.

c. Fragmentation of protection areas and public space

The intensification of urbanization in all its forms (expansion, urban consolidation, sub-urbanization) has meant that green areas are becoming less accessible and less able to deliver public services and fulfil ecological functions. The City is largely car-dependent, despite investment in public transport; the automotive fleet has grown 62% and motorcycles 153% between 2006-2010, which has aggravated the problems of air pollution derived from mobile sources. Topographic conditions exacerbate poor air quality conditions generated through vehicle emissions.

DPSIR analysis framework for Medellín: current challenges.

Medellín has high potential as a follower city with extensive remnant ecosystems and enthusiasm for NBS. Following is the result of the analysis framework carried out for Medellin, recognizing the city's multiple challenges and mapping the challenges with relevant social economic activities. The city has identified several challenges including: urban regeneration to redress inequality in the City, the lower income communities developed in vulnerable areas; air pollution due to increased traffic coupled with the unfavourable microclimatic condition of the valley topography; high summer temperatures; local flooding; loss of biodiversity and lack of connectivity of green space.

Driving force (human demand)	**Pressure** Use of natural resources (Pressure) Exogenous, Unmanaged Pressure (e.g., due to climate change)	**State** (Condition of natural resources)	**Impact** (Change in natural resources)	**Spatial extent of impact** (Widespread, local, site) **Additional component to the DPSIR framework**	**Responses** (actions/policies) **NBS development referring to the NBS catalogue in WP1**
Primary					
Development and economic activities	Economic segregation	Landscape features	Local regeneration Development towards hill side	Widespread	Accessible green corridor along the river axis Location, linkages and connectivity **Policy** ▪ Municipal Territorial Ordinance Plan
Increase transportation system	Air pollution Microclimate difficulty of the valley	Air circulation and self-cleaning process	Human and environmental health	Widespread	**Infrastructure** Urban Trees (Planting and renewal of urban trees; Shade Trees; Cooling trees); Urban Garden BioFilter; Green Façade with climbing plant, Green shady structures Mobile gardens Pollinator wall

Driving force (human demand)	**Pressure** Use of natural resources (Pressure) Exogenous, Unmanaged Pressure (e.g., due to climate change)	**State** (Condition of natural resources)	**Impact** (Change in natural resources)	**Spatial extent of impact** (Widespread, local, site) **Additional component to the DPSIR framework**	**Responses** (actions/policies) **NBS development referring to the NBS catalogue in WP1**
Demand for new urban housing	Land-use change	Landscape features	Heat island effect	Local (city centre)	**Infrastructure** ▪ Urban Trees (Planting and renewal; Shade & Cooling trees ▪ Urban garden biofilter ▪ Green corridor: New cycle lane and renaturing current cycle lane
Demand for urban development and economic activities	Land-use change	Ecological processes and balance Landscape features Habitat quality	Loss of biodiversity	Widespread	**Infrastructure** ▪ Urban Trees (Planting and renewal of urban trees; Shade Trees; Cooling trees; ▪ Trees for re-naturing parking); Pollinator's modules (compact and natural designs); ▪ Green corridor: New cycle lane and renaturing current

Driving force (human demand)	**Pressure** Use of natural resources (Pressure) Exogenous, Unmanaged Pressure (e.g., due to climate change)	**State** (Condition of natural resources)	**Impact** (Change in natural resources)	**Spatial extent of impact** (Widespread, local, site) **Additional component to the DPSIR framework**	**Responses** (actions/policies) **NBS development referring to the NBS catalogue in WP1**
					cycle lane
Urbanization with development on flood plain of Medellín river	Narrowing of watercourses Climate change with rainfall	Natural overflow to flood plain in rainy season	Flooding	Local	**Infrastructure** Floodable park; SUDs; rain garden.

Table 6: DPSIR framework for the characterization of Medellín toward NBS applications

Through the DPSIR framework for Medellín, Table 6 presents several severe challenges faced by the highly active city in Colombia. The high priority given to options to mitigate the impact of local segregation with difficult community developed into high risk area, the air pollution as the result of the local climatic condition and the loss of biodiversity as the urbanization process has altered the land use, fragmented the natural landscape, dis-utilization of the city's valuable river axis which entail varieties of responses the city is considered extensively in its Municipal Territorial Ordinance Plan. Medellín, through the analysis has huge potential to apply NBS to harmonize the urbanization process to preserve and restore the naturalness of its landscape with the river serving as the axis of the city and mitigate many of the current impact due to economic development.

vii. Quy Nhon

Social, natural, and economic conditions and legal/institutional frameworks related to NBS application

Quy Nhon is a coastal city in Binh Dinh Province, located in the southeast of Binh Dinh Province, central of Vietnam in the tropical monsoon region. The city is downstream of the Kone - Ha Thanh river basin, which is the key economic area of the province. The city is full of landscape types from mountainous areas to a river delta, together with aquatic systems including: coral reefs, seagrass and the Thi Nai coastal lagoon.

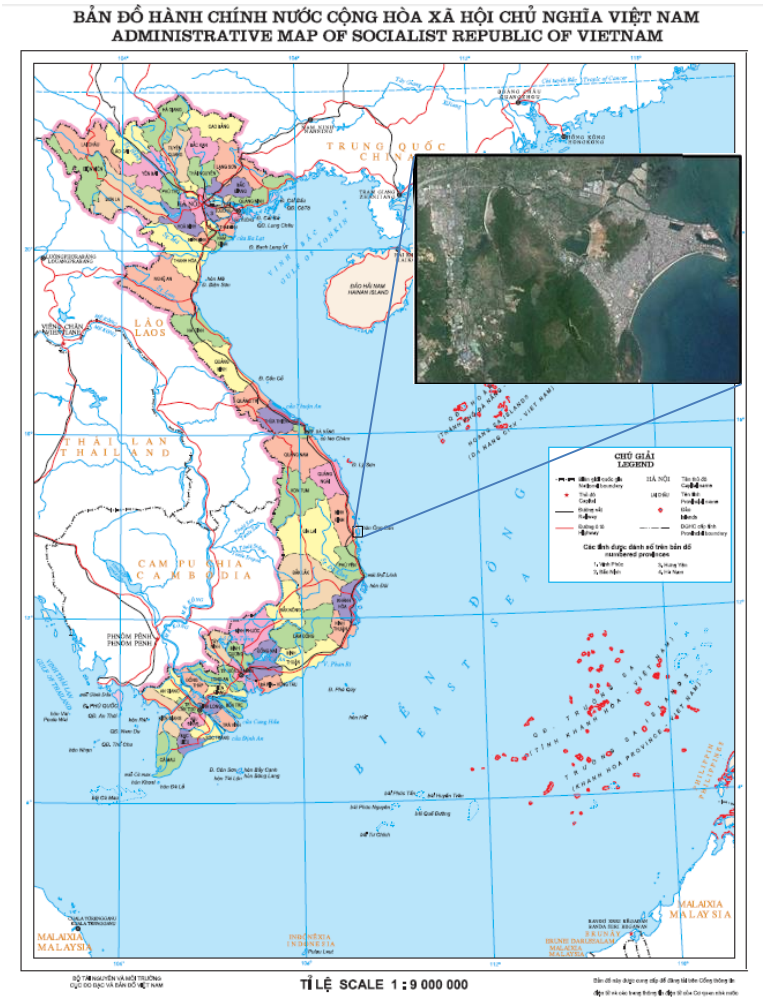

Figure 14: Quy Nhon city (insert) – Binh Dinh province – Vietnam (source: https://www.bandovn.vn)

Quy Nhon has a population of 287,300 and covers an area of 886.85 hectares. In recent years, Quy Nhon's economic growth has been stable at high levels compared to other localities in Binh Dinh Province; According to statistics (2017), Quy Nhon city has 31,236 employees in the fields of agriculture, forestry and fisheries; industrial and construction is 33,866 people; trade, service is 71.818 people. The percentage of workface working in the agro-forestry sector accounts for 25.5%, the industry-construction 43.4%, the service sector 31.1% % of total

employment. The city total budget revenue is at VND1,990.6 billion with export value is at 630 million USD.

The urban form of Quy Nhon city was strongly influenced by the French colonial period when the colonial left to create a unique architecture of the city. The urban center's structure spatial arrangement is in the shape of a fan along an east-west axis associated with the coastline. Quy Nhon city mainly based on the main axis in the north - south direction (National Highway 1A) and east - west (Tran Hung Dao axis), transport routes are arranged along the coast line, aiming to exploit the coastal curve of Quy Nhon from Bai Dai to Mui Tan.

The Office of Climate Change Coordination in Binh Dinh Province (CCCO Binh Dinh) is the assisting body for the Steering Committee for the implementation of the National Target Program to Respond to Climate Change in Binh Dinh Province. It advises and assists the Steering Committee to coordinate the activities of the National Target Program to respond to climate change and other programs and projects on climate change in the province. CCCO is responsible for working closely with departments, branches, localities and relevant units according to their functions, tasks and CCCO in the implementation of planning, design, construction and maintenance of NBS.

Quy Nhon has a number of important guiding strategies and laws. Decision No. 495 / QD-TTg dated April 14, 2015 of the Prime Minister, approved the Adjustment of the General Plan of Construction of Quy Nhon City and its vicinity to 2035, and established a vision to 2050. The decision gave direction on the plan of construction of different civil service facilities, as well as the direction for development of residential areas with basic infrastructure including roads, wastewater, environment and the park system.

The second important plan for the city is the Green Growth Urban Development Plan in Binh Dinh province by 2030 was issued in April 2018 by Binh Dinh Province People's Committee. This policy is a vision to 2030 for the authorities and people of Quy Nhon city. Binh Dinh province achieves its goal when developing a green growth city in order to promote the transformation of urban economic model towards green growth, improve competitiveness, and ensure rapid urban economic development effective, sustainable, contributing to creating jobs, eradicating poverty, improving people's material and spiritual life, improving resilience and responding to climate change of the urban system in the local area.

Quy Nhon urban present challenges

Quy Nhon city is located downstream of two large rivers, these being the Ha Thanh and Kone rivers. These two rivers are characterized by a narrow and steep topography. When there is heavy and prolonged rain, the water is concentrated quickly, causing flooding in Northern district of the city. The situation can get worse if the events occur at the same time of the high tide season, flooding water couple with high tide cause widespread inundation of the city. Due to the topography of the tectonic plate in the area, the city's shore line is also vulnerable to coastal erosion, and indeed coastal erosion has been shrinking the arable land area of some parts of the city.

Climate change together with water pollution has had impacts on the fragile coastal ecosystem and the coral reefs of Quy Nhon in the lagoon. Degradation of the coral reef of Nhon Hai commune due to coral mining, destructive fishing, discharge of sediments and freshwater and pollution has been the main causes. There has been effort from local and international organization in preserving the precious fragile ecosystem from UNDP such as Management and conservation of coral reefs ecosystems associated with ecotourism development in Nhon Hai commune funded by GEF and UNDP.

DPSIR analysis framework for Quy Nhon: current challenges.

Quy Nhon is a coastal city with high potential for restoration of coastal ecosystems. Table 7, below is the result of the analysis framework carried out for Quy Nhon, recognizing the city's multiple challenges and mapping the challenges, linked to relevant social economic activities that contribute to the challenges. From the analysis, the framework together with the available catalogue on the NBS applications and the selection of the city has presented the relevant responses of the cities corresponding with the current challenges and the pressures that Quy Nhon city environment is facing. The city has identified its main challenges: local flooding due to urban development downstream of two big rivers coupling with the coastal erosion; loss of biodiversity and the quality of wetland and coral reef.

DPSIR analysis framework shows direct link between human activities (urbanization process and the economic activities) with the impacts the city is facing regarding flooding and the loss of biodiversity. However, the loss of biodiversity has been identified on the coastal area rather than on land part of the city. The city therefore should rely on the current issued Green Growth Urban Plan to promote the link between NBS as the mitigation measures for its many challenges.

Driving force (human demand)	**Pressure** Use of natural resources (Pressure) Exogenous, Unmanaged Pressure (e.g., due to climate change)	**State** (Condition of natural resources)	**Impact** (Change in natural resources)	**Spatial extent of impact** (Widespread, local, site) **Additional component to the DPSIR framework**	**Responses** (actions/policies) **NBS development referring to the NBS catalogue in WP1**
Primary					
Urbanization with development on flood plain of Kone and Ha Thanh river	Narrowing of watercourses Climate change sea level rise	Natural overflow to flood plain in rainy season	Flooding	Patchy	**Infrastructure** Grassed swales Sustainable Urban Drainage Wetland regeneration
Demand for urban development and economic activities (fishery, tourism, pollution)	Land-use change	Ecological processes and balance Habitat quality	Loss of biodiversity and the quality of wetland and coral reef	Widespread coastal area	**Infrastructure** Wetland regeneration and restoration Rain garden, floodable park for water purification **Policy** Green Growth Urban Development Plan

Table 7: DPSIR framework for the characterization of Quy Nhon toward NBS applications

4. Conclusion

A driver-pressure-state-impact-response analysis framework has been carried out in an effort to characterize city regarding its current multiple challenges, pressures and its appropriate responses to the challenges (the final combined comparison between front runner cities and follower cities has been summarised in table 8). The characterization process using the framework was able to link the current challenges with different anthropogenic and natural processes/activities happening at the city (different transportation and noise, air pollution, local built up to typical microclimatic weather condition of the city). From identified pressures and states of the cities, different NBSs have been identifies as possible to be implemented to counter the effect of these challenges to the communities. Carrying out the characterization will further help the city to identify different pressures and appropriate responses to the pressure. Follower city also can identify the sequence of responses from front runner cities to adapt to their situation, where there are commonalities in term of challenges, driver and pressure.

	Liverpool	Valladolid	Izmir	Mantova	Ludwigsburg	Medellin	Quy Nhom
Drivers	Demand for urban development Increasing culverting of natural streams	Urbanization with development on flood plain Increase economic activities, transport	Development on flood plain of Peynircioğlu stream Demand for new urban housing, rapid urbanization Increase transport and economic activities	Urbanization with development on flood plain of Mincio river Narrowing of watercourses Increase economic activities	Increase Economic activities, Urbanization processes,	Development and economic activities, landscape features, Increase transportation system, Demand for new urban housing	Demand for urban development and economic activities (fishery, tourism, pollution) Urbanization with development on flood plain
Challenges	Flooding Loss of biodiversity Low quality green space	Local flooding, Air quality deteriorating, heat island effect	Air quality deteriorating, degradation and loss of coastal wetlands, Heat island	Conserving ecosystem, heat island effect, local flooding	Air pollution, Noise, Heat island effect, local flooding	Heat island effect, Loss of biodiversity, air pollution, functional segregation	Local flooding, coastal erosion, Loss of biodiversity and the

	Liverpool	Valladolid	Izmir	Mantova	Ludwigsburg	Medellin	Quy Nhom
			effect			of the territory	quality of wetland
Adopted responses	**Policy** Sustainable Urban Development Strategy Liverpool Green Infrastructure Strategy	**Policy** Clean vehicles agenda Comprehensive Urban, Sustainable and Safe Mobility Plan Local Action Plan for flood risk	**Policy** Izmir Green Infrastructure Strategy (IGS)	**Policy** Sustainable Mobility Urban Plan	**Policy** Ludwigsburg Strategic Concept for Open Space and Green Areas Integrated Urban Development Strategy	**Policy** Municipal Territorial Ordinance Plan	**Policy** Green Growth Urban Development Plan
	NBS considered Aquatic planting Tree Planting Floating island Rain gardens Open water SUDS Permeable paving Tree SuDS	**NBS considered** Green noise barriers Urban Trees (Planting and renewal of urban trees; Shade Trees; Cooling trees); Urban Garden BioFilter; Green Façade, Green shady structures	**NBS considered** Smart soil into green shady structures, Parklets, Cool pavements, Coastal wetland regeneration, Green Corridor	**NBS considered** Greening Shade trees Planting and renewal urban trees, Urban Carbon Sink Trees re-naturing parking Cool pavements, Grassed swales and Water retentions ponds	**NBS considered** cool pavements, green covering structures, Green shady structure, green facades, green noise barrier	**NBS considered** Urban Trees (Planting and renewal of urban trees; Shade Trees; Cooling trees); Accessible green corridor Urban Garden BioFilter; Green Façade with climbing plant, Green shady structures Mobile gardens	**NBS considered** Grassed swales Sustainable Urban Drainage Wetland regeneration Rain garden, floodable park for water purification

	Liverpool	Valladolid	Izmir	Mantova	Ludwigsburg	Medellin	Quy Nhom
Known barriers	Land ownership, land owner permissions, risk and future liability			Legal barriers connected with UNESCO site			

Table 8: Cities characterization comparison

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