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D01.06: Guideline to city zoning

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0 Abstract

City and municipality zoning has a long history. The need to organise land use and to allocate resources, including financial resources, often leads to targeting of areas, creating "zones" for action.

Zoning has different connotations in different countries. In many countries zoning is understood to be statutory; a key part of any planning document. In other countries, it has a less formal meaning, indicating areas of interest, with no statutory basis. In this guide we mainly describe the less formal zoning approach, mindful that that this may act as a stepping stone to more formal planning policy.

This principle of zoning applies to targeting Nature Based Solutions (NBS). As part of the Urban GreenUP project, this guide to zoning is one element of the Renaturing Urban Plan (RUP) framework that is being developed.

The RUP is a four phase, stepped process that enables a strategic approach to implementing NBS in towns, cities and municipalities.

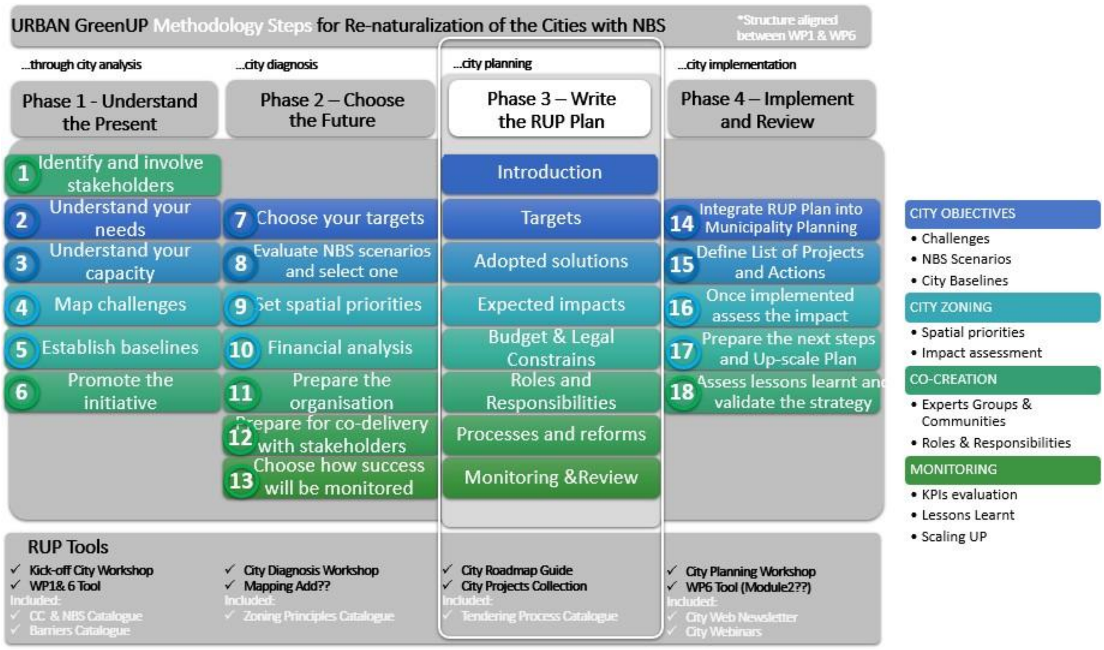

Figure 1 RUP phases and Steps

Zoning is an important element in each phase of the RUP.

Figure 2 The place of zoning within the RUP – Steps 4, 9 and 16

The driving force of zoning is data. There is an increasing amount of open source and public data available that can be incorporated in GIS and/or used alongside other information to inform zoning. New technology, satellite and drone for example, are opening new opportunities for localised mapping and zoning.

1. Traditional data collection methods to collect public and municipalities' owned data already available

2. Capture of data from high resolution satellite imagery analisys

3. Capture of data from aerial inspection via drones

The guide shows some examples of how this new technology is being used in cities such as Mantova.

Geographic information Systems (GIS) are important tools that assist in managing and analysing complex data, enabling zoning to be carried out relatively quickly and dynamically once the data is assembled. The guide identifies a range of open source and commercial GIS and suggests some examples that might be most helpful for zoning

NBS are identified as approaches to meet specific need in a city, for example, a need to reduce flood risk or improve access to greenspace to increase rates of physical activity in areas of higher health deprivation. These needs are identified and categorised within the Eklipse Framework. Eklipse identifies ten challenges, including Climate Change. This framework is used in many EU Horizon 2020 projects, including Urban GreenUP

One approach to collating and assessing the data that might be gathered using measures of need (to address the challenges faced) and the functionality of the existing green infrastructure across the city is described in the guide. From these assessments assets and pinch points are identified. Pinch Points help to zone areas of activity for NBS. This approach has been used successfully in Liverpool City Region.

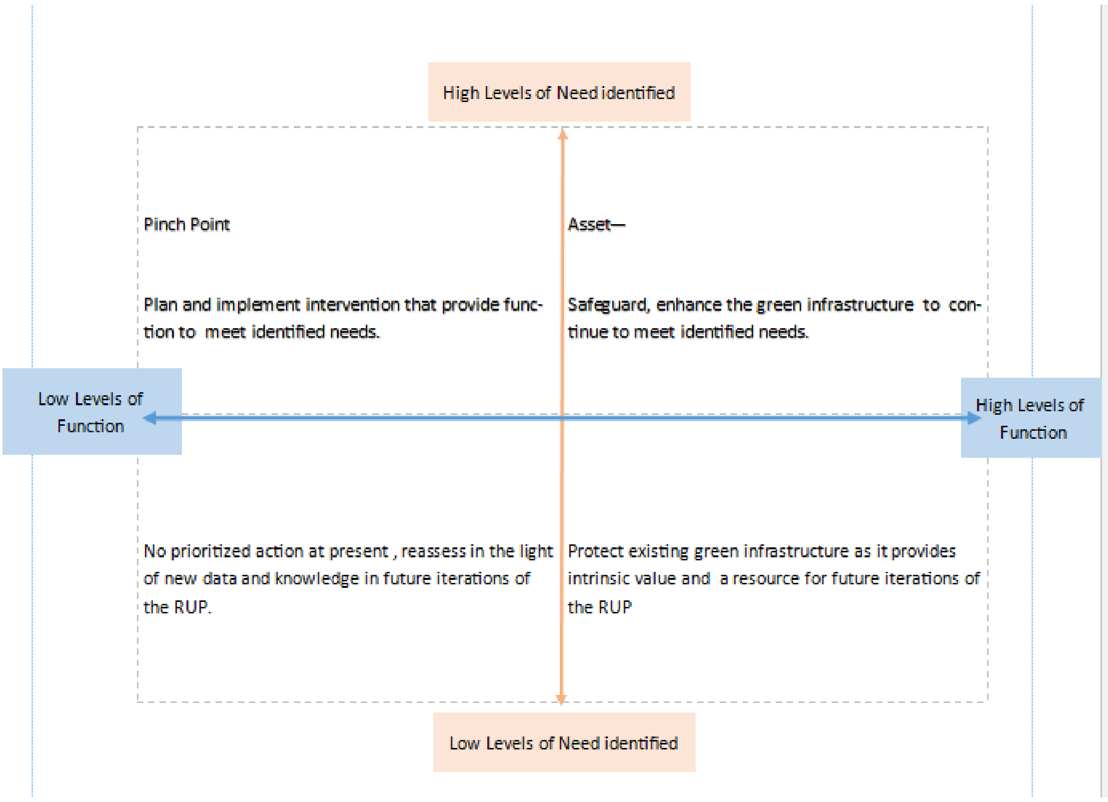

Figure 3 Assessing Assets and Pinch Points

Several other examples of challenge mapping are provided in the guide including Valladolid, Mantova, Ludwidsberg, Vitoria-Garsteiz and Barcelona.

The use of Eklipse as a monitoring framework is described, with examples of how the three lead cities in Urban GreenUP have used Eklipse for their NBS. Baseline data for each of these cities has been gathered and now, with many NBS in place, monitoring of the impact of the interventions is taking place.

Finally, the guide provides some information about how this work relates to other work underway to develop the RUP as a major output from Urban GreenUP

Definition of concepts

Several technical terms and concepts are used when referring to mapping, tools for mapping, and describing how and why areas in a municipality are zoned. The following table provides a definition of these terms and concepts as they are used in this document to help understanding of the document, particularly for individuals who may be new to the subjects covered in this guide.

Term	Description
Asset	Green infrastructure that is delivering a function or functions in an area of identified need. For example, woodland that is intercepting and storing water in an area of flood risk is a water management asset; it is providing functions that help to reduce the risk of flooding.
Zoning	The term "zoning" has a number of meanings and can often be used to identify areas that have statutory policy in place for their development and management. In other cases, zoning can be a generic term for identifying "areas of focus" or interest that have no statutory implications. In this document the term zoning is used to refer to targeting areas for NBS. It is not used to infer that any area through this process has specific planning policy or "zoning" in the sense of statutory planning that might be carried out by a municipality.
Nature Based Solutions	Nature-Based Solutions (NBS) are solutions to societal challenges that are inspired and supported by nature.
Geographic Information Systems (GIS)	Geographic information systems (GIS) provides the ability to capture and analyse spatial and geographic data. GIS applications are computer-based tools that allow the user to create interactive queries (user-created searches), analyse spatial information output, edit information presented within maps, and visually share the results of these operations[1].
Benefits	Green infrastructure planning is set firmly in the context of public benefit. Benefits include managing water, locking up carbon, providing opportunities for access. There are many ways of identifying and categorising benefits.
Ecosystem Services approach	An ecosystems approach provides a framework for looking at whole ecosystems in decision making, and for valuing the ecosystem services they provide, to ensure that society can maintain a healthy and resilient natural environment now and for future generations.

[1] https://en.wikipedia.org/wiki/Geographic_information_system

Term	Description
Functions	Describes what the green infrastructure type does; it could range from intercepting water to reducing noise. It is the functions that determine that are provided by NBS.
Green Infrastructure	Our life support system – the network of natural environmental components and green and blue spaces that lies within and our towns and city and provides multiple social, economic, and environmental benefits.
Green Infrastructure Planning	Assessment and geographical expression of issues related to Green infrastructure and identifying interdisciplinary and comprehensive approaches directed towards sustainable development. These will include land use management and land use planning.
Multi-functionality	One of the strengths of a green infrastructure approach is that it can be used to deliver several functions from a single intervention. For example, the opportunity to expand a key habitat may also provide an opportunity to improve water management, improve image and capture air borne pollution. Often, because the wider functions are not considered, the opportunities to get more value from an intervention are not taken.
Pinch Point	Area where a need has been identified and where green infrastructure could provide part of the solution to address the need but at present is not.
Green Infrastructure Types	A description of the elements that make up our green infrastructure. For example, rivers, wetlands, woodlands, grasslands etc.
Value	Where possible we should attempt to put an economic value of green infrastructure investments, recognising that the natural environment has intrinsic value, but mindful that political and investment decisions often also are informed by economic assessment. Value is closely linked to the ideas of ecosystem services and green infrastructure benefits described above.

Abbreviations used in this document

GI – Green Infrastructure

GIS – Geographic Information System

KPI – Key Performance Indicator

NBS – Nature Based Solutions

RUP – Renaturing Urban Plan

SDG – Sustainable Development Goals

1 Background

This guide to city zoning is one strand of a methodology that has been developed through the Urban GreenUP project for the creation of a Renaturing Urban areas Plan (RUP).

The aim of the RUP is to increase the quantity and quality of nature in our city and show how nature can help address challenges that cities face. Using nature to help tackle these challenges is referred to as Nature Based Solutions (NBS).

Green Infrastructure is a term used to describe the strategic assessment of the natural environment, describing the extent and location of habitats and green spaces. Green Infrastructure mapping and planning has an important role to play in assessing NBS.

The RUP is a phased and stepped approach which leads from the initial needs' assessment of an urban area, through prioritization of actions, to delivery and monitoring of NBS.

The four phase, 18 step RUP methodology is shown in the diagram below. Through the Urban GreenUP project, work is underway to provide guidance for each of the RUP phases, leading to a suite of tools that will support the development of a RUP by a city or municipality.

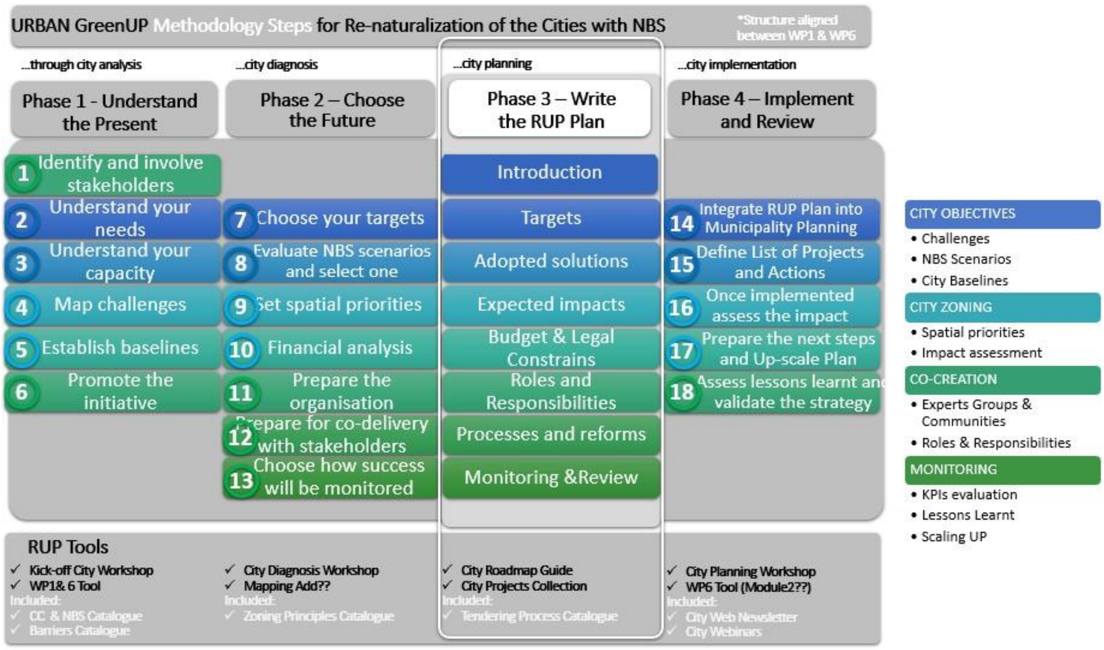

Figure 4: RUP Framework.

Mapping and zoning play a key role within each of the four RUP phases. Zoning is particularly important in the first two phases. Once delivery of NBS is completed, it plays a role in identifying where the likely impacts of NBS interventions will be achieved, enabling assessment of the projected impacts to determine the efficacy and cost: benefit analysis of the NBS interventions. This continued cycle of planning, delivery and assessment of NBS allows for the evolution of best practice within city, both in terms of what works best, but also how NBS is integrated into other city infrastructure programmes and policies.

Figure 5: Elements of the RUP Framework linked to zoning.

This guide considers Steps 4 and 9 within the RUP in detail. The guide will set out the case for zoning, some explanation of how zoning has developed over time and how it has slightly different meaning and strength of regulation/legislation in different countries.

The guide provides examples of existing methodologies, tools and technology that might assist in developing the zoning for NBS, in particular mapping and analysis of data. The guide also considers monitoring frameworks that will be needed to assess expected impacts from NBS; though these are considered more fully in other RUP guide documents.

It is important that this guide is considered alongside other guidance on the RUP that is being developed by the Urban GreenUP project[2].

[2] https://www.urbangreenup.eu/

2 Zoning for Nature Based Solutions

Zoning of city and city regions for NBS is carried out to focus attention, due to limited resources, on particular areas where there the challenges are greatest and where NBS interventions can have the most impact. For example, financial resources are invariably limited in cities, as will be time and the availability of a skilled workforce to design, implement and manage NBS.

Zoning often makes use of array of socio-economic information, green infrastructure mapping and other environmental data to help direct resources and activity to areas of high need and where there is evidence that NBS could provide a benefit.

2.1 Zoning

2.1.1 Background to zoning for NBS

The term "zoning" has a number of meanings and can often be used to identify areas that have statutory policy in place for their development and management. In other cases, zoning can be a generic term for identifying "areas of focus" or interest that have no statutory implications.

In this document the term zoning is used to refer to targeting areas for NBS. It is not used to infer that any area through this process has specific planning policy or "zoning" in the sense of statutory planning that might be carried out by a municipality. For Urban GreenUP, this non-statutory zoning is important in the development of the RUP

However, using the evidence and outputs from this zoning process as part of the overall RUP may help to shape policy and strategy and so inform statutory documents, proving a stronger basis for the implementation of NBS. The RUP may be seen as a possible stepping stone toward policy or statutory zoning.

2.1.2 What is zoning?

Zoning as a municipal, often statutory, instrument has shaped the built environment in several countries including USA, Germany and France over the last century[3]. Zoning operates by categorising land into different sections, or zones, with differing rules governing the 'activities' that can take place on that land. Zoning systems provide a written definition of the conditions under which development may take place in a specific area and are based on a desire to maximise certainty for two different groups of actors: *landowners and developers*, and *decision-makers*[4]. The utilisation of a process of zoning a strategic approach to development management can be developed that systematically structures the allocation of land uses over a sustained period of time for landowners and developers, "the intention [of zoning] is to give

[3] Hirt, S.A. (2018). Split apart: how regulations designated populations to different parts of the city. In *One hundred years of zoning and the future of cities* (pp. 3-26). Springer, Cham.

[4] Booth, P. (1995). Zoning or discretionary action: certainty and responsiveness in implementing planning policy. *Journal of Planning Education and Research*, *14*(2), pp.103-112.

them an incontrovertible brief for the future use of land and the potential for development, and thus permit them to put forward proposals within minimum risk". For decision-makers it provides certainty in the form of providing the least possible chance for decisions over land use/designation according to occur by whim or chance. This certainty is often cited as a significant benefit of land use zoning, as it provides a clear direction of travel for investment and limits the impacts of land value fluctuation or change, although, zoning can be criticised for established inflated real estate markets due to its rigidity in places. For Booth there are three central characteristics of zoning ordinance:

1. There is an 'absolute' right to carry out the development which the zoning ordinance has allowed.
2. The main form of accountability regarding zoning plans is through the court of law, as decisions upon them are ultimately rendered legal or illegal.
3. Third parties are provided with the right to challenge the decision making on the grounds of legality/illegality.

These three characteristics of zoning establish a structure at the local level that could be considered to provide a level of continuity for a city, as the direction of investment, development and management will be known to all public-private stakeholders. However, we can, and should ask: why 'zone'?

The 'necessity' for zoning can be understood as a way to navigate and manage the complexity and uncertainty that urbanity creates and perpetuates. As Whitnall[5] puts it:

> "Whether or not the practice of zoning began exactly at the time that most of our population became urban is unimportant. It does seem significant, however, that it occurred when the concentration of population in cities began to be pronounced. The significance of this fact seems heightened when we again note that it was in some of the larger centres of population where the practice of zoning assumed serious proportions."

Zoning is therefore inherently linked to the urbanisation process and the need for planners to prepare strategic assessment of what development should occur and where. It also raises a significant question regarding the parity of alternative land uses on this process. Are environmental resources given the same primacy as the economic development opportunities afforded to housing or commercial/industrial uses, and if not, what does this mean for the capacity of the landscape to function sustainably. The reasons why, and how, zoning systems evolved will be explored in the following section focussing on specific examples of zoning in practice.

[5] Whitnall, G. (1931). History of zoning. *The Annals of the American Academy of Political and Social Science*, *155*(2), pp.1-14.

2.1.3 Evolution of Modern Zoning

Urban land segregation, especially pertaining to different types and zones of residence, has existed for thousands of years. In the Shang-dynasty in China (approximately 200 BCE) for example, the city was physically divided on the grounds of class; only the royal members of society had the 'right' to live within the inner walls, whilst the rest of the population were housed in the outer parts of the city[6]. For Basset[7], the zoning advocates of the early 1900s in the U.S perceived examples such as these to be the pre-cursors to modern zoning. However, the most significant 'root' of modern zoning stems from shifts within urban planning in Germany in the late 19th Century. In 1876, Professor Reinhard Baumeister observed that land uses such as manufacturing and warehousing tended to dominate European industrial age cities at a greater scale and intensity than at any other point in history. He thus recommended the creation of an instrument that would "mandate a greater separation between industry and dwelling quarters, since industry posed greater hazards to human health than ever before".

Unlike the Chinese example, where the city was divided into sectors that would contain different 'types' of people, Baumeister's did not (explicitly, at least) envision zoning as a tool to segregate German urbanites on the grounds of class or ethnicity. Instead, this form of zoning was predicated on the idea that the urban fabric can be re-shaped and moulded to make cities both healthier and more efficient. Despite being the first form of 'modern' zoning, the German model contained detailed regulations on the type of regulations that pervade in modern zoning codes e.g. building density, shape and land use[8]. Baumeister's ideas were first enshrined within Frankfurt's zoning act of 1891 which divided the city into six zones (akin to strips): two residential, two mixed use and two residential. Commercial uses were allowed in all parts of town, except for residential areas where they were banned if they emitted noxious fumes. By way of comparison, industrial enterprises that required permits were banned from all residential areas, all others were allowed under specific criteria.

Regarding the two residential zones, the first was clearly intended for the wealthy, as it was situated away from the city's manufacturing hub. In this zone, each residential lot was to be kept open, thus encouraging the proliferation of detached homes at low density. The other residential zone was in a less desirable area and was intended for the denser, smaller homes of the poor. Nonetheless, this division did allow flexibility; it was legally possible, for example, to build small individual homes in the more 'privileged' residential area and multi-family homes in the 'poorer' residential area. Indeed, the prominent early 20th German planner Josef Stübben argued that it was imperative for 1) places of businesses to be connected to, and mixed with, residential areas, and 2) promote the mixing of the wealthy and poor within zonal planning[9].

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[6] Hirt, S. (2010). To zone or not to zone? Comparing European and American Land-use Regulation. PNDonline II.

[7] Bassett, E. M. (1920). Zoning. *Nat'l Mun. Rev.*, *9*, 311.

[8] Hirt, 2010, ibid.

[9] Hirt, 2010, ibid.

However, when the German model was emulated across in North America, and specifically the USA, this 'mixed' approach to zoning swiftly eroded. As Nolen stated in 1914, the key U.S. contribution to planning, and, by proxy, zoning may well be "the separation of business and residential neighbourhood"[10]. Explicit distinctions in where development occurs, and what it focusses on remain prominent in landscape and urban planning debates but have, in many locations, placed limited value on situating investment in environmental resources centrally in these discussions.

New York Zoning Code (1916)

For Hirt, 20th century American planners invented four zoning ideas: *hierarchical zoning*, the *exclusively residential zone*, the *exclusive single-family zone*, and *non-hierarchical zoning*. The application of these ideas facilitated a trajectory towards increasing land use separation. The 1916 New York City Building Zone Resolution can be seen as the event that 'triggered' this trajectory. The first comprehensive scheme to divide an entire city into zones, the *New York Resolution* permitted land uses, building height restrictions and building volumes amongst other measures[11].Concordantly, it established three quasi-separationist types of zones: residence, business and unrestricted, which catalysed the notion of a land-use pyramid:

> "Residential uses made the top of the pyramid, whilst industrial uses make the bottom. Residential uses could locate freely in all zones that were below them in the pyramid (i.e., in business and industrial zones), but non-residential uses could not be built in the residential zones. Similarly, commercial uses could freely exist in the industrial zones, but industrial uses were barred from commercial zones"[12]

On the surface, demand for this type of zoning code centred upon the rapid unplanned growth to U.S. cities following the mass immigration and industrialisation that began in the mid-nineteenth century. Alongside the high residential densities and the socio-environmental issues, i.e. healthy inequality and crime, these factors created, many urban dwellers, especially in New York, objected to the 'canyon effect[13]' created by extensive, unbroken rows of skyscrapers and the impacts this had on sunlight and air flow. However, alongside these socio-environmental considerations, the New York zoning act appears to have been driven by a concern over the

[10] Talen, E. (2005). New Urbanism and American Planning: The Conflict of Cultures. London: Routledge.

[11] Lehavi, A. (2018). The missing link in the evolution of zoning. In *One hundred years of zoning and the future of cities* (pp. 51-73). Springer, Cham.

[12] Hirt, 2010:5. Ibid.

[13] An issue that remains pertinent in many rapidly expanding cities, especially those in China, where limited natural light and circulation of clean air have been linked to lower quality of life. In Stuttgart the city zoning/development plan have integrated green aeration corridors within the city's structure to mitigate the negative impacts of air pollution using zoning to allocate development according to height, density and air flow patterns (Kazmierczak. & Carter, 2010). Kazmierczak, A. & Carter, J, 2010, Adaptation to climate change using green and blue infrastructure A database of case studies. Interreg IVC Green and blue space adaptation for urban areas and eco towns (GRaBS) project. University of Manchester, Manchester.

market effects of unsustainable urban development[14]For powerful realtors, financiers and insurers of commercial properties in New York, there was a desire to protect property values from the perceived threats associated with the encroachment of both 'undesirable' land uses and peoples[15].

In an ironic turn of events, the very economic actors who wished to utilise zoning to "grease the wheels of commerce"[16] were joined within the early zoning movement by progressives and reformers, who viewed the planning tool as a way to protect the city from the will of unfettered capitalism and render it simultaneously more aesthetically pleasing and liveable. What this illustrates is that during the first wave of zoning, a singular unified vision of what 'zoning' could, or should, offer cities did not exist. Visions were myriad; each mobilised by a specific ideology that imagined the entanglement of the social, economic and environmental spheres in divergent ways. Speaking on this point, Fischler[17] explains how the collective issue of urban congestion and sprawl gave people who came from different backgrounds and embodied different political agendas e.g. office developers, housing reformers, advocates of scientific planning and owners of luxury shops, "a common object of concern" and ultimately helped to "catalyse the disparate planning movement into a national organization"[18]. Ultimately, it was precisely because zoning meant different things to different people that the practice proliferated so rapidly across the U.S. and beyond.

Additional information about the role of Robert Moses and his zoning legacy is provided in Appendix 3.

The Berkeley Code (1916) and the widespread adoption of separationist zoning

The trajectory towards increasing land use separation was bolstered further by the Berkeley zoning code of 1916, which went beyond the hierarchical pyramid model set out in New York. It treated each zone as suitable for only a single use, meaning that not only industry was banned in residential zones, but also the inverse. Moreover, the Berkeley code 'invented' the idea of a purely single-family zone, which essentially outlawed the construction of different types of housing. Despite the existence of both the New York and Berkeley zoning codes, widespread adoption of zoning in the USA did not occur until 1926 with the Supreme Court Ruling in the

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[14] Lehavi, 2018, ibid.

[15] Shertzer, A., Twinam, T. & Walsh, R.P. (2018). Zoning and the economic geography of cities. *Journal of Urban Economics*, *105*, pp.20-39.

[16] Fischler, R. (1998). The metropolitan dimension of early zoning: revisiting the 1916 New York City ordinance. *Journal of the American Planning Association*, *64*(2), pp.170-188.

[17] Fischler:1998, ibid

[18] Kantor, H.A. (1983). Benjamin C. Marsh and the Fight over Population Congestion. In *The American Planner: Biographies and Recollections,* edited by Donald A. Krueckeberg. New York: Methuen. 58-74.

Euclid v. Ambler case and the adoption of the Standard Zoning Enabling Act[19]. The court case affirmed zoning as a "valid exercise of police power" (Hirt, 2010) and buttressed the Berkeley zoning code by declaring apartments in single-family zones as a 'nuisance'. This was mirrored by the Standard Zoning Enabling Act which endorsed the idea of single-use areas, as well as the zoning of urban areas into areas of 'trade', 'industry', 'residence', or 'other purpose'. The hegemony of Berkeley's non-hierarchical code increased post-WWII, and by 1961 even New York moved towards segregating urban space by limiting residential-business mix and creating 'pure' single family zones. By the late 20th Century, the building of new mixed-use areas had become practically outlawed in the U.S., as the vast majority of locales have adopted non-hierarchical codes, thus cementing separation as the nation's default planning system[20].

2.1.4 Contemporary Zoning Systems in the U.S. and Germany

In many ways, the historic connection between German and U.S. zoning systems persists today. For example, whilst the German system has traditionally focused on regulating bulk and density and the U.S. system centred on land-use control (primarily through land-type segregation), they both share an overarching premise: development is guaranteed by right as long as property owners abide by legal rules[21].

Contemporary zoning in the U.S. is highly homogenous; with an estimated 99% of districts use land-use-based zoning measures[22]. There are 4 macro standard classes of districts: residential, commercial (split into retail and office), industrial and agricultural, which are themselves composed of subclasses. For example, residential classes split into one-family, two-family and multi-family subdivisions. Speaking upon land-use districts, Booth writes "the zoning code typically specifies the primary (or by-right) permitted uses, the accessory uses (which are closely related uses, e.g. garages in residential zones), and the conditional uses (e.g. civic buildings in residential zones)"[23].

Land-use classes in the German zoning system appear highly similar to that of the U.S. Regulation being guided and mediated by the Federal Land Use Ordinance (*Baunutzungsverorndung* or *BauNVO*), which defines several districts and the land-uses they permit[24]. This ordinance lists four-land use classes: *residential, mixed, commercial* and *special*, which are then divided into ten subclasses: *small-scale residential, exclusively residential, general residential, special residential, village-type, mixed-use, town-centre, commercial,*

[19] Hirt, 2010:5, ibid.

[20] Hirt, 2010; Talen, 2006, ibid.

[21] Hirt, 2010, ibid.

[22] Katz, P. (2004). Form first: The New Urbanist alternative to conventional zoning. Planning (November).

[23] Booth 1995:6, ibid.

[24] Booth: 1995, ibid.

industrial and *special districts*. Whilst the *BauNVO* allows locales to choose which federal categories to use on their land, they must comply with the list of uses permitted under each of these categories. From a U.S. perspective, almost all of the *BauNVO* categories would fall under mixed-use. For example, despite its name, the 'exclusively residential area' category permits all dwellings types, and allows certain types of other land use, namely smalls shops, crafts and hotels. Thus, unlike the U.S. zoning system, land-use 'segregation' is encouraged less, as no specific area is envisioned for solely single-family houses, for example. As Booth (1995) outlines, the guiding principle is that at least half of the land in residential zones should be set aside for dwellings. The rest is to be taken up by smaller-scale shops, such as bakeries, which are being a crucial part of a 'living' district. As an expert interviewed by Booth[25] puts it: "you cannot really sustain living without an easy access to things that make it possible – like buying bread and other basic necessities".

France: a hybrid zoning example

The French zoning system can be understood as a hybrid of the German and U.S. models in that it establishes individuals' development rights (aligned with the former model), but also allows the administration to envisage what Gaudin[26] calls the "potential restoration of order" (associated with the latter model). The contemporary French zoning system recognises the basic principle of government and the *code de l'urbanisme* (town planning code) explains the nature of planning instruments, as well as the procedures to carry out and control-making decisions. The system consists of *schemas directeurs*; upper-level strategy documents which set out long term policy at a conurbation or sub-region level, as well as *plans d'occupation de sols* (POS) which are detailed land use zoning plans which predominantly cover the area of a single local authority[27]. The function of the POS is to identify a specific use for every part of a given area, which will then be zoned according to categories that are subdivided according to local conditions. Ultimately, the POS is rendered an indisputable statement of development rights that all administrative regions are subject to identically.

Flexibility is built into the French system in multiple ways, namely in the wording of regulations and in the form of action area zoning. Despite the *code de l'urbanisme* being a regulatory document, many of its rules offer "permissive options to the decision maker" through the use of the verb *peut* (may) instead of *doit* (must). Indeed, of the 32 sections of French zoning code that deal with the control of development, nearly half (15) offer discretionary power. Regarding action area zoning, or *zones d'amenagement concerte* (ZAC), Booth[28] states that:

[25] Booth: 1995:7, ibid.

[26] Gaudin, J.P. (1985). *L'avenir en plan: technique et politique dans la prévision urbaine, 1900-1930*. Editions Champ Vallon.

[27] Booth: 1995, ibid.

[28] Booth 1995:107, ibid.

> "Where development is not merely permissible, but actually promoted in a coherent form – the legislation allows for the declaration of a ZAC to spell out, in detail, the parameters for such development and its infrastructure… In principle, ZAC had to relate to POS, but as French commentators unite in observing, all too frequently, often in damaging ways, creation of a ZAC becomes a way of departing from the regulations in force".

2.1.5 Non-statutory zoning

Zoning is also used beyond the remit of binding legislation. Organisations at the national, regional and local level are increasingly utilising the concept of zoning within green space and green infrastructure plans. Whilst these do not always contain zoning regulations pertaining to what is allowed in each zone in terms of land 'use', they commonly utilise zone mapping to designate areas for specific types of 'action'. The URBAN GreenUP project itself utilises non-statutory zone mapping. In Liverpool, for example, the project has re-territorialised three zones within which NBS interventions are to be implemented: The Baltic Triangle, The Otterspool Corridor and the City Centre. Whilst the demarcation of these sites already existed in some form or another (see Liverpool's Green Infrastructure Strategy (2010) [29]), URBAN GreenUP has bounded them further using strategic zoning. Several examples can be identified applying this approach to non-statutory mapping/zoning, 4 of which will now be discussed.

The Northern Forest in the UK is an example of non-statutory zoning. A plan to create a forest of 50 million new trees that stretches from Liverpool to Hull, through Manchester, Leeds and Sheffield, the Northern Forest aims to reduce the risk of flooding, sequester thousands of tonnes of carbon, create new jobs and make people in the North of England happier and healthier. Together, its governing bodies – Manchester City of Trees, HEYwoods Forest, White Rose Forest, The Mersey Forest and the Woodland Trust – have constructed a strategy that contains a zoning map that illustrates the extent and 'shape' of this project (Figure 3). Here, physical zones are established, but without the presence of statutory legislation.

[29] Liverpool Green Infrastructure Strategy. (2010). [online] 2010. [Accessed: 21/05/2020] Available at: http://www.greeninfrastructurenw.co.uk/liverpool/Technical_Document.pdf

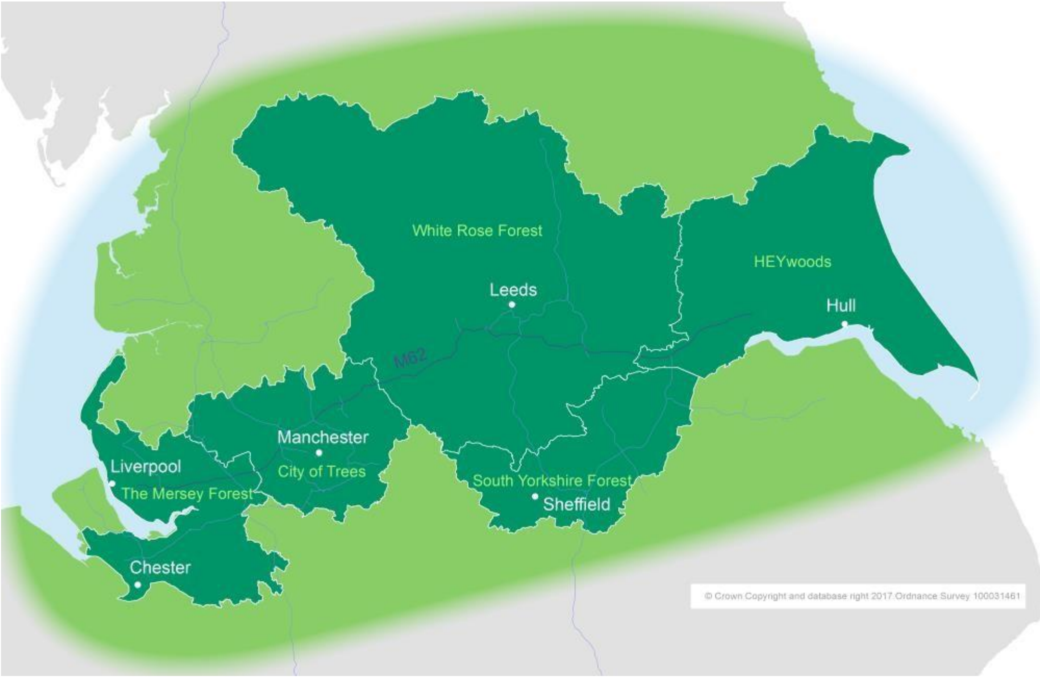


Figure 6: The different 'zones' that make up the Northern Forest (The Mersey Forest, 2020).

Zone mapping has also been used within the green space and green infrastructure (GI) plans several local authorities in the UK. The 'West of England Strategic Green Infrastructure Framework' (2011)[30], for example, utilises zone mapping to support strategic GI delivery. Figure 4 illustrates how the project has divided the geographical area of jurisdiction into 6 zones based on specific land-type indicators e.g. Strategic Nature Gardens, Local Nature Reserves, Flood-zones and Commons. The UK does not formally utilise zoning within its planning system, so the land-type 'zones' utilised within this plan are in fact the 'creations' of the actors and organisations who designed it. The construction of zoning codes for the provision of green infrastructure is also present within Southampton's Green Space Strategy (2008)[31]. With the aim of making green spaces more accessible and inclusive to people with mobility issues, the strategy divides the city into three zones (see Figure 5). Each zone is composed of specific green space types e.g. city parks or amenity green space, an accessibility standard and corresponding measures to ensure this standard e.g. paths at a specific height and width.

[30] North Somerset Council. (2011). 'West of England Strategic Green Infrastructure Framework'. [online]. 2011. [Date Accessed: 21/05/2020). Available from: https://www.bathnes.gov.uk/sites/default/files/westofengland_gi_framework.pdf

[31] Southampton City Council. (2008) 'Southampton's Green Space Strategy Summary and Action Plan'. [online] 2008. [Date Accessed: 21/05/2020) Available from: https://www.southampton.gov.uk/policies/green%20space%20strategy%20summary%20and%20action%20plan_tcm63-363566.pdf

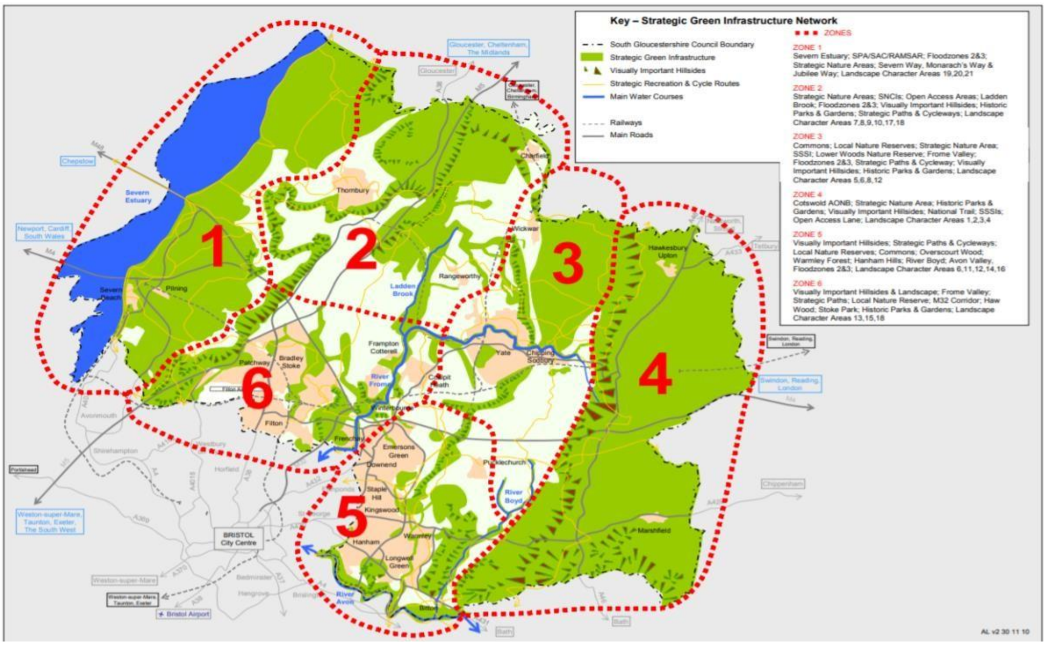


Figure 7: An illustration of how the West of England Strategic Green Infrastructure Framework has utilised zone mapping.

Standard	Definition
Ideal	Includes standards such as: No physical barriers, non-slip well drained hard paths, no surface breaks, Path gradients less than 1:20, passing places eat least every 50m, resting places every 100m
Zone A	
Provides access for most people, especially those with mobility impairments	Includes standards such as: No steps higher than 15mm, some loose stones in footpath, paths at least 1m wide, path gradient no more than 1:10, passing places every 150m, resting places every 150m. **Zone A –** City Park, some District Parks, Sports
Zone B	
Provides access for many people, especially those with mobility impairments	Includes standards such as: No steps higher than 40mm, some stones, occasional tree roots, potholes and short stretches of rutting on paths, paths at least 900mm wide, path gradient no more than 1:10, passing places not formalised but at least one passing opportunity every 150m, resting places at least every 1000m. **Zone B –** District Park, Some Local Parks, Some Sports, cemeteries and Churchyards
Zone C	
Provides access for some people, especially those with mobility impairments	Includes standards such as: No steps higher than 100mm, larger loose stones, occasional tree roots potholes and short stretches of rutting on paths, paths at least 900mm wide, natural gradients not limited, passing places not formalised but should be at least one passing opportunity every 150m, resting places not formalised. **Zone C –** Local Park, Amenity Green Space, Woodlands and Nature areas, Allotments, some cemeteries and churchyards.

Figure 8: Southampton's Green Space Strategy uses zoning to render the city's existing green spaces more accessible to people with disabilities.

Non-statutory zoning is also being mobilised within the remit of carbon emission reduction. Transport for London (TfL), for example, has implemented the 'London Low Emission Zone' (LEZ)[32]; a traffic pollution charging system that applies London-wide to commercial vehicles. Introduced in 2008, the LEZ scheme is based on European emission standards relating to

[32] Taylor, M. (2019). 'ULEZ cuts number of worst polluting cars in central London'. *The Guardian*. [Online]. 2019. [Date Accessed: 21/05/2020] Available from: https://www.theguardian.com/uk-news/2019/may/16/ulez-cuts-number-of-worst-polluting-cars-in-central-london

particulate matter and ultimately aims to reduce diesel-powered vehicles in the British capital. The zone covers most of Greater London (see Figure 6), is marked by signs and operates 24 hours a day, 7 days a week, and 365 days a year. If one does not comply with the standards, a daily access fee or penalty charge is levied at the offender. As well as paying this charge (up to £100-£200 each calendar day the vehicle travels within the LEZ), owners of non-compliant vehicles can also be expected to commit to one of the following actions: fit a filter, replace the vehicle or reorganise their fleet to use only compliant vehicles in London. Building upon the LEZ, TfL introduced the 'Ultra Low Emission Zone' (ULEZ) in 2019 to cover all vehicles within city limits (see Figure 7). Within the first week of its implementation, the ULEZ standards caused a 20% reduction in harmful emissions and catalysed a drop in the worst polluting vehicles entering the zone by 10, 000 (Taylor, 2019). What this illustrates is that even without statutory backing, exercising zoning can have a dramatic impact on both the behaviour of people and sustainability outcomes.

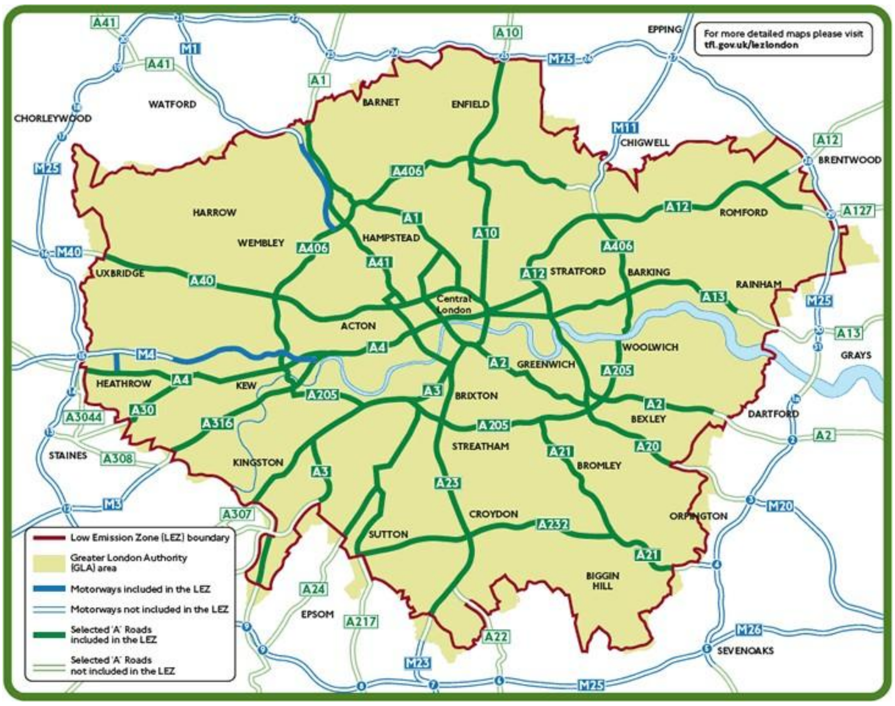


Figure 9: Illustration of the extent of the LEZ boundary and which roads are included within/beyond its jurisdiction (Leading UK Logistics, 2020).

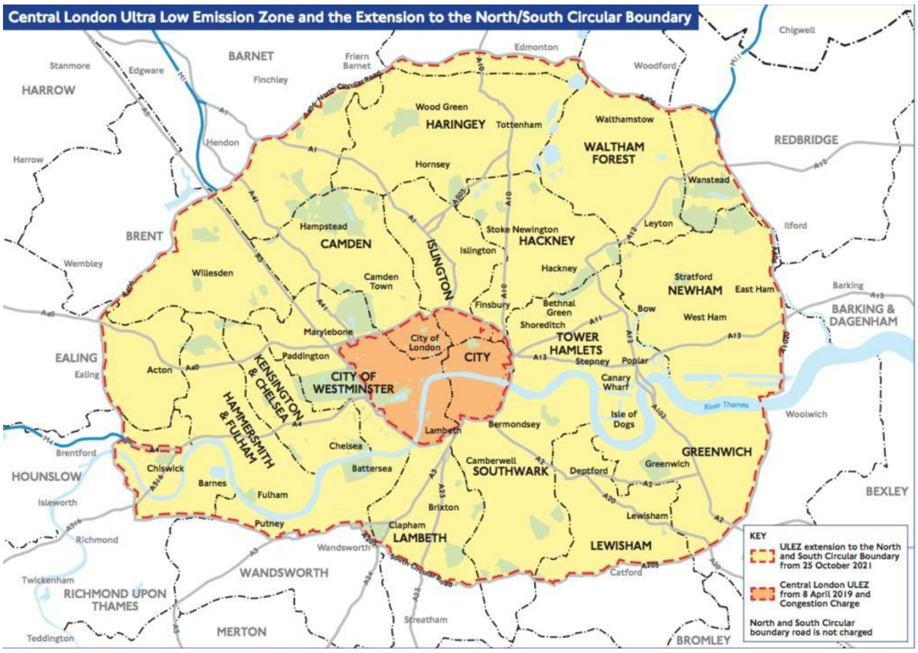


Figure 10: Extent of the ULEZ and its planned future extension (On London, 2019).

Collectively, these cases illustrate that zoning is not solely a statutory tool and that it is utilised – predominantly in the form of zone mapping – by a wide range of actors and institutions with differing aims and domains.

2.1.6 Issues with zoning:

A series of critiques have been made of zoning that reflect on the spatial and political allocation of land for development, and the problems inherent with using fixed classifications/categories of use that are inflexible to rapid change. The first issue relates to the uncertainty associated with trying to predict future human and infrastructural needs. As Booth[33] writes: “it is hardly surprising that sooner or later the apparently watertight system is tested by considerations that were not present when the plan was prepared”. One solution to this issue of uncertainty is to make zoning more detailed, in theory making them more capable of navigating a greater degree of possibilities. However, it remains open to question whether zoning can ever be rendered immune to the issues of uncertainty through this pathway. Hence, flexible zoning has been put forward as an alternative solution, i.e. in France. Nonetheless, even flexible zoning, which allows for the integration of negotiation and greater plasticity into the system may fall short, as the growing complexity of regulations risks obscuring the basic rights of those immediately affected by the plan. It also raises questions regarding where accountability lies for addressing the negative implications of zoning on existing communities of interest.

[33] Booth:1995:104, ibid

Another issue with zoning is that absolute certainty over regulations may not be desired by developers. This relates to the view that "economic conditions force them [developers] to try and retain leeway through negotiation or because they wish to maximise speculative profit" (Booth, 1995:105). This speaks to a broader issue of zoning: the fear of upsetting land users and stakeholders within new or updated plans. Because of such heightened sensitivity, three potentially problematic outcomes may occur:

1. Firstly, zoning plans can uncritically promote the status-quo instead of taking a more strategic view of long-term strategy.
2. Secondly, plans could encourage highly-restrictive zoning "to protect adjacent land values and retain a degree of social purity";
3. Thirdly, shaped by the potentially skewed local stances, zoning plans may err on the side of reflecting local ambitions for the development of an area, which either exceed or go curtail what it may 'require' or 'need' in the future.

A final issue with zoning systems is related to scale, and centres around the question as to how zoning at the detailed, local level relates to larger scale strategies. As Booth (ibid) writes:

> "Because zoning systems propose a tight relationship between a zoning plan and decisions on individual applications for development, by the same token they weaken the link between individual development decisions and longer-term, larger-scale strategies for a conurbation as a whole or for a region".

2.1.7 Zoning for Nature-Based Solutions

The allocation of specific zones for investment in NBS could be perceived as positive as it locates the value of environmental enhancement or creation within comparable conversations as other built infrastructure. In practice this should mean that within a given locations that a proportion of space should be allocated to resources that deliver ecological functions. For many cities, especially those growing rapidly or confined by historical urban forms, this would be a positive as it would provide scope for planners to strategically locate NBS. This could be used to complement the existing resources, to maximise the functionality of current landscape features, and to ensure the protection of the landscape at a strategic scale. For cities who are planning for extensive development of environmental resources zoning can be a valuable process enabling them to address gaps in provision. It also provides decision-makers with a set of delivery options that can be retrofitted into urban areas to address ward/district scale issues.

However, although zoning be a positive mechanism to reinforce environmental management practice there are complexities aligned to this process which must be addressed. First, NBS and wider urban greening/Green Infrastructure thinking needs to consider the mirroring of zoning for nature and the existing network of greenspace in a given location. If the zoning of NBS does not map onto current resources then the connective nature, functionality or capacity to support ecosystem services could be compromised. Thus, a network of spatially and ecologically connected NBS is critical to the delivery of socio-economic and ecological benefits associated with investment. Second, zoning could limit the added-value of NBS via their location in ecologically residual landscapes. Although NBS are being integrated into urban areas these may not have the ecological capacity in terms of soil composition, the availability or amount of water, air quality, relationship to existing infrastructure to support nature. Thus, the zoning of NBS should not be located investment in ecologically marginal places. Moreover, to ensure the maximum return on investment NBS need to be in accessible places linked to connective corridors or other larger resources. Establishing links between people, place and nature are therefore critical so the location of investment needs to be reflective of this. Finally, the size of investment needs to be considered within any discussion of zoning. Are NBS to fill a space or provide pockets/resources within a whole space? Is a large-scale city or urban-fringe park better than a series of stepping stone/nodes within a landscape? All these questions need to be addressed to provide scope to invest in NBS of various sizes, functions and qualities, if they are to provide a variety of socio-economic and ecological functions. It is unclear though whether each of these concerns has been addressed in the development of NBS to date.

2.2 The need for mapping

Many of the opportunities and challenges described in 3.1 above can be helped by mapping to assemble, analyse and communicate often difficult, complex issues. Many of the challenges that our cities face are best identified as “wicked issues”[34], that are complex and for which it is impossible to find a single solution. Mapping can help to organise and communicate data in these complex situations.

Data provided by a robust mapping database is essential during the identification of city challenges. This geographical pre-analysis, as well as other non-geographical elements, will allow answer two key questions linked to zoning: WHAT actions should be addressed, and WHERE to locate them.

Therefore, the mapping process becomes a powerful tool for a clear understanding of urban needs and zoning. For this propose, mapping should cover three main contexts.

2.2.1 Physical context

Terrain data provided by digital elevation models set the basis of the geographical information of a given city or area. For instance, areas with little shade or shelter can be identified as areas more likely to suffer high temperatures[35] or the presence of valleys would contribute to increase the effects of air pollution due to phenomena such as temperature inversion[36].

Other physical data such as surface watercourses and their watershed, land morphology and soil composition allow to estimate runoff and therefore to identify the areas of the city with the greatest potential risk of flooding[37].

2.2.2 Biotic context

A general vision of the distribution of natural areas not only within the city, but also in its surrounding area, will provide a information about ecological connectivity inside and outside

[34] http://www.cec.lu.se/sites/cec.prodwebb.lu.se/files/rittel_and_webber_1973_planning_problems_are_wicked_problems.pdf

[35] Kaoru Matsuo, Takahiro Tanaka. Analysis of spatial and temporal distribution patterns of temperatures in urban and rural areas: Making urban environmental climate maps for supporting urban environmental planning and management in Hiroshima, Sustainable Cities and Society, Volume 47, 2019,

[36] Juan J. Henao, Angela M. Rendón, Juan F. Salazar,Trade-off between urban heat island mitigation and air quality in urban valleys, Urban Climate, Volume 31, 2020,

[37] Lucas Borges Leal da Silva, Júlia Santos Humberto, Marcelo Hazin Alencar, Rodrigo José Pires Ferreira, Adiel Teixeira de Almeida, GIS-based multidimensional decision model for enhancing flood risk prioritization in urban areas, International Journal of Disaster Risk Reduction, Volume 48, 2020,

the city[38]. If this mapping also considers the range of services and benefits that the natural environment is delivering, the term 'Green Infrastructure Mapping' may be used to describe the activity. Geographic information with potential natural habitats and distribution of native flora and fauna species in each region will help in the planning and creation of wildlife corridors and wider networks. The design of green infrastructure may contribute to create green corridors and habitats within the cities.

2.2.3 Social and economic context

The social statistics in a geographical context, allows us to establish criteria of suitability for the location of the green infrastructures. Criteria such as proximity to green areas, quantity of green areas per area or accessibility will help to build a green network across the city. It is also necessary to consider the age composition and a range of economic factors in a given area, since this will determine the relationship of people with green infrastructure.

The study of land use and how the different categories are distributed within the city will contribute to the identification of areas with potential risks from flood, poor image, impacts of noise and gaps within the green infrastructure network.

The economic context (commercial activity, property prices) will contribute to the identification of opportunity areas for more NBS implementation. There is a relationship between the presence of green areas and their power to attract new business and increase the value of properties.

Mapping also helps to communicate the data to audiences who may not be familiar with the data, or who find numbers alone unhelpful in gaining an understanding of an issue.

Mapping, and analysis of the data capture using GIS allows comparisons between different scenarios to be explored relatively simply and at low cost. For example, NBS that can help to tackle urban heat island can be looked at within a GIS to consider their distribution in different climate change projection scenarios and in relation to the changing demographics and distribution of population across the city. The GIS helps to identify the space available and the proximity of the NBS to vulnerable communities.

[38] Joel Jalkanen, Kati Vierikko, Atte Moilanen, Spatial prioritization for urban Biodiversity Quality using biotope maps and expert opinion, Urban Forestry & Urban Greening, Volume 49, 2020,

2.3 Tools and technology that might assist in mapping

This section is divided in two parts: capture of data and mapping tools, which are complementary to reach the aim of a mapping action.

2.3.1 Collecting data

A key aspect of all the data collection activities is to ensure consistency of data across all tools, data requirements and pilots. To achieve this scope, a systematic methodology for the data collection management shall be ensured.

Good data management practices include developing effective process for:

- consistently collecting and recording data (data should be adequate to the purpose, complete, precise, up to date and clearly referenced);
- effectively presenting data and making data accessible for verification;
- checking data consistency with experts;
- storing data securely, clearly and in a traceable way, making data accessible for further uses.

There are three main options of collecting data:

1. Traditional data collection methods to collect public and municipalities' owned data already available	2. Capture of data from high resolution satellite imagery analisys	3. Capture of data from aerial inspection via drones

1. Traditional data collection methods to **collect public and municipalities' data** that is already available and possible already widely used by the municipalities. The data may be available on the city platforms with open sources and services, following the possible key word to city/municipality data, georeferenced data, cartography data, GIS viewers, ortho- photos, historical maps, and dynamic maps. This method is cost effective and provides access to data that is already likely to be accepted as accurate by the municipality.

2. Innovative ways to collect data to fill data gaps and data collection difficulties include data from **high-resolution satellite imagery analyses**. They can be used to collect and produce urban data at a city and neighbourhood scale. Indeed, using remote sensing, it is possible to characterise the urban environment at different scales, sampling electromagnetic radiation (EMR), acquiring and interpreting non-immediate geospatial data from which to extract information about urban spaces. Remote sensing systems that acquires images with small spatial extents will generally have a higher resolution and thereby capture more details, than

images acquired with larger extents and therefore lower resolution. The data may be available at European access points to the data provided by EU Member States according to the European directives or as a result of research projects and observation programs such as Copernicus, accessing the global earth observation system platforms and data bases, open street maps, local or euro statistics or networks.

3. In a similar way to high-resolution satellite imagery analysis, **aerial inspections by drones** can be used to capture and produce urban data in an innovative way[39], allowing new insights and filling gaps in available data. Drone inspections allow investigation and acquisition of information at small urban scale, for which the high-resolution imagery analyses are not adequate due to the presence of shadows that can hide certain elements of the images. The use of drone inspections allows to achieve higher resolution than using satellite imagery, this could be useful and needed in some cases. Depending on the drone equipment (type of camera, thermal sensors, CO_2 sensors and other) it is possible to capture different parameters. Most of the constraints to the application of aerial inspection by drones for the data collection is represented by the limits related to citizen's privacy and the presence of secure-sensitive areas (restricted flight zones).

4. Data may be available from local open sources data bases and services, or as a result of research projects and observation programs. A private service is available to specify or/and focus the data obtained from the global earth observation systems. The data may be gathered for sectors like audiovisual, industry, R&D, agriculture, other, consultancy and assessment.

2.3.2 Mapping tools

The tools proposed for mapping are mainly based in GIS (Geographic Information System) because this is the more appropriate technology to capture, store, manipulate, analyze, manage, and present spatial or geographic data. GIS makes perfect sense if one looks at the layering of information.

The aim of the zoning work within the RUP is to simplify reality through the creation of a data structure and a basic model in which information about these spaces can be stored and managed, and presenting data towards end users of a smart city (citizens, companies, governmental institutions etc.).

Table 1 below, summarises the main open geospatial sources that might be considered when looking at options for zoning.

[39] See Ludwigsburg case study Appendix 2

Table 1 GIS Software.

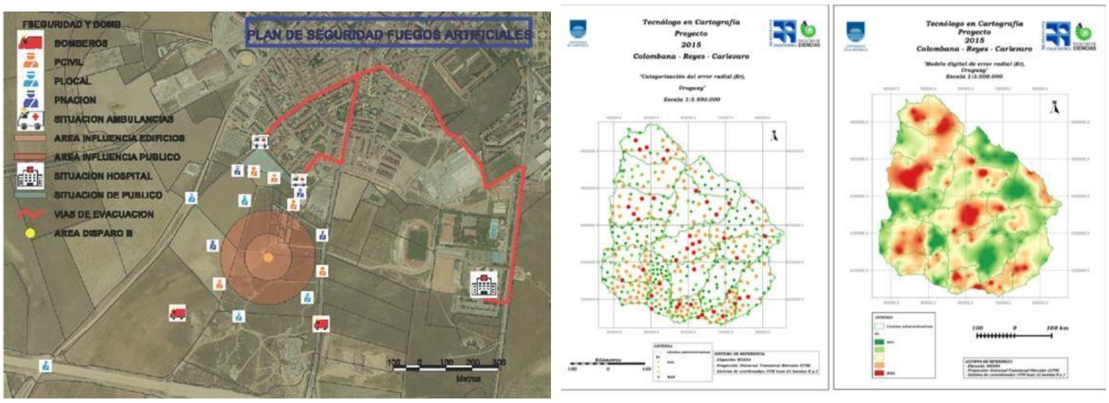
Desktop GIS Software	
QGIS*	Desktop GIS for data viewing, editing and analysis — Windows, Mac and Linux.
GRASS GIS	Extensible GIS for image processing and analysing raster, topological vector and graphic data.
OSSIM	Libraries and applications used to process imagery, maps, terrain, and vector data.
Marble	Virtual globe and world atlas.
gvSIG*	Desktop GIS for data capturing, storing, handling, analysing and deploying. Includes map editing.
GIS on-line software	
MapServer	Fast web mapping engine for publishing spatial data and services on the web; written in C.
Geomajas	Development software for web-based and cloud-based GIS applications.
GeoServer*	Allows users to share and edit geospatial data. Written in Java using GeoTools.
deegree	Java framework
PyWPS	implementation of the OGC Web Processing Service standard, using Python
GeoMoose	JavaScript Framework for displaying distributed GIS data.
Mapbender	Framework to display, overlay, edit and manage distributed Web Map Services using PHP and JavaScript.
MapGuide Open Source	Platform for developing and deploying web mapping applications and geospatial web services. Windows-based, native file format.
MapFish	Framework for building rich web-mapping applications based on the Pylons Python web framework.

OpenLayers	AJAX library (API) for accessing geographic data layers of all kinds.
GIS data bases and components	
FDO	API (C++, .Net) between GIS application and sources; for manipulating, defining and analysing geospatial data
GDAL/OGR	Library between GIS application and sources; for reading and writing raster geospatial data formats (GDAL) and simple features vector data (OGR).
GeoTools	Open source GIS toolkit (Java); to enable the creation of interactive geographic visualization clients.
GEOS	A C++ port of the Java Topology Suite (JTS), a geometry model.
MetaCRS	Projections and coordinate system technologies, including PROJ.
Orfeo ToolBox (OTB)	Open source tools to process satellite images and extract information.
OSSIM	Extensive geospatial image processing libraries with support for satellite and aerial sensors and common image formats.
PostGIS	Spatial extensions for the PostgreSQL database, enabling geospatial queries

Source: Open Source Geospatial Foundation

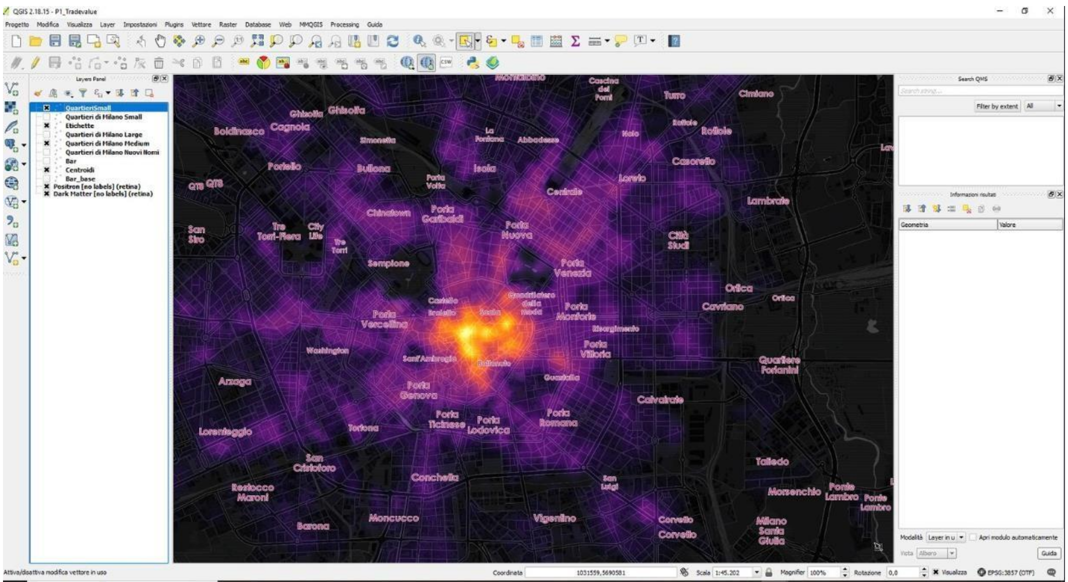
From this analysis above and from our experience in working with open source tools, the following work well for zoning:

- **GvSIG** has a user-friendly interface, being able to access the most common formats, vector and raster files, databases and remote services. It features a wide range of tools for working with geographic-like information (query tools, layout creation, geoprocessing, networks, etc.), and available in several languages. There is also gvSIG mobile. Example of use: Fireworks safety plan in Medina del Campo (Valladolid) and Evaluation of Google Earth's planimetric positional accuracy for Uruguay



Source: http://www.gvsig.com/es

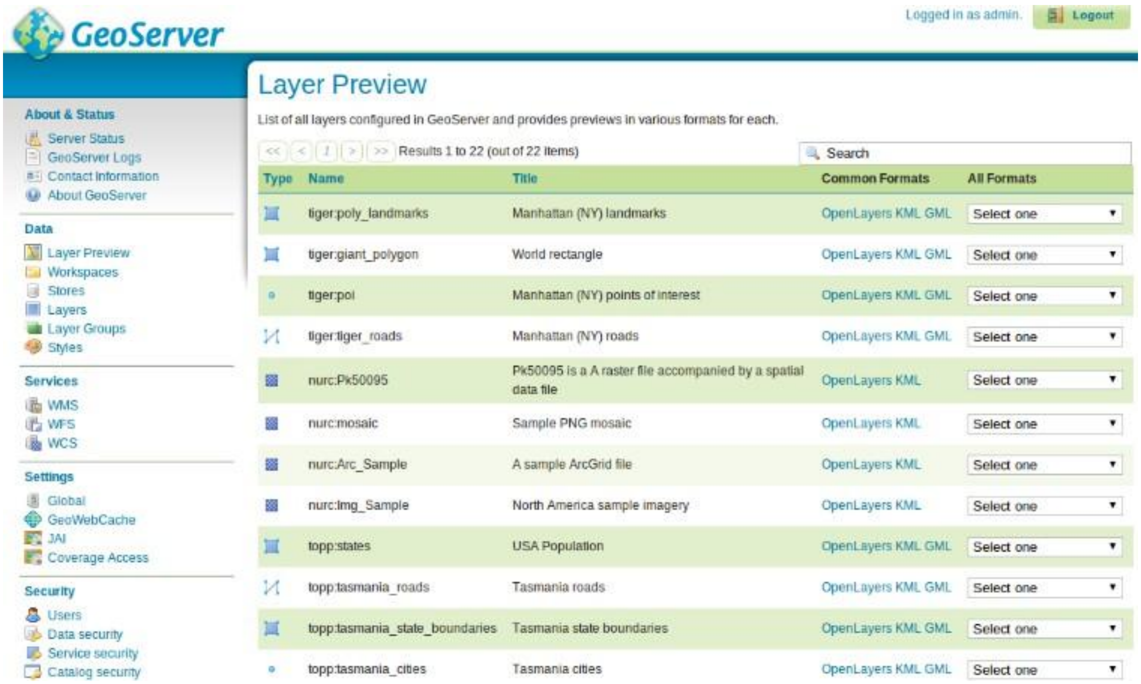
- **QGIS** offers an easy-to-navigate GUI for importing data, running analyses, editing data, modifying the map layout by joining multiple datasets based on their spatial relationships (intersect, overlap, falling within a certain buffer distance), data interpolation, raster calculation, zonal statistics, hot spot analyses etc. QGIS integrates with other open-source GIS packages, including PostGIS, GRASS GIS, and MapServer. Supports shapefiles, coverages, personal geodatabases, dxf, and other formats. Web services, including Web Map Service and Web Feature Service, are also supported to allow use of data from external sources. Using 3rd-party plugins, QGIS includes a continuously updated list of basemaps including but not limited to ArcGIS Online, Google Maps and OpenStreetMap.



Source: https://www.qgis.org/en/site/

- **GeoServer**: because it is the reference implementation of the Open Geospatial Consortium (OGC) Web Feature Service (WFS) and Web Coverage Service

(WCS) standards, as well as a high performance certified compliant Web Map Service (WMS) and the use of these standards make easier to include the tool in third party applications.



Source: http://geoserver.org/

Apart from open source GIS tools, below there is a table comparing both open and commercial software that offer free options:

GIS software	Free software	Open source	Windows	Mac OS X	Linux	BSD	Unix	Web	Other
ArcGIS	Viewer(s)	No	Yes	Yes	No	No	Yes	Yes	Google Earth Plugin, KML, WMS
Autodesk	Viewer(s)	No	Yes	No	Yes	No	No	Yes	No
Cadcorp	Viewer(s)	No	Yes	No	No	No	No	Yes	No
CAPAWARE	Yes	Yes	Yes	No	No	No	No	No	No
Chameleon	Yes	Yes	Yes	Yes	Yes	Yes	Yes	AMP	No
Deegree	Yes	Yes	Java	Java	Java	Java	Java	Yes	No
Erdas Imagine	Viewers & Plug-ins	No	Yes	No	No	No	No	Yes	No
GeoBase - Telogis	Trial	No	Yes	No	Yes	Yes	No	Yes	Traffic, WMS, ADAS, Routing
GeoNetwork	Yes	Yes	Java	Java	Java	Java	Java	Yes	No
GeoServer	Yes	Yes	Java	Java	Java	Java	Java	Java	No
GeoTools	Yes	Yes	Java	Java	Java	Java	Java	No	No
GRASS	Yes	Yes	Yes	Yes	Yes	Yes	Yes	via pyWPS[1]	No
gvSIG	Yes	Yes	Java	Java	Java	Java	Java	No	No
IDRISI	No	No	Yes	No	No	No	No	No	No
ILWIS	Yes	Yes	Yes	No	No	No	No	No	No
GeoMedia	Viewer(s)	No	Yes	No	No	No	CLIX	Yes	KML
JUMP GIS	Yes	Yes	Java	Java	Java	Java	Java	No	No
Kosmo	Yes	Yes	Java	Java	Java	Java	Java	No	No
LandSerf	No	No	Java	Java	Java	Java	Java	No	No
MapDotNet	No	No	Yes	No	No	No	No	Yes	
Manifold System	No	No	Yes	No	No	No	No	Yes	No
Microsoft MapPoint	Discontinued	No	Yes	No	No	No	No	Yes	No
Pitney Bowes MapInfo Pro	Viewer(s)	No	Yes	No	No	No	Yes	Yes	No
MapServer	Yes	Yes	Yes	Yes	Yes	Yes	Yes	AMP	No
Maptitude Caliper software	No	No	Yes	No	No	No	No	Yes	No
MapWindow GIS	Yes	Yes	Yes	No	No	No	No	No	No
Oracle Spatial	No	No	Yes	Yes	Yes	No	Yes	Yes	No
PostGIS	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
QGIS	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Google Earth Plugin, KML, WMS
RegioGraph	No	No	Yes	No	No	No	No	No	No
RemoteView	No	No	Yes	No	No	No	No	No	No
SAGA GIS	Yes	Yes	Yes	Yes	Yes	Yes	No	No	KLM
SAP HANA	Free Trial	No	No	No	Yes	No	No	Yes	No
Smallworld	No	Yes	Yes	No	Yes	No	Yes	Read-only	OLE, XML, Multiuser, Utility Data Model, Data Translator export/import
SPRING	Yes	Yes	Yes	No	Yes	No	Solaris	No	No
TerraLib TerraView	Yes	Yes	Yes	No	Yes	No	No	No	No
TNTmips	Viewer(s)	No	Yes	Yes	Yes	No	Yes	No	No
TransModeler Caliper Software	No	No	Yes	No	No	No	No	No	No
uDIG	Yes	Yes	Java	Java	Java	Java	Java	No	No
GIS software	Free software	Open source	Windows	Mac OS X	Linux	BSD	Unix	Web	Other

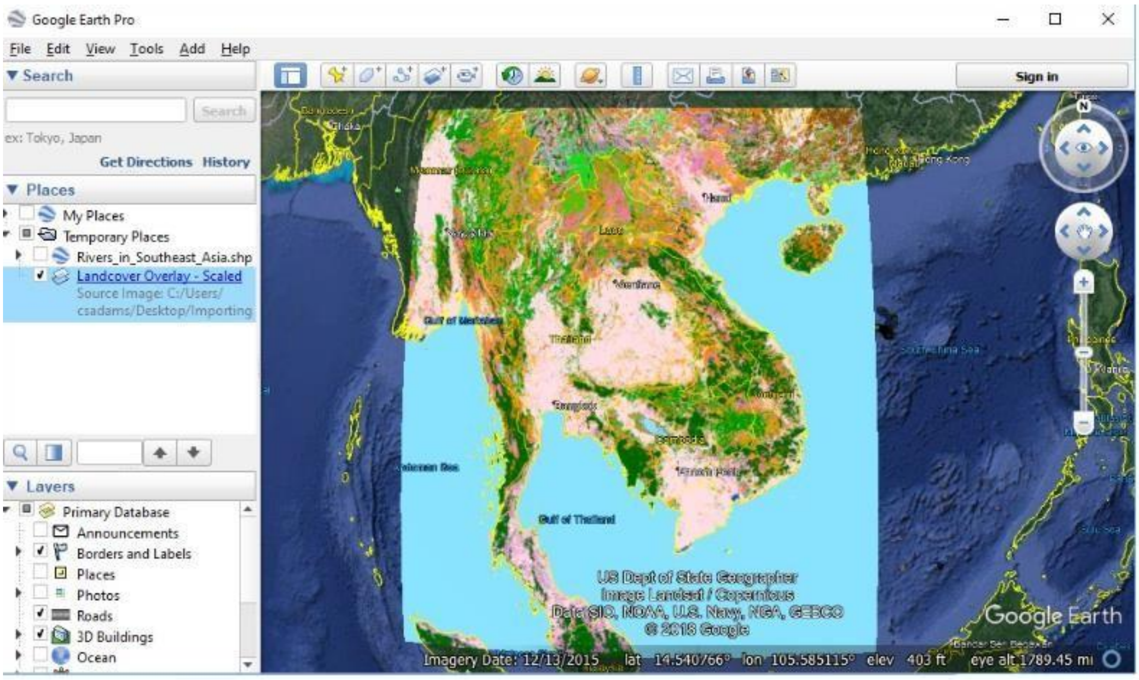
Source:
https://en.wikipedia.org/wiki/Comparison_of_geographic_information_systems_software

To enable the efficient analysis of all datasets that are required for the various purposes of the project and to render data processing feasible, access to important computer applications is necessary. In this context, the sole use of openly available applications would facilitate open access and ensure an increase in the accessibility rates of gathered information. However, to simultaneously increase the quality of the project's results, other applications, requiring software licenses, are possible as well. Among all software above-mentioned (Wiki source), the most common one is ArcGIS with the viewer still free. This software allows geo-referenced raster and vector data analysis, using geodatabase data formats, and supported by file-based data types DBMS data. ArcGIS contains several extensions among which ArcMap is included.

It is necessary to mention other open support such as **Google Earth**, due to its wide distribution and ease of use. The main advantages are:

- Worldwide historical imagery
- Interoperability of KMZ format with GIS tools

Google Earth can be used to visualize or disseminate geospatial information but not to work with it as a tool, which is the aim of this section.



Source: https://www.google.com/earth/outreach/learn/

The use of infographics to communicate the data might be a useful addition in implementing to "supporting decision tools". The results from GIS analysis may be compared directly, and through the complex matrix analysis, help to visualize the impacts of the potential scenarios, the same to predict the alerts and to take the correct decisions in advance.

The example of such a tool, and communicating of the GIS data, is currently used for urban areas and traffic infrastructure linking such areas to climate change. Smart use of existing climate intelligence can increase urban resilience and generate added value for businesses and society. The operational eco-system of cloud-based climate services are provided to calculate and present the expected effects of climate change induced and amplified hazards at the level of risk, vulnerability and impact functions. As an example, the EU H2020 project like CLARITY "Integrated Climate Adaptation Service Tools for Improving Resilience Measure Efficiency"[40].

On the other hand, tools combining downscaled climate change scenarios with simulation tools and actual data to provide the operators with an integrated tool able to support more effective management of their infrastructures at planning, maintenance and operation level, as an example PANOPTIS "Development of a Decision Support System for increasing the Resilience of

[40] https://cordis.europa.eu/project/id/730355

Transportation Infrastructure based on combined use of terrestrial and airborne sensors and advanced modelling tools”[41].

2.3.3 GIS mapping recommendation

In summary of this section, we consider GIS tools as the best option for mapping data thanks to their wide possibilities of not only storing data but mainly for providing a clear view of geographical patterns that are impossible to see otherwise. Visualization, understanding and interpretation of reality, facilitate smarter decision making at all levels by making georeferenced data understandable and manageable.

The GIS potential can be definitely attached to Urban GreenUP project NBS scenarios generation tool, visualization potential, with the supporting decision function of Scenarios Tool developed for the project.

[41] https://cordis.europa.eu/project/id/769129

2.4 RUP Phase 1, Step 4 - Mapping Challenges

Having considered the background to zoning; its usefulness in helping to develop a RUP that leads to an increase in NBS and an enhanced green infrastructure network; data collection and the availability of mapping tools, the following section provide some guidance on how challenges in a city can be mapped and assessed.

2.4.1 Identifying challenges

As part of the Phase 1 in the development of the RUP[42], Step 4 identifies the existing and predicted challenges facing a city or urban areas.

These challenges will vary significantly between urban areas depending on local conditions and are likely to include economic, social as well as environmental challenges. This is a crucial step in the development of the RUP. Understanding the range, scale and complexity of the challenges facing a city is essential if arguments for NBS are to be made and resources found to implement NBS.

Within the Urban GreenUP project (and other EU Horizon 2020 projects), The Eklipse[43] Framework has been used to identify challenges that municipalities might face. Eklipse identifies ten broad challenges.

1) Climate mitigation and adaptation;

2) Water management;

3) Coastal resilience;

4) Green space management (including enhancing/conserving urban biodiversity);

5) Air/ambient quality;

6) Urban regeneration;

7) Participatory planning and governance;

8) Social justice and social cohesion;

9) Public health and well-being;

10) Potential for new economic opportunities and green jobs.

These broad challenges can be used as a starting point for discussion about the priorities for a municipality and, once information starts to be gathered, as a way to organize data for analysis.

[42] See Page 16

[43] Eklipse Framework http://www.eklipse-mechanism.eu/apps/Eklipse_data/website/EKLIPSE_Report1-NBS_FINAL_Complete-08022017_LowRes_4Web.pdf

The Eklipse Framework also provides some guidance on the types of indicator and KPIs that might appropriate for each challenge. These are discussed further later in this document.

For example, within the Climate Change Challenge there are a number of indicators and suggested KPIs for each indicator.

CHALLENGES	TYPE OF INDICATORS	CODE	KPI NAME
CHALLENGE 1: Climate mitigation & adaptation	**Carbon savings per unit area** (environmental, chemical) **Carbon storage and sequestration in vegetation and soil**	**CH0101**	Ton C02 CARBON REMOVED per Ha
		CH0102	Ton C02 CARBON REMOVED per year
		CH0103	CARBON STORED
		CH0104	CARBON SEQUESTRATION
	Temperature reduction (environmental, physical)	**CH0105**	TEMPERATURE DECREASE
		CH0106	TEMPERATURE REDUCTION (PROJECTION)
		CH0107	HUMAN COMFORT
		CH0108	HEATWAVE RISK
	Energy and carbon savings from reduced building energy consumption (environmental, physical)	**CH0109**	kWh savings per year
		CH0110	t C/y savings per year
	Other	**CH0111**	SPECIES MOVEMENT
		CH0112	INCREASE IN SHADOW SURFACE

Table 2. Suggested KPIs for Climate Change Challenge.

In this guide, we are interested in how we might map these challenges across an area or an entire municipality.

Step 4 aims to map these challenges and so spatial data is required wherever possible for each of these challenges. Where spatial data is not available, it may be possible to use the information to provide context for the RUP. However, robust spatial data is always going to be the most useful type of information for zoning.

As described in 2.3.1, data that has been collected and used to develop existing policy or data sets from local or national government are readily available for many of the challenges that may need to be addressed. This data has the added advantage that is likely to be already linked to statutory plans and strategies and therefore to have been scrutinized and accepted and as a robust dataset.

Gathering new data can be expensive and may only be an option for well-resourced projects. Within the RUP, the steps that precede "Mapping of Challenges" will set the scale and scope for the mapping that is required in this step.

For a well-resourced RUP this might mean in Step 2 "Identifying Your Need" a comprehensive policy analysis has been carried out, with a wide range of consultation and engagement to arrive at consensus on the challenges that the RUP might address. Data sources might be collated and agreed with partners which are robust and sound.

A less well-resourced RUP might look at key statutory documents and national/regional policy in Step 2, with limited engagement on the priority challenges.

A basic RUP may simply look at national/regional strategy and policy and assess how these are being addressed locally.

Step 3 of the RUP "Assessing Your Capacity", will also influence the amount of work and the scope of the work, perhaps limiting the geographic area within the municipality that is being considered or looking at a smaller set of challenges.

These decisions should be taken with the partners and stakeholder identified and engaged in Step 1.

In Appendix 4 Bringing together function and needs mapping with the Eklipse framework (based on work for Liverpool City Region), we have suggested types of mapping that can be used for the Eklipse indicators and in particular to provide information to zone areas as described in the following sections of this guide.

2.4.2 Mapping of Challenges

Based on the work that has been carried out in Steps 2 and 3, the challenges that have been identified can be mapped. Information in section 2.3 can be used to assess mapping tools that are available for this task if there are no systems already available.

For example, as part of the Liverpool Baseline Assessment, climate change was identified as a challenge. Based on the national Heatwave Plan[44] it was possible to map the populations that are likely to be most at risk from projected increase in the number of days that are identified as "heatwave" and which can cause serious health problems for vulnerable communities. This "vulnerability" mapping used population data from national datasets for the vulnerable communities identified in the Heatwave Plan.

- Young children
- Older people
- People with chronic illnesses
- People with disabilities.

[44] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/888668/Heatwave_plan_for_England_2020.pdf

Mapping the data from national datasets allowed a vulnerability map to be created. This shows the distribution of people who might be most affected by heatwave across the city.

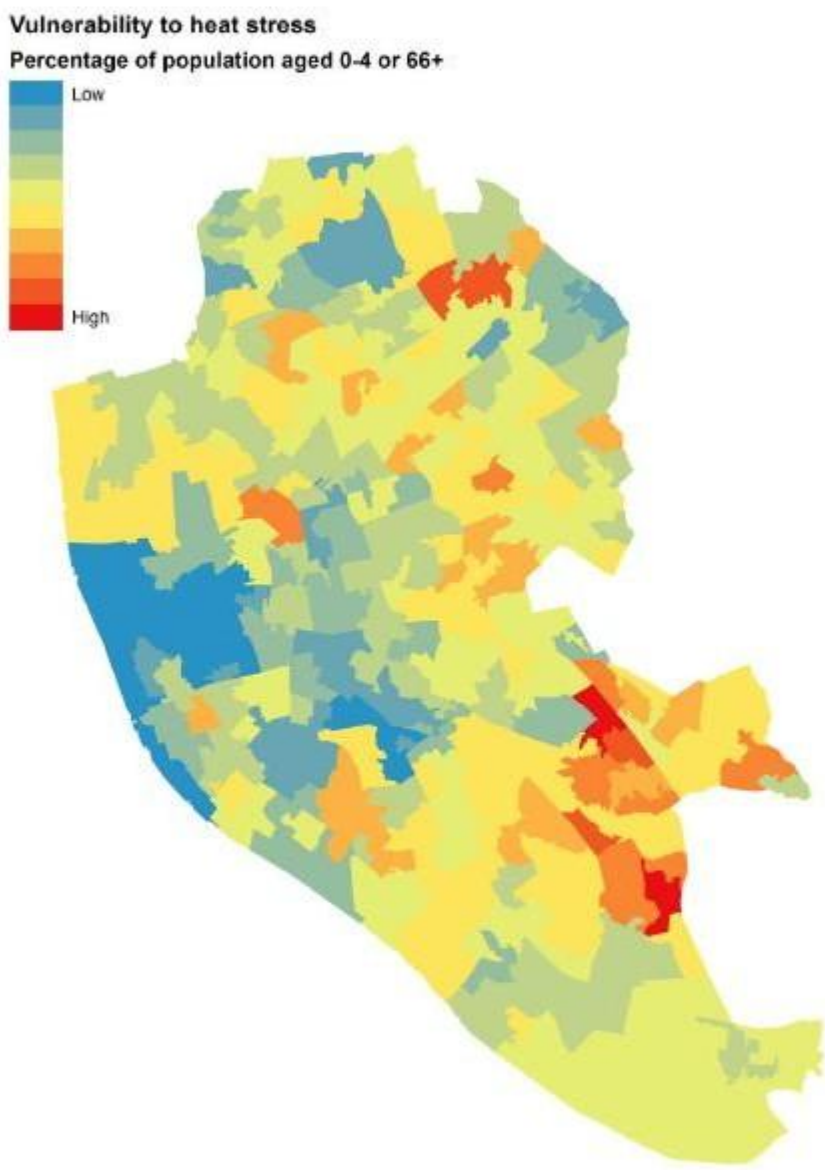


Figure 11: Community vulnerability to heatwave stress in Liverpool.

Figure 12: Reminder of RUP Phase 1 steps.

From this mapping it is possible to identify the target areas for NBS interventions that could help to reduce the risk of heatwaves affecting vulnerable people in the area.

For the work in Liverpool, ArcGIS was used as the platform to map and analyse the data that was available for this challenge. Section 3.3 provides some information about the use of Geographic Information Systems and other tools that will assist in mapping challenges using data that is already available or data that has been gathered in the process of developing the RUP.

There is no one single methodology for mapping challenges. The key aspects to consider in any method that is used are;

- Ensure that any partners or end users of this mapping have agreed and are happy with the mapping approach.
- Whenever possible use verified data, with a sound evidence base to support the mapping. This is important to enable the mapping to withstand challenge, particularly challenge to resource allocation.
- Consider how data might be updated if the RUP is to be taken forward as a long-term plan rather that a short-term guide for interventions.

Appendix 5 Further examples of challenge mapping provides further examples of mapping that has been or which can be used to help to map challenges in cities.

2.4.3 Mapping of existing green infrastructure

As well as mapping the challenges faced by a city or municipality it is helpful to map the existing green infrastructure. The importance of this additional baseline mapping is highlighted in 2.1.6 which looked at the challenges of zoning for NBS.

The same process as described for Mapping Challenges can be applied i.e. the scale and scope of this mapping will have been determined in Steps 1-3 of the RUP, where possible existing and up to date data that is robust and considered sound should be used. Where resources allow, this data can be supplemented by collecting new data.

Increasingly green infrastructure datasets are available at a municipal or country level. For example, in the UK the Ordnance Survey provides information on greenspaces across the country[45]. This data provides an excellent basis for green infrastructure mapping.

The Liverpool Green Infrastructure Strategy looked to map at a finer scale, looking to include private gardens for example, to try to develop a picture of the total amount of green infrastructure in an area. The methodology for this mapping is described in the Strategy document[46]. Figure 13: Liverpool Green Infrastructure **Typology**, shows the result of this mapping process. New data and technology mean that creating similar mapping as a baseline for the RUP is becoming easier and less expensive to carry out.

[45] https://www.ordnancesurvey.co.uk/news/open-greenspace-dataset-released

[46] http://www.greeninfrastructurenw.co.uk/liverpool/

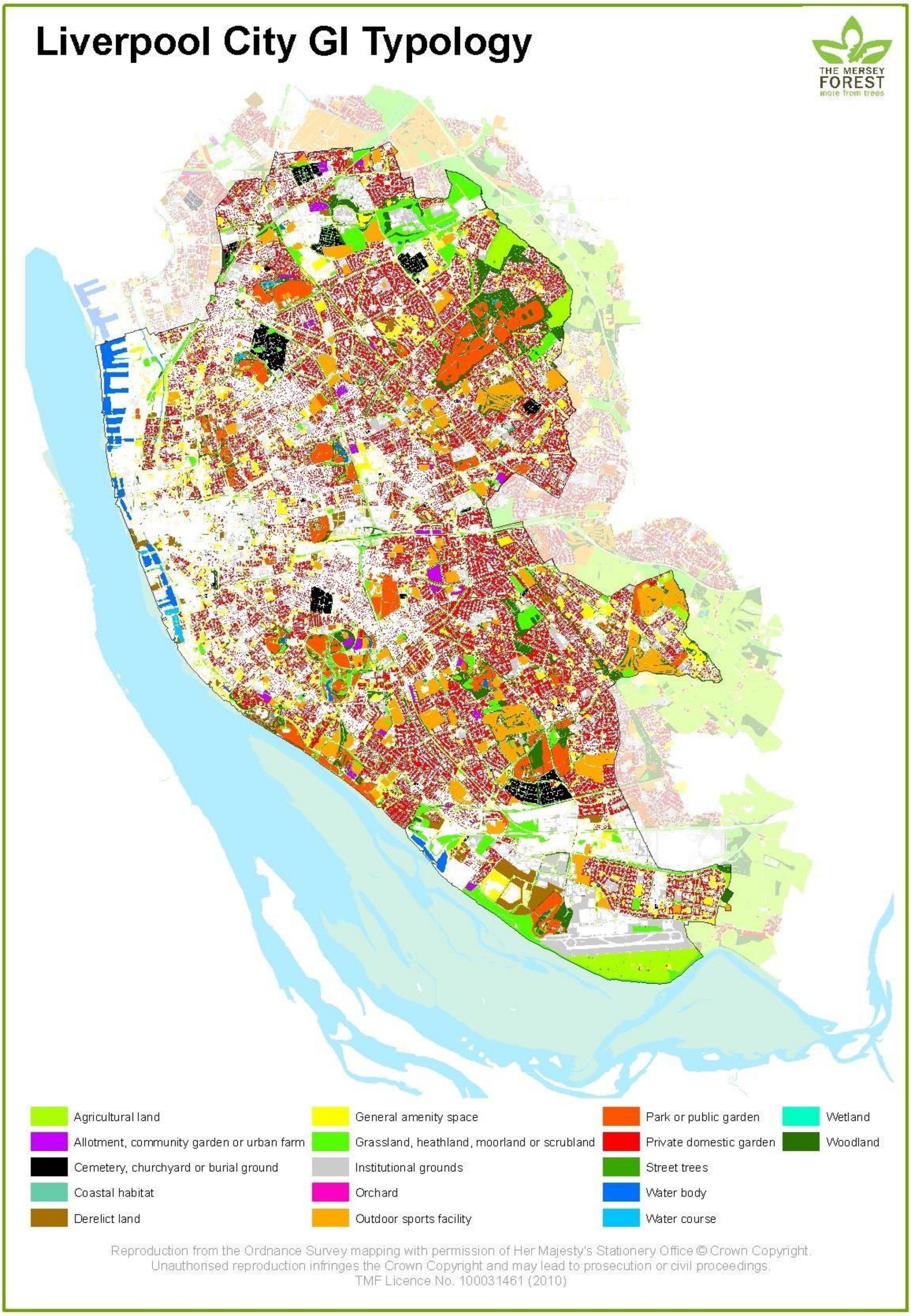


Figure 13: Liverpool Green Infrastructure Typology.

This example from Liverpool provides a comprehensive assessment of green infrastructure across the urban area. Table 3 shows the area of each green infrastructure type across the city.

This shows that even in a city that might, on first impression seem mostly built up, the majority of land types are green infrastructure (though The River Mersey makes a very large difference to this assessment, at nearly 10% of the municipality land cover.

TYPE	TOTAL AREA (HA)	TOTAL AREA PERCENTAGE	PERCENTAGE OF GREEN SPACE
Not green infrastructure	5113.0	38.12%	-
Private domestic garden	2162.3	16.12%	26.05%
Coastal habitat	1298.2	9.68%	15.64%
Water course	892.4	6.65%	10.75%
General amenity space	645.5	4.81%	7.78%
Grassland, heathland, moorland or scrubland	618.3	4.61%	7.45%
Outdoor sports facility	569.8	4.25%	6.87%
Park or public garden	518.4	3.87%	6.25%
Woodland	456.8	3.41%	5.50%
Institutional grounds	413.1	3.08%	4.98%
Agricultural land	165.5	1.23%	1.99%
Cemetery, churchyard or burial ground	154.2	1.15%	1.86%
Derelict land	129.1	0.96%	1.56%
Street trees	111.4	0.83%	1.34%
Water body	106.3	0.79%	1.28%
Allotment, community garden or urban farm	57.0	0.42%	0.69%
Orchard	0.8	0.01%	0.01%
Wetland	0.3	0.00%	0.00%

Table 3. Breakdown of Liverpool Green Infrastructure Typology.

Figure 14: Liverpool Green Infrastructure - omitting private gardens to show the impact on GI cover in the **city**, shows the difference that including private gardens has on the mapping of green infrastructure.

Private gardens make up around 16% of the land use in Liverpool, it is likely to be similar in other cities. These private spaces provide a wide range of benefits. However, private gardens are often omitted from assessments of green infrastructure and so recommendations for zoning intervention, as we are attempting to do in the RUP, may be distorted.

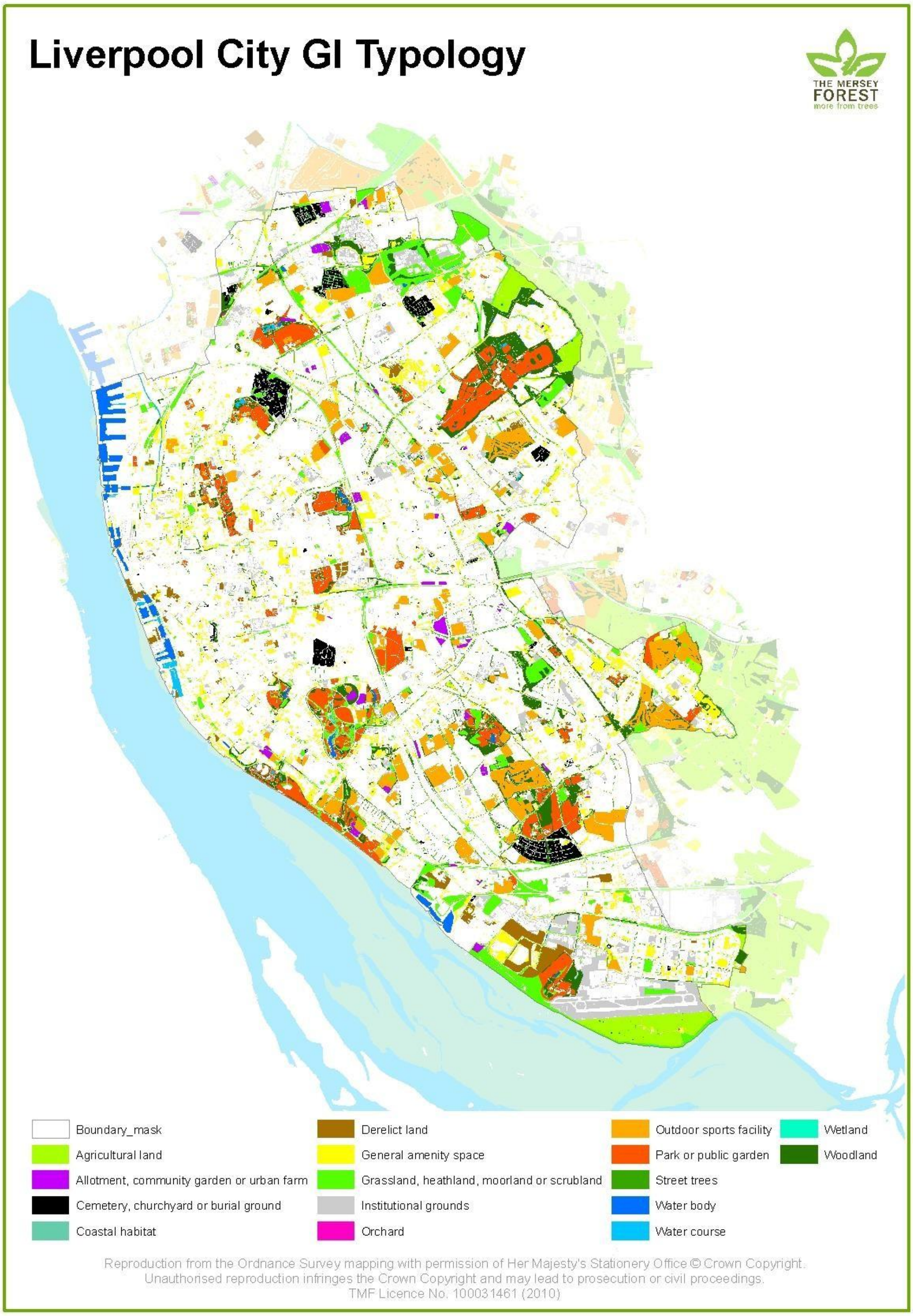


Figure 14: Liverpool Green Infrastructure - omitting private gardens to show the impact on GI cover in the city.

Mapping to include as much detail as possible, given other constraints of budget, people and time, allows a better evidence base to be created and therefore a greater chance of delivering the impact from NBS that might be expected.

A final stage in the mapping and assessment of green infrastructure is to look at the benefits that the existing green infrastructure is providing. Is it providing shade and shelter in public spaces, reducing heatwave impacts? is it slowing the flow of water, reducing flood risk? is it providing an attractive setting for a business district, sustaining property value and attracting new businesses? Etc.

This is important. If we want to target resources for NBS we need to know what green infrastructure is already in place in the potential target areas.

For, example, if there is already a large amount of green infrastructure in an area where there are identified challenges, it may be that:

- The green infrastructure is not able to deliver the types of benefits that are needed in the target area to address the needs identified. It may be that the issues are mainly social or economic and any amount of green infrastructure will not remedy the situation.
- The green infrastructure is not managed in a way that addresses the challenges. For example, in an area of identified high levels of poor health or health inequality, a social challenge, green spaces may not be publicly accessible, or are difficult to access. Therefore, to realise the benefit that the green space could provide to improve health there would need to be a change in management of the green spaces in that area.

We can also look at the challenges and ask what is “needed” to reduce the impact of the challenge.

2.4.4 Set Spatial Priorities for NBS

Step 4 mapping will have identified

- Key challenges
- The existing green infrastructure

Phase 2 of the RUP starts use this data to set targets and identify NBS that will meet the challenges faced and in Step 9, start to set spatial priorities - where are we going to direct effort and resources to deliver NBS?

Figure 15: Setting spatial priorities.

As the mapping above shows, the challenges that we are looking to address are often not evenly distributed across a city; neither is the green infrastructure. In terms of impact and value for money, NBS need to be targeted:

- To areas of greatest need for the benefits that NBS can deliver to meet the challenges identified
- Where there is evidence that NBS can tackle the issue
- Where there is an opportunity to make the NBS intervention in the timescale of the RUP.

The evidence base for the interventions will have been evaluated in Step 8 “Evaluate NBS Scenarios and select one” and the outputs from Step 8 can inform the Setting of Spatial Priorities.

Considering an NBS Intervention Opportunity is objective and can be differentiated from the data driven approach to mapping. For example, opportunity for NBS intervention may arise due to a new national funding programme, plans for regeneration of an area or simply through the lobbying and interest of local communities.

Projects and programmes that are planned for the city may increase the opportunity to implement NBS perhaps because there is new building or maintenance works planned into which NBS can be incorporated. However, setting Spatial Priorities that include areas where there are unlikely to be opportunities to implement NBS sets the RUP up to fail to deliver the impacts needed, damaging the reputation of NBS and reducing future opportunities.

An example of an approach to setting spatial priorities is described in 2.4.5. This section is not meant to be prescriptive. It is included to show one approach that might stimulate ideas locally.

2.4.5 Setting spatial priorities using a "Pinch Points and Assets" approach

The concepts of Pinch Points and Assets uses the mapping undertaken in Step 4. The mapping of the challenges identifies area of "need", as described in RUP Phase 1, Step 4 - Mapping Challenges.

These are areas of the city where some action is required. We need to ensure that there is a sound evidence base to support NBS addressing the issues that have been identified. NBS is not a panacea, selecting issues for which there is strong evidence that NBS can help to mitigate or provide adaptation benefits is critical in establishing the long-term justification for NBS and to ensure value for money in terms of tackling issues in cities.

From the data and mapping of needs and green infrastructure functionality we can start to look at differing needs across the city, starting to "zone" the city, based on a need, into areas of:

- Assets –the term "asset" is used to describe green infrastructure that is delivering a function or functions in an area of identified need. For example, a woodland or wetland that is intercepting and storing water in an area of flood risk is a water management asset; it is providing functions that help to reduce the risk of flooding.
- Pinch Points - Pinch Points are identified as areas where a "need" has been identified, for which green infrastructure functionality could provide a solution, but where that functionality is not provided now. This is where NBS interventions can be targeted.

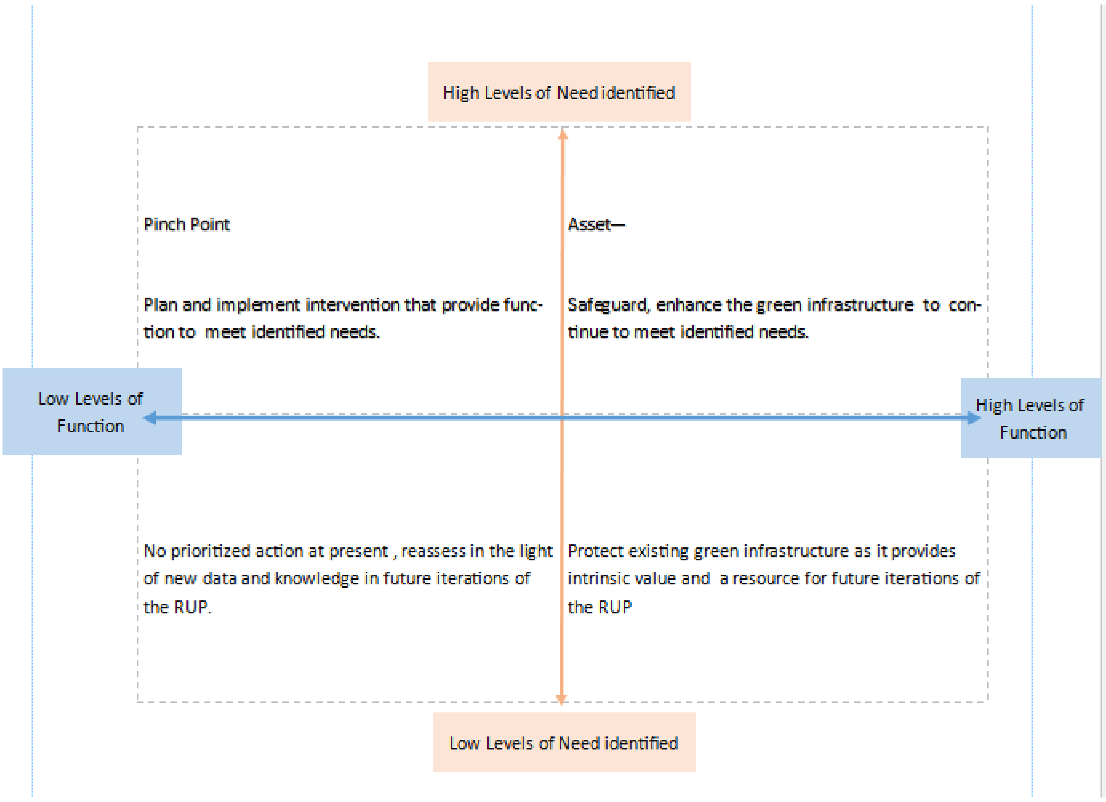


Figure 16: Assets and Pinch Points.

We can describe each of the quadrants in the Need and Function Figure.

- Where there is need and the function is currently performed, potentially fulfilling the need – these areas of land are green infrastructure **Assets** and their functionality should be protected
- Where there is need, but the function is not currently performed these can be described as **Pinch Points** which should be remedied, if possible, by suitable creation or enhancement of green infrastructure
- Where there is no particular need but the function is currently performed – here the green infrastructure should also be protected if possible, because there is likely to be a lower level of need, which may increase in the future, and the functionality may be mitigating a lack of provision elsewhere. The green infrastructure in these areas has intrinsic value.
- Where there is no particular need and the function is not currently performed – no action required, except to take any opportunities that present themselves, for the reasons described above. There is no prioritized action for these places, but they should be reviewed in future iterations of the RUP.

A lack of functionality may be because there is no green infrastructure or because the existing type of green infrastructure cannot provide the functionality that is needed.

For example, in an area of high flood risk, a lack of water management functionality creates a pinch point.

In the development of the RUP, it is also important to recognise and highlight the existing NBS assets, as these will already be providing services for the city. Safeguarding existing NBS assets, enhancing their function where possible and extending their impact to meet need by increasing their area is an effective way to develop NBS in our cities.

The flow chart below sets out the process for a city to start strategic zoning, based on issues faced, into Asset and Pinch Point.

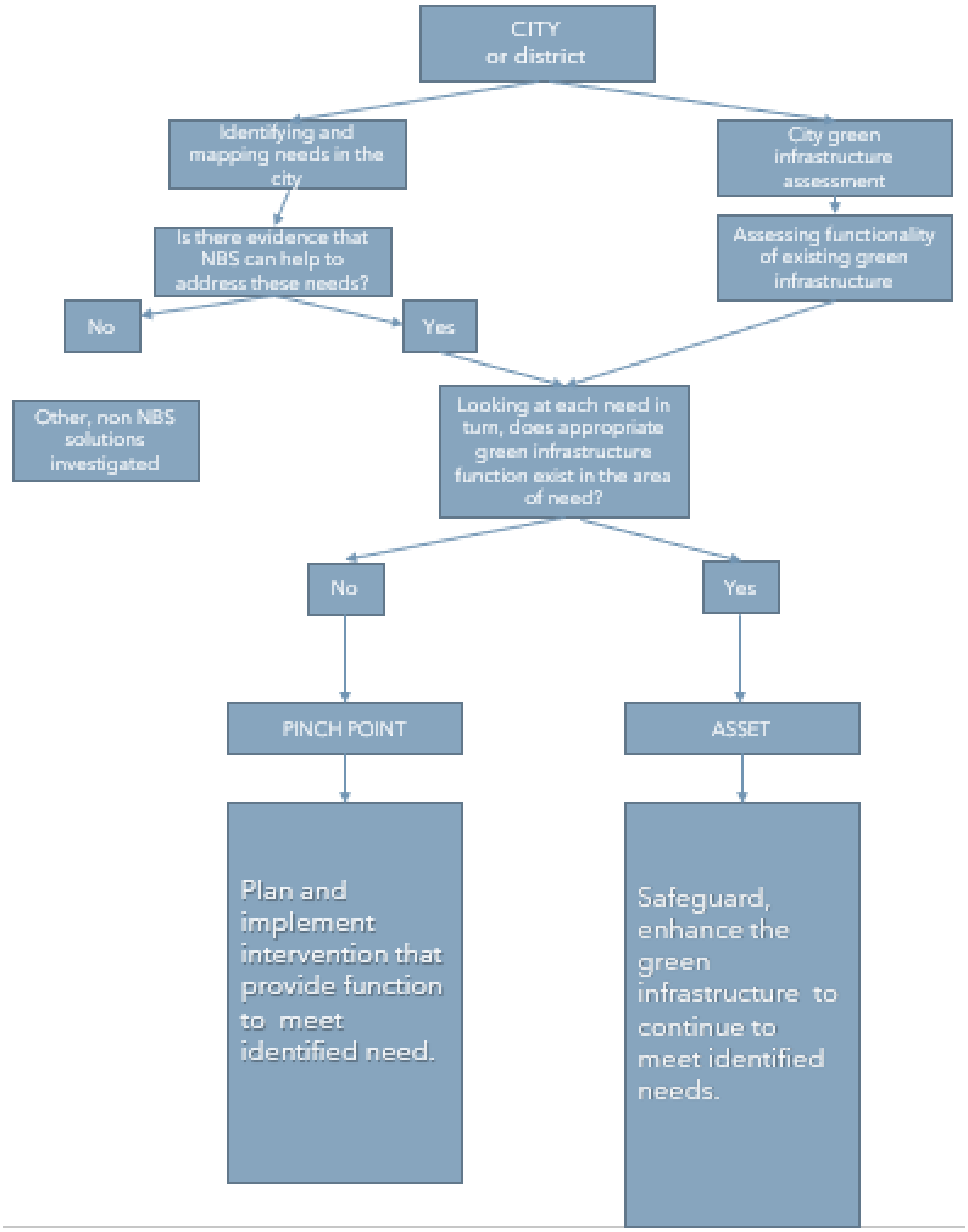


Figure 17: Asset and Pinch Point flow chart

There is a wide range of potential green infrastructure interventions that can help to address Pinch Points. These are described in the NBS Catalogue and will have been identified in Step 8 of the RUP.

Below is an example of the use of the Asset and Pinch Point approach at the Liverpool City Region level, taken from the Liverpool City Region Green Infrastructure Framework[47].

Figure 18: Greatest need for trapping air **pollution**, shows the location of the areas of greatest "need", based on the methodology described in Appendix 2 Mapping Needs, for improved air quality/trapping air pollutants.

This mapping simply assesses the locations across the city region that have the highest levels of air pollution as described in above. The threshold for "greatest" need is arbitrary. It could be a legal or recommended level, the top 10%, or another threshold that is considered useful.

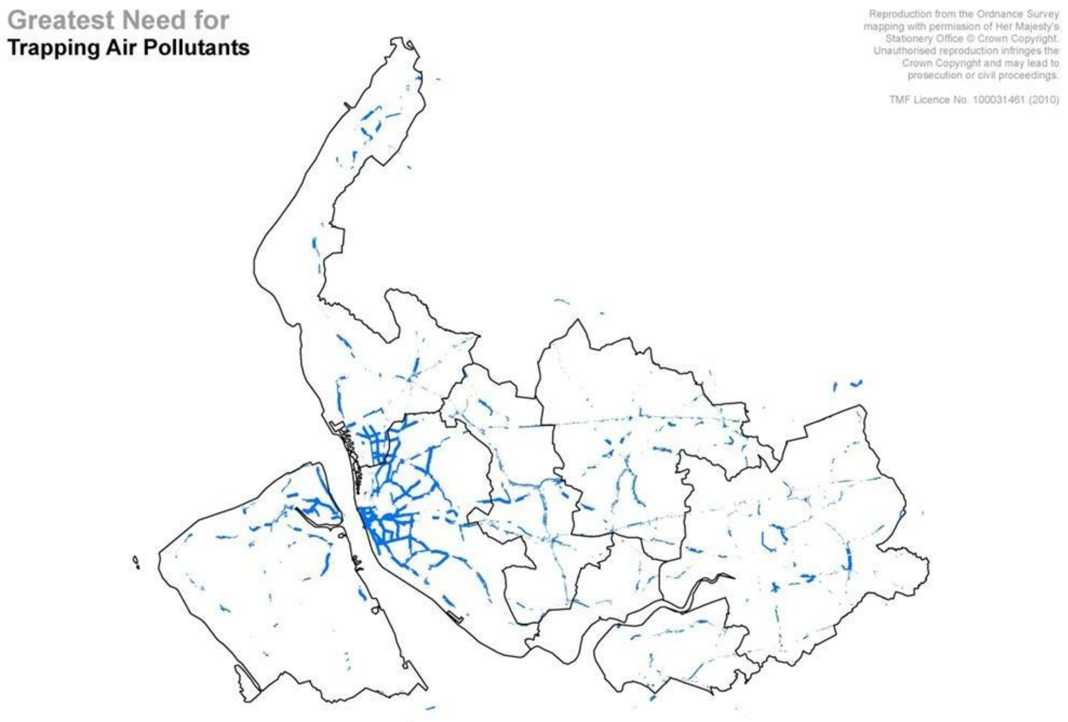


Figure 18: Greatest need for trapping air pollution.

Figure 19: Green Infrastructure that can function to trap air **pollution**, shows where green infrastructure types with the functionality to trap pollutants are already in place in the Liverpool city region[48].

[47] Liverpool City Region Green Infrastructure Framework, https://www.merseyforest.org.uk/Technical_document.pdf

[48] Liverpool City Region Green Infrastructure Strategy *ibid*

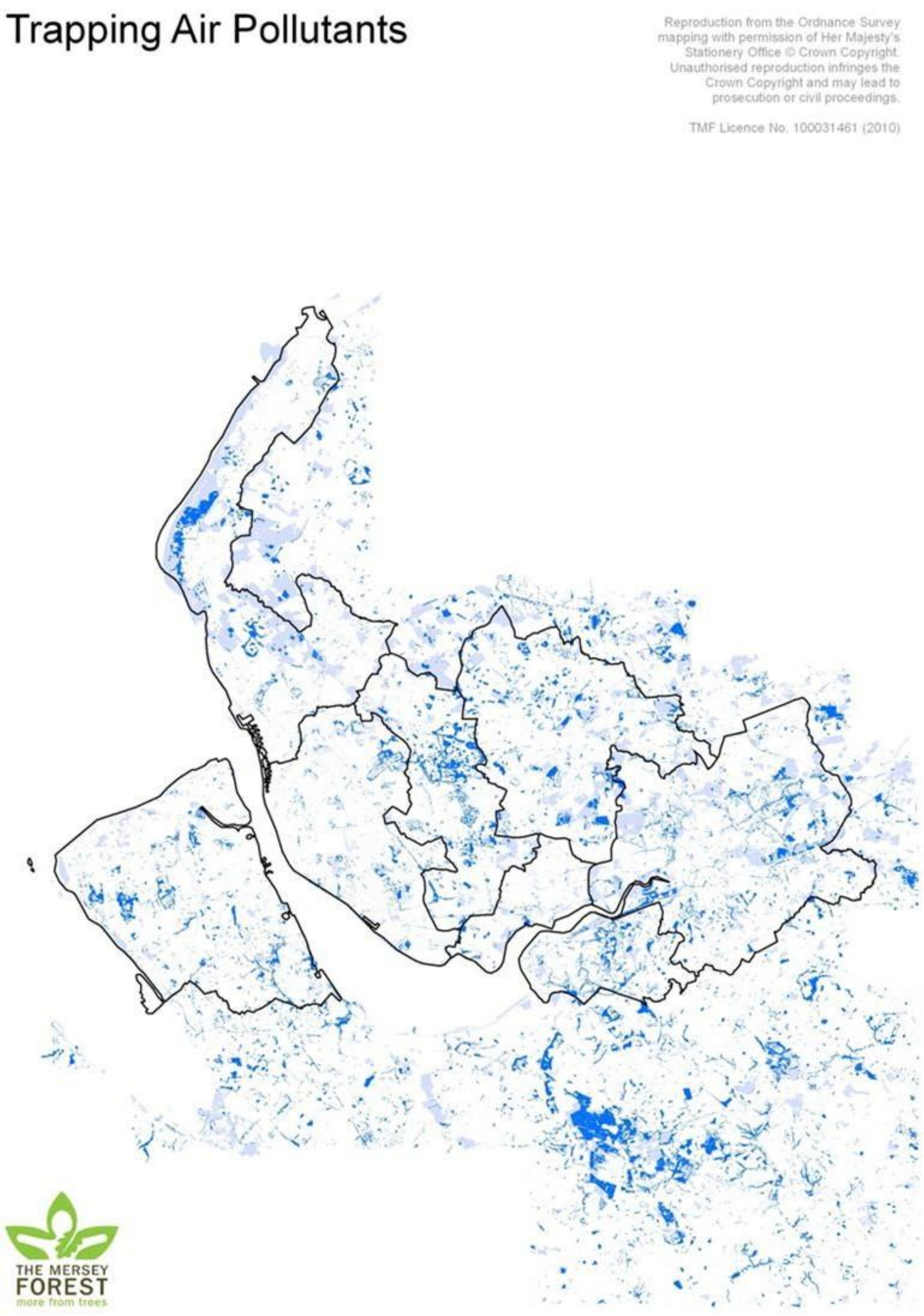


Figure 19: Green Infrastructure that can function to trap air pollution.

Using GIS, we can analyse these two maps, overlaying the areas of greatest need with the areas where there is green infrastructure already in place that can play in air pollution reduction function. From this we can identify;

- Assets - where need and function overlap, In this case there is green infrastructure in place that may already be trapping air pollution.
- Pinch Points – Where there is a need, but no green infrastructure in place or where the green infrastructure that is in place does not have the functionality that is needed to trap air pollutants and so improve air quality.

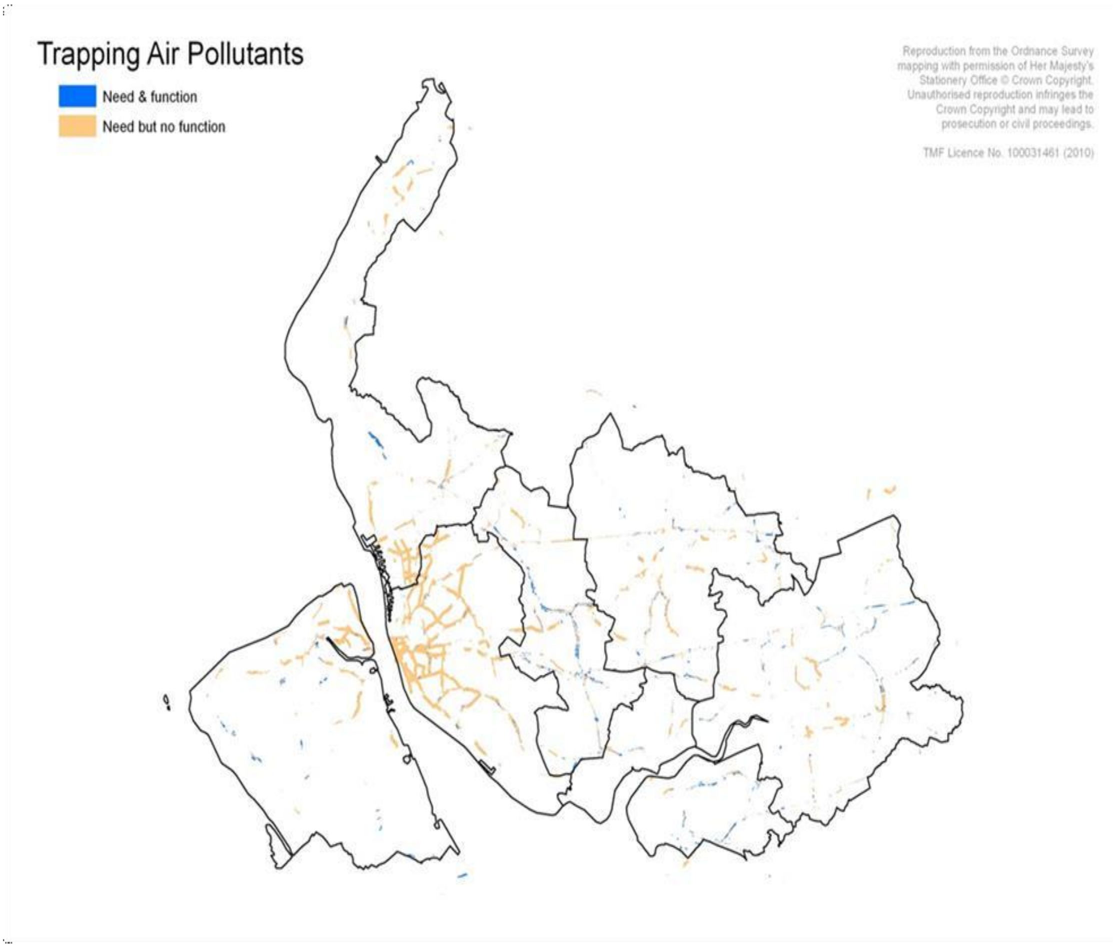


Figure 20: Pinch Points and Assets map.

Using this approach, it is possible to zone areas for intervention and identify appropriate NBS.

3 Expected impacts and the Monitoring framework

Applying the URBAN GreenUP methodology will improve the expected impacts in each area of the city and optimize available resources. Usually, an impact evaluation framework includes a list of criteria for assessing the performance of NBS in dealing with challenges related to climate resilience in urban areas. The introduction of zoning will help to address each challenge in the proper areas of the cities to maximize beneficial impacts while optimizing resources.

Phase 3 of the RUP and building on the zoning work completed in Phases 1 and 2, the task is to assess the expected impacts from the targeted delivery of NBS to tackle key challenges for the city/urban area.

In some ways, this is a relatively straightforward step. In Phase 2, the NBS to tackle the identified challenges have been selected. These NBS will have been selected on the evidence that they can have an impact on the identified challenge. For instance, where flooding has been identified as a risk, a targeted intervention of Sustainable Urban Drainage Systems (SUDs) might have been selected as one of the potentially beneficial NBS.

The expected impact of the intervention will counter the challenge for which it has been selected. To continue the previous example, the case of SUDs, the intervention is expected to reduce the total amount of water that is discharged to the drain and to slow the flow of water, so reducing peak flow to reduce flood risk.

A simple logic chain is often used to help to develop thinking about impact.

Challenge	NBS Intervention	Description	Output	Outcome	Impact(s)
Flood risk	SUDs	Use of design and targeted NBS to reduce water volume and slow water in the drain system	Reduction in water volume in system (quantified) Slowing of flow through system	% Reduction in flood risk	Reduced costs of flood clean up, improved quality of life for residents, better quality of place

Table 4: Simple logic chain to think about impact of NBS.

The outputs in this chain are relatively straightforward to assess and quantify. For many NBS outcomes and impacts may be more difficult to quantify. In certain challenges and cities, the zoning of needs is not so clear and the benefits of the application of this type of tool is not so clear for identification purposes. However, it is interesting anyway to map the results of the impact assessment studies.

Each NBS generates several impacts. These may be assessed through a set of indicators by using specific types of methods. An objective method to evaluate the actions, impacts and performance is necessary. URBAN GreenUP has been working to adopt several KPIs for the evaluation of NBS impacts. Within the selection process, the EKLIPSE framework was used as starting point to elaborate a homogeneous framework for the evaluation of NBS and to compare results through cities regarding the impact categories identified in the mentioned methodology. Other KPIs have been adopted to frame the project evaluation not just in the European context but also in an international one. This framework takes into consideration all NBS impacts at different scales. Initiatives that have been included are European Green Capital Award, Sustainable Development Goals (SDGs), Convention on Biological Diversity - Aichi targets, The Economics of Ecosystem Services (TEEB) and Mapping and Assessment of Ecosystem Services (MAES). The aim was focused on showing how the proposed actions in the Project and selected NBS will tackle the mentioned challenges that each city is and will be facing now and the upcoming years.

The first step into the preparation of the impact evaluation framework is to define the main challenges at city scale. Apart from climate change, there are other societal challenges, mainly at city scale, that can be addressed with NBS. During the initial defining process of the approach and scope, it was decided to follow the societal challenge classification developed by the EKLIPSE Expert Working Group[49] collected in their report as a reference. This approach contains 10 challenges:

It is for these reasons that an easy-to-use catalogue has been designed by projecting a multi-card structure and delivered as one of the results of WP1 (Deliverable 1.2). The catalogue collects several environmental challenge characteristics and in practice, it is a **climate change & societal threats repository** that includes **existing information** about **current challenges**, **NBS recommended to deal with them** as well as **technical** and **parametrisation** aspects, in a standardised manner ready to be used in a systemic procedure of planning or decision-making processes.

Apart from a societal challenge approach for KPIs design process, URBAN GreenUP used Ecosystem services for also identifying impact categories and indicators. Ecosystem services are "the direct and indirect contributions of ecosystems to human wellbeing[50]". Several classifications of ecosystem services exist including those presented by the Millennium Ecosystem Assessment[51], TEEB[12] and the Common International Classification of Ecosystem Services (CICES 2013). Building on previous categorizations of ecosystem services[52,53] the TEEB

[49] "An impact evaluation framework to support planning and evaluation of nature-based solutions projects" EKLIPSE Report.
[50] The Economics of Ecosystems and Biodiversity, (TEEB). (2010). "The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations". London: Earthscan.
[51] Millennium Ecosystem Assessment, (MA). (2005). "Ecosystems and human well-being: the assessment series". Island Press, Washington DC.
[52] Millennium Ecosystem Assessment, (MA). (2003). "Ecosystems and human well-being: a framework for assessment". Island Press, Washington, D.C., USA
[53] De Groot, R.S. De Groot, M.A. Wilson, R.M.J. Boumans. (2002). "A typology for the classification, description and valuation of ecosystem function, goods and services". Ecological Economics, 41, 393-408.

report identifies 22 types of ecosystem services grouped in four categories:

1. provisioning
2. regulating
3. supporting
4. cultural

NBS are actions "inspired, supported by or copied from nature"[54] that use complex system processes of nature to reduce disaster risk, to improve human well-being and to promote a socially inclusive green growth. Furthermore, NBS can deliver services, such as the ability to regulate water or store carbon, comparable to traditional, grey infrastructures in a more cost-efficient way; on the other hand, by their intrinsic nature, NBS do deliver a series of other services that are commonly defined as social, economic and environmental co-benefits.

In cities, for example, urban parks and green areas, in general, can offer ecosystem services such as storm control, carbon dioxide conversion, wildlife diversity, outdoor recreation opportunities, noise dampening and offsetting city pollution.

However, these benefits are not valued in a consistent and complete way. There is the need to compile a more comprehensive evidence base on the social, economic, and environmental effectiveness of NBS since the current knowledge base is rather dispersed and fragmented. "The valuation (monetary and nonmonetary) of the multiple benefits of NBS and the development of performance indicators, standards, technical and scientific reference models for NBS is necessary for their wider and systemic implementation", as well as the availability of tailored assessment tools[55].

Ecosystem Services Assessment (ESA) approach is based on urban ecosystem services. URBAN GreenUP combined EKLIPSE methodology with ESA to identify and assess the generation of new, enhanced, restored flows of ecosystem services promoted by urban renaturing and the NBS implemented in coach cities, quantifying these flows in physical and monetary terms. A categorization of ecosystem services tailored to the urban context will be elaborated within the Urban GreenUP project. Designing and applying an innovative analytical framework to assess NBS based on their provision of ecosystem services explicitly tailored on the urban context will allow assessing their cost-effectiveness also in relation to alternative solutions.

Recent contributions in the field of ecosystem services have stressed the need to focus on the products (benefits) when valuing ecosystem services. This approach helps to avoid double counting of ecosystem functions, intermediate services and final services[56] [57].

[54] European Commission (2015), "Towards an EU Research and Innovation policy agenda for Nature-Based Solutions & Re-Naturing Cities".
[55] European Commission (2015), "Towards an EU Research and Innovation policy agenda for Nature-Based Solutions & Re-Naturing Cities".
[56] Boyd, J., and S. Banzhaf. (2007). "What are ecosystem services?". Ecological Economics 63: 616-626.
[57] Fisher, B., Turner, R.K., Morling, P. (2009). "Defining and classifying ecosystem services for decision making". Ecological Economics 68, 643 – 653.

URBAN GreenUP created a complete set of KPIs for the evaluation of NBS impacts in front-runner cities. The starting point for the creation for the set of KPIs was the EKLIPSE framework to elaborate a homogeneous framework for the evaluation of NBS and to compare results through cities. Other KPIs were also adopted to frame the project evaluation not just in the European context but also in an international one. In fact, initiatives like the European Green Capital Award, SDGs, Aichi targets, TEEB and MAES have been analysed to verify the possibility to build up a more complete set of KPIs for the evaluation of NBSs in URBAN GreenUP project. The KPIs creation process has been developed considering front-runner cities and their capacity to adopt and use the set of KPIs proposed. The KPIs creation process included the following steps:

1. KPIs analysis of European and international initiatives to evaluate the sustainability and the performances of NBSs in cities and their territories (European Green Capital Award, SDGs, Aichi targets, TEEB and MAES);
2. Involvement of coach cities in the selection of the KPIs based on their experiences and needs;
3. Identification and categorisation of core KPIs to measure and evaluate ecosystem services.

Through the analysis of the European Green Capital Award, SDGs, Aichi targets, TEEB and MAES initiatives a list of 135 indicators have been individuated to complete the EKLIPSE framework. Each indicator has been associated with a societal challenge and a category of ecosystem services to measure and evaluate the performances of NBS implemented in cities. The KPIs have been categorised based on the societal challenges and on the ecosystem services categories:

EKLIPSE	ESA
16 indicators of Climate mitigation and adaptation 21 indicators of Water Management 12 indicators of Coastal Resilience 22 indicators of Green Space Management 13 indicators of Air Quality 16 indicators of Urban Regeneration 6 indicators of Participatory Planning and Gov. 9 indicators of Social Justice and Cohesion 10 indicators of Public Health and Wellbeing 11 indicators of Potential Economic Opportunities and Green Jobs	16 indicators of cultural services; 6 indicators of provisioning services; 39 indicators of regulating services; 9 indicators of supporting services.

Table 5. Categorised KPIs from EKLIPSE and ESA.

These indicators have been integrated with the EKLIPSE framework, the KPIs set was sent to cities to involve them in the process. Valladolid, Liverpool and Izmir have selected the KPIs that will be used in the monitoring and evaluation process of NBS implemented in their cities.

Furthermore, front-runner cities have included in the set of indicators several KPIs that they are going to use in their territories to monitor NBS performances.

An additional selection of KPIs has been made to create a group of indicators that have to be adopted by all front-runner cities. The core group of KPIs will be used i) to create a homogeneous dataset of NBSs impacts and performances and ii) to ensure the evaluation of co-benefits and side effects of NBSs. 21 KPIs have been individuated to evaluate regulating, provisioning, supporting and cultural ecosystem services provided by NBSs implemented by cities and to compare their performances. Front-runner cities have the possibility to use additional specific KPIs during the monitoring phase.

Core KPIs

The intention of the KPIs is to list a robust set of indicators that will evaluate the progress and the application of the NBS in demo cities. To guarantee a comparable approach among the demo cities, there were selected a set of KPIs named Core KPI, see the table and figure below.

CH	TYPE OF INDICATOR	KPI DEFINITION
Challenge 1	Environmental, Chemical	**Tonnes of carbon removed or stored per unit area per unit time (ton CO2/Ha) (ton CO2/year). Total amount of carbon stored in vegetation (ton)**
	Environmental, Physical	**Decrease in mean or peak daytime local temperatures (°C)**
		Heatwave risks (number of combined tropical nights (>20 °C) and hot days (>35 °C)
	Others	**Use of *Star tools* to calculate projected maximum surface temperature reduction (°C)**
Challenge 2	Physical indicators	**Run-off coefficient in relation to precipitation quantities (mm/%)**
		Absorption capacity of green surfaces, bioretention structures and single trees (m3/m2) (m3/tree)
		Temperature reduction in urban areas (°C, % of energy reduction for cooling)
		Areas (Ha) and population (inhab) exposed to flooding
	Chemical indicators (water quality)	**Drinking water provision (m3 ha-1year-1)**
		Water for irrigations purposes (m3 ha-1year-1)
	Economic indicators (benefits)	**Volume of water removed from water treatment system**
		Volume of water slowed down entering sewer system
Challenge 4	Social indicators (benefits)	**Accessibility (measured as distance or time) of urban green spaces for population (Tamosiunas et al., 2014).**
		Weighted recreation opportunities provided by Urban Green Infrastructure (Derkzen et al. 2015)
	Environmental (biological)	**Production of food (ton/Ha/year)**
		Increased connectivity to existing GI
		Pollinator species increase (number)
Challen	Environmental (chemical)	**Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted) concentration recorded ug/m3**
		Trends in emissions NOX, SOX

CH	TYPE OF INDICATOR	KPI DEFINITION
	Economic	**Monetary values: value of air pollution reduction; total monetary value of urban forests including air quality, run-off mitigation, energy savings, and increase in property values. use of GI val to calculate the value of air quality improvements**
	Social (physiological)	**Number of deaths from air, water and soil pollution and contamination (proposed indicator for SDG target 3.9)**
		Air quality parameters NOx, VOC, PM etc
Ch 6	Urban green indicators (environmental, biological)	**Accessibility: distribution, configuration, and diversity of green space and land use changes (multi-scale ;). - Green spaces quantity**
	Socio-cultural indicators	**Savings in energy use due to improved GI**
Ch 7	Social	**Perceptions of citizens on urban nature - Green spaces quality**
C h	Social Cohesion	**Green intelligence awareness.**
Challenge 9	Psychological indicators (Relaxation and restoration, sense of place, exploratory behaviour, socializing).	**Noise reduction rates applied to UGI within a defined road buffer dB(A) m-2 vegetation unit**
	Health indicators related to ecosystem service provision (Buffering of noise and air pollution, reduced heat, exposure to microflora).	**Increase in walking and cycling in and around areas of interventions**
Ch	Economic	**Number of jobs created; gross value added**

Table 6. Core KPIs list of URBAN GreenUP project.

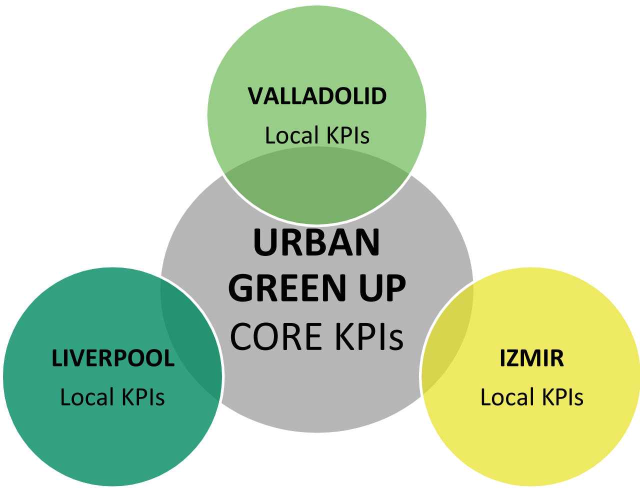


Figure 21. Infographic of the URBAN GreenUP KPIs.

Additionally, each city selected local KPIs for a better impact assessment of its NBS.

Valladolid local KPIs:

- kWh y^{-1} and t C y^{-1} saved.
- Flood peak reduction. Increase in time to peak (%).
- Reduction of drought risk (probability).
- Intercepted rainfall (m^3 $year^{-1}$).
- Share of green areas in zones in danger of floods (%).
- Population exposed to flood risk (% per unit area).
- Nutrient abatement, abatement of pollutants (%, nutrient load, heavy metals). (Chemical Oxygen Demand (COD) (mg/L); Biochemical Oxygen Demand (BOD) (mg/L); Total Solids (SST) (mg/L)).
- Distribution of public green space – total surface or per capita.
- Recreational (number of visitors, number of recreational activities) or cultural (number of cultural events, people involved, children in educational activities) value.
- Sustainability of green areas.
- Quality of life for elderly people.
- Perceptions of connectivity and mobility.
- Mean levels of exposure to ambient air pollution (population weighted) (proposed indicator for SDG target 3.9).
- Assessment of typology, functionality and benefits provided pre and post interventions.
- Openness of participatory processes.
- Legitimacy of knowledge in participatory processes.
- Crime reduction through police reports and local authority data.
- Number of subsidies or tax reductions applied for (private) NBS measures[58].
- New businesses attracted and additional business rates[59].
- Consumption benefits: property betterment and visual amenity enhancement resulting from NBS[60].

Liverpool Local KPIs:

- Measurements of gross and net carbon sequestration of urban trees based on calculation of the biomass of each measured tree (i-Tree Eco model), translated into avoided social costs of CO_2 emissions (USD t-1 carbon).
- Use of Star Tools to calculate projected maximum surface temperature reduction.
- Run-off coefficient in relation to precipitation quantities (mm/%).
- Nutrient abatement, abatement of pollutants (%, nutrient load, heavy metals). (Chemical Oxygen Demand (COD) (mg/L); Biochemical Oxygen Demand (BOD) (mg/L); Total Solids (SST) (mg/L)).

[58] Meulen, S. et al. Vergoedingen voor ecosysteemdiensten, 2013.
[59] Economics for the Environment Consultancy (Eftec). Green Infrastructure's contribution to economic growth: a review. A Final Report for DEFRA and Natural England, London, 2013.
[60] Tyler, P. et al. Valuing the benefits of urban regeneration. Urban Stud. 50, 169–190, 2013.

- Recreational (number of visitors, number of recreational activities) or cultural (number of cultural events, people involved, children in educational activities) value.
- Increase in density and seasonal spread of floral resources for pollinators.
- Increase in plant species richness and functional diversity as a result of NBS.
- Number of deaths from air, water and soil pollution and contamination (proposed indicator for SDG target 3.9).
- Assessment of typology, functionality and benefits provided pre and post interventions
- Savings in energy use due to improved GI.
- Perceptions of citizens on urban nature- green spaces quality[61,62,63,64,65].
- Crime reduction through police reports and local authority data.
- Perceptions of health and quality of life.
- Change in mean or median land and property prices (Forestry Commission, 2005). LIV WORDING: Changes in mean house prices/rental markets.
- New businesses attracted and additional business rates (Eftec, 2013). LIV WORDING: Increased returns of business rates with NBS.

Izmir Local KPIs[66]:

- Measures of human comfort e.g. ENVIMET PET — Personal Equivalent Temperature, or PMV — Predicted Mean Vote.
- KWh/y and t C/y saved.
- Energy, water and carbon reduction via urban farming (Climate-smart Greenhouse).
- Increase in shadow surface (m^2)
- Distribution of public green space – total surface or per capita[67,68,69].
- Annual mean levels of fine particulate matter (e.g. $PM_{2.5}$ and PM_{10}) in cities (population weighted) concentration recorded $\mu g/m^3$.
- Pollutants removed by vegetation (in leaves, stems and roots) (kg ha^{-1} $year^{-1}$).

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[61] Buchel, S. et Frantzeskaki, N. Citizens' voice: A case study about perceived ecosystem services by urban park users in Rotterdam, the Netherlands. Ecosyst. Serv. 12, 169–177, 2015.
[62] Colding, J., Barthel, S. The potential of "Urban Green Commons" in the resilience building of cities. Ecol. Econ. 86, 156–166, 2013.
[63] Gerstenberg, T., Hofmann, M. Perception and preference of trees: A psychological contribution to tree species selection in urban areas. Urban For. Urban Green. 15, 103–111, 2016.
[64] Scholte, S.S.K. et al. Integrating socio-cultural perspectives into ecosystem service valuation: A review of concepts and methods. Ecol. Econ. 114, 67–78, 2015.
[65] Vierikko, K., Niemelä, J. Bottom-up thinking—Identifying socio-cultural values of ecosystem services in local blue–green infrastructure planning in Helsinki, Finland. Land Use Policy 50, 537–547, 2016.
[66] The number of KPIs selected depends on the NBS typology and expected impact in each city. Izmir KPIs list cover most of core KPIs even when the total number is smaller than in the other two cities.
[67] Badiu, D.L., et al. Is urban green space per capita a valuable target to achieve cities' sustainability goals? Romania as a case study Ecol. Indic. 70, 53–66, 2016.
[68] Gómez-Baggethun, E., Barton, D.N. Classifying and valuing ecosystem services for urban planning. Ecol. Econ. 86, 235–245, 2013.
[69] La Rosa, D., Spyra, M., Inostroza, L. Indicators of cultural ecosystem services for urban planning: A review. Ecol. Indic. 61, 74–89, 2016.

- Perceptions of citizens on urban nature - Green spaces quality.
- Urban green spaces per capita
- Urban Farming Educative/ participate activities, Learning for producers.

The use of the framework within the URBAN GreenUP project and KPIs are described fully in different deliverables of the Project such as D2.3, D3.3, D4.3, D5.1 and D5.3. The framework is populated with data for the three front-runner cities in the Project, for example, **Table 7**, provides information on the Challenges that are being addressed by the different types of NBS in one of the demonstration areas in Liverpool (Baltic Corridor demonstration area).

LIV Sub demo A NBSs	CODE	CODE of each CHALLENGE													
		CH1		CH2		CH4			CH5			CH6	CH7	CH9	CH10
		CH0103	CH0107	CH0201	CH0218	CH0403	CH0411	CH0412	CH0502	CH0504	CH0507	CH0601	CH0704	CH0902	CH1003
Re-naturing urbanization															
Arboreal Interventions	Lac5	X	X	-	X	X	X	-	-	-	-	-	-	X	-
	Lac6	X	X		X	-	X	-	-	-	-	X	-	-	-
Green Route	Lac1	-	-	-	-	X	X	-	X	X	-	-	-	X	-
Resting Areas	Lac-add1	-	X	X	X	-	X	-	X	X	-	-	X	-	X
Water Interventions															
Green pavements	Lac10	X	X	X	X	-	X	-	-	-	-	X	X	-	-
Flood actions	Lac4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUDs	Lac8	X	X	X	X	-	X	-	-	-	-	X	X	-	-
Singular GI															
Pollinators	Lac12	X	X	X	X		X	X				X			
	Lac13	X	X				X	X	X	X			X		
Smart Soils	Lac11	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Horizontal GI	Lac16	X	X	X	-	-	X	-	-	-	-	X	-	-	-
	Lac-add2	-	X	-	X	-	X	-	X	X	X	-	-	-	-

Table 7. NBS types and related KPIs for Baltic Corridor in Liverpool demonstration.

It is possible to show the links between the Eklipse monitoring framework and the mapping work to identify the green infrastructure functionality and the areas of need or greatest need to tackle the challenges identified in a city or municipality.

Appendix 4 Bringing together function and needs mapping with the Eklipse framework (based on work for Liverpool City Region), provides a full table from which Figure 22: Extract from Appendix 2 showing function and need mapping for challenge for challenge **indicators** is an extract.

CHALLENGES	TYPE OF INDICATORS	KPI NAME	Example of mapping Green Infrastructure Function	Example of mapping Green Infrastructure Need
CHALLENGE 1: Climate mitigation & adaptation	Carbon savings per unit area (environmental, chemical) Carbon storage and sequestration in vegetation and soil	Ton C02 CARBON REMOVED per Ha		
	Temperature reduction (environmental, physical)	TEMPERATURE DECREASE	Evaporative cooling	Urban Lower Layer Super Output Areas with >500 population with limiting long-term illness, >30% population aged 65+ (male) or 60+ (female), or >25% population aged 0 - 15
	Energy and carbon savings from reduced building energy consumption (environmental, physical)	kWh savings per year	Wind shelter	
	Other	SPECIES MOVEMENT	Corridor for Wildlife/Habitat for Wildlife	Use of Condatis[70] or similar habitat connectivity mapping

Figure 22: Extract from Appendix 2 showing function and need mapping for challenge for challenge indicators.

There are other tools available that may assist in developing thinking about the impacts, outputs, outcomes and impacts. For example; an evaluation of tools to assess green infrastructure carried out by Natural England can be found here;

[70] http://wordpress.condatis.org.uk/

http://publications.naturalengland.org.uk/publication/6264318517575680. It provides links to a variety of tools and describes the positive and negative aspects of each tool.

The partnership developing the RUP may wish to create a bespoke monitoring framework, based on existing local examples or an entirely new framework. There are also recognised frameworks that could be used alongside which a logic chain could be used.

For example, some projects may choose to set their targets within the context of the Sustainable Development Goals[71]. For example, NBS may be seen to provide for good health (goal 3), clean water (goal 6), reduced inequalities (goal 10) etc.

Figure 23: Sustainable Development Goals (SDGs).

In this case, using the Sustainable Development Goals, the development of the logic chain is to add the target from the monitoring framework.

Target	Challenge	NBS Intervention	Description	Output	Outcome	Impact(s)
SD Goal 13 Climate Action	Increased flood risk due to climate change.	SUDs	Use of designed and targeted NBS to reduce water volume and slow water in the drain system	Reduction in water volume in system (quantified) Slowing of flow through system	% Reduction in flood risk	Reduced costs of flood clean up, improved quality of life for residents, better quality of place

Table 8. Example of using SDGs in developing a login chain to think about impact of NBS.

[71] https://www.un.org/sustainabledevelopment/sustainable-development-goals/

4 Linking Zoning to Urban GreenUP's Scenarios Tool

This short section considers the role of zoning and mapping in the context of the development of a Scenario Tool that is part of the Urban GreenUP project outputs.

The URBAN GreenUP NBS generation tool, as a part of the evaluation method for NBS scenarios definition, is a base guide to evaluate different city NBS scenarios sets. In consequence, it allows the selection of one or several NBS alternatives previously identified, working in an integrated way, and solving possible city problems holistically.

Combining the mapping concept into this supporting tool will help in the visualization of possible impacts city may experience during and after of the renaturing process, also it may help to anticipate the possible barriers to overcome into the wilder city context.

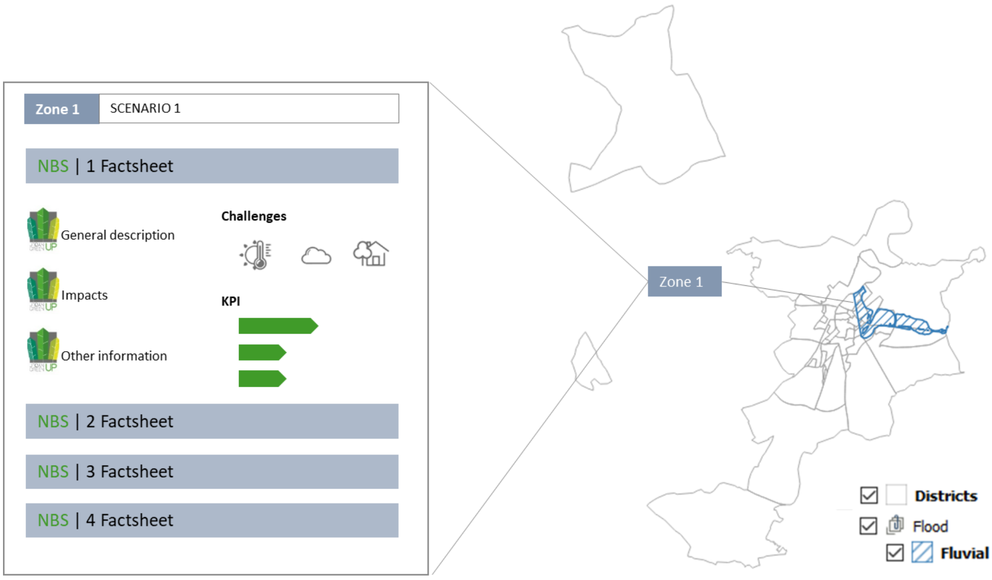

Figure 24: Mapping and Zoning relationship for the RUP.

Mapping and scenario tools development can be included at different stages:

1. Analysis and selection of NBS according to challenges selected by a city
   The selection of challenges and assignment of weights made by the user, based on the mapping carried out to zone the city or area, will pass through the matrix obtaining a score for each NBS proposed. NBS with the highest score suggested as outputs, could be potentially mapped over the zones of the cities where pinch points have been identified.

2. Analysis and selection of NBS according to city barriers and boundaries.
   The evaluation of the impact of the potential limits and barriers on the NBS will aliment the previous analysis. A double entry matrix will assign the level of the risk and probability of occurrence to each barrier, also will help to identify the requirement for NBS

implementation. The geographic distribution of barriers and boundaries to NBS will form part of the Zoning approach.

3. City Scenarios visualisation and selection. KPIs assignation.
   As the final step, the city potential scenarios can be visualised depending on different contexts and line of actions adopted. The KPIs indicators can be than prioritize to each scenario, and monitoring plan adopted and distributed by city specific zones. This can be used for both assets and pinchpoints.

4.1 How to implement it?

At different levels of city renaturing analysis, different levels of tool development may be considered:

- Baseline Questions to be answered

	PHASE1	PHASE2	PHASE 3	PHASE4
METHODOLOGY STEP	Map Challenges	Get Spatial Priorities	Adopted Solutions	Expected Impact
THE OBJECTIVE	To identify the areas of need, depending on different Challenges and Sub-challenges to be achieved	To visualize the Boundaries and the Barriers associated with the City by identifying and visualizing the Pinch Points and Assets	To present the NBS selected crossing the Aspects Defined in Phases 1 and 2,	To establish the evaluation rules (monitoring) or to visualize the potential impact to be achieved
ASPECTS TO BE CONSIDERED	By Challenge and Sub-challenge	By 5 types of Barriers Agreed	By NBS or NBS groups	Value impact of KPIs or KPIs groups agreed
THE QUESTION TO BE ANSWERED	How to divide the space?	How to establish limits and constraints?	How to present the Solutions Adopted?	How to evaluate the expected impact?

Table 9: Scenarios Tool Matrix including Mapping Aspects at different Methodology Steps and Phases.

- Zoning constraints

	PHASE1	PHASE2	PHASE 3	PHASE4
ZONING	**Defined by District/City Zone/Street or emerging Pinch Point and Assets** **List of Pinch Points and Assets associated** **Matrix list to the Challenges and Barriers**		NBS list linked to the challenges selected previously and listed and visualized in Scenarios Tool (T1.6)	KPIs list linked to the NBS selected previously

Table 10: Scenarios Tool Matrix including Mapping Aspects at different Methodology Steps and Phases.

- The mapping potential and GIS tools to be considered

	PHASE1	PHASE2	PHASE 3	PHASE4
MAPPING	Linked **GeoServer,** or **gvSIG** externally Not linked directly, external GIS visor Supported by **Geospatial Libraries** and **Google Earth** linked		Listed or/and visualized in **Scenarios Tool (T1.6)** **Supported by Google Earth linked**	

Table 11: Scenarios Tool Matrix including Mapping Aspects at different Methodology Steps and Phases.

- Linked guides and deliverables from the Urban GreenUP project.

	PHASE1	PHASE2	PHASE 3	PHASE4
LINKED TASKS	D1.2 Societal Challenge Catalogue	D1.5 Barriers and Boundaries	D1.6 Scenarios Support Tool, Matrix CH vs NBS vs Barriers	WP5 KPIs Catalogue

Table 12: Scenarios Tool Matrix including Mapping Aspects at different Methodology Steps and Phases.

5 Conclusion

This guide provides a resource to use to help cities zone areas, to target NBS to areas where they can be most effective, have most likelihood of being implemented and where need is greatest. All cities and municipalities face complex choices, the use of data to help zone areas of need can help to inform choices and support policy.

Involving communities as well as experts in zoning assures people that robust data is being used and that the needs of people are being taken into account.

Zoning has a long history in land use planning. In this guide we briefly looked at approaches that have been taken in EU and non EU countries; some of the benefits of zoning and some of the limitations. There are specific limitations to consider when zoning for NBS. Assessing existing habitat and it functionality, ensuring that the right growing conditions are available and have a sound plan for managing NBS are important considerations.

The increasing availability of data and power of Geographic Information Systems means that it becoming easier to collate, analyse and interpret data that can help to zone areas of challenges for a city, or direct NBS resources to areas of need.

Pinch Points and Assets mapping has been a useful tool in identifying zones in the Liverpool City Region. Other cities across the world have developed or are developing techniques for zoning, but there is no consistent approach that is being used, even at a strategic level and not even within countries.

The Renaturing Urban Plan is an important output from the Urban GreenUP project. It will help to support cities that wish to incorporate greater amounts of NBS into their towns and cities. The RUO has four distinct phases, with zoning playing an important role in each phase.

The RUP can start to provide a framework for a more consistent approach to zoning and the assessment of NBS in towns and cities.

6 Appendix 1 Mapping Assets and Pinch Points

Based on work that has been carried out to map Assets and Pinch Points in the Liverpool City Region, the following sections provide some ideas/guidance on how functionality has been described for the purposes of mapping and zoning in the city region.

These are provided for information, each city in developing their RUP will want to assess how it might map and zone based on the types of green infrastructure and its functions locally.

This will be informed by local discussion. The examples from a range of cities in the Urban GreenUP project may also inform these local discussions. See Appendix 5 Further examples of challenge mapping

The functions have been linked to the Eklipse framework of challenges in Appendix 4 Bringing together function and needs mapping with the Eklipse framework (based on work for Liverpool City Region).

6.1 Functionality

As described in the main text of this guide 'Functionality' determines which polygons within the green infrastructure mapping currently perform which functions, which again comes from the general methodology for Liverpool City Region. The functions are defined below, which references confirming that green infrastructure can perform them where necessary and available.

6.1.1 Recreation – public

Anyone can use for recreational purposes (formal/informal and active/passive), without having to pay or have access to keys. Can include areas which are closed at night, on specific days, or seasonally but a judgement call will be required as to whether this restricts public use. Can include sports fields, fishing lakes, playgrounds, etc. and open access land.

6.1.2 Recreation – private

Land which is used for recreation but only by owners of the land or those invited by the owners to use. This includes private gardens and other privately-owned green spaces to which access for the public is prohibited.

6.1.3 Recreation public – with restrictions

Public use for recreational purposes (formal/informal and active/passive) is allowed but is restricted to those who pay or have keys. Can include sports fields, golf courses, fishing lakes, allotments, etc., but not public rights of way.

6.1.4 Green travel route

Off road routes through greenery for pedestrians and cyclists (for recreational purposes as well as for getting between places), can include public rights of way, Sustrans, and private routes which are not on roads. Useful in urban areas and often located close to large centres of population. Also includes the green infrastructure which surrounds green travel routes, making them an attractive alternative route.

6.1.5 Shading from sun

Shading of people, buildings, and surfaces from solar radiation to reduce temperatures and increase comfort levels. Usually provided by trees and taller plants and vegetation. Particularly found in urban areas to reduce the urban heat island, this function will become more critical as we have to adapt to a changing climate. Green infrastructure which provides shade will also be important for protecting agricultural land and other species from solar damage.

6.1.6 Evaporative cooling

As plants transpire water is evaporated from their surfaces cooling their immediate locality. All types of green infrastructure can provide this function, including open water. Plants with a larger leaf area are likely to be better than those with a smaller leaf area. During a drought, irrigation is likely to be necessary to maximise this function in plants, whilst open water will continue to be valuable in its own right.

6.1.7 Trapping air pollutants

Removal of pollutants, especially ozone, nitrogen dioxide and particles from the air, through uptake via leaf stomata and deposition on leaf surfaces. Once inside the leaf, gases diffuse into intercellular spaces and may be absorbed by water films to form acids or react with inner leaf surfaces. This function is usually associated with more urban areas, especially close to travel routes.

6.1.8 Noise absorption

Screening of noise, especially from major transport routes. Requires certain types of green infrastructure which are tall enough to incept and absorb sound waves. This function is usually associated with more urban areas, especially close to travel routes.

6.1.9 Habitat for wildlife

Providing a habitat for wildlife – a place to live with a source of food. Different types of green infrastructure will provide habitats for a widely different range of species. The range of species will also be dependent on other factors such as climate and disturbance.

6.1.10 Corridor for wildlife

Conduit of green and blue spaces through which wildlife can disperse to and from habitat spaces. This function will increase in importance in the future; species will need the capacity to move upwards and northwards as the climate changes. Connectivity is vital for this function. Different types of green infrastructure will provide a corridor for a widely different range of species. Range of species will also be dependent on other factors such as climate and disturbance.

6.1.11 Heritage

Historic links in the landscape (including ancient woodlands, canals, designated sites and monuments). Heritage is "that which is inherited".

6.1.12 Cultural asset

Green space used for cultural purposes, the hosting of public art, events and festivals. Examples include international garden festivals and sculpture parks.

6.1.13 Carbon storage

Removing carbon from the atmosphere and storing it in plants, trees and soils. Trees and peat soils are particularly important types of green infrastructure for storing carbon. Varying types of green infrastructure will take different amounts of time to sequester carbon; some types of green infrastructure are slow growing in nature and therefore will take longer to sequester carbon. Stored carbon in trees will stay locked away inside the wood if felled for material substitution.

6.1.14 Food production

Land used for growing crops or the grazing of animals.

6.1.15 Timber production

Growing trees and woodlands for timber. Includes for use as a substitute for other materials. Can be on a large scale for construction materials or a smaller scale for smaller wood products. Stored carbon in trees will stay locked away inside the wood if felled for material substitution.

6.1.16 Wind shelter

Green infrastructure can provide shelter from winds at a local level by slowing or diverting currents.

6.1.17 Learning

Opportunities for lifelong learning. Green infrastructure can provide a backdrop for outdoor classrooms and learning outside of the indoor school environment, and also a setting for learning new skills that may help adults back to work.

6.1.18 Inaccessible water storage

Water stored in soils and vegetation. Certain types of sustainable urban drainage systems and soils will store large amounts of water. Certain soils such as clay and peat will store more water than others. This water is inaccessible for human use or for irrigation.

6.1.19 Accessible water storage

Water stored in ponds, lakes, reservoirs and certain wetlands. This water is accessible for human use and for irrigation should it be required.

6.1.20 Water interception

Interception of rainwater before it reaches the ground, e.g. by the leaves of trees and plants. This will slow the flow of water to the ground. All types of green infrastructure will intercept water in some way, though certain types with a greater leaf area will intercept a greater amount and slow its flow to greater extent. This can help to reduce the risk of flooding.

6.1.21 Water infiltration

Vegetation and roots aid in the movement of rainwater and floodwater into the ground. Green infrastructure will help water to drain naturally into the soil. Includes both surface infiltration and deep infiltration. Green infrastructure is a permeable surface as opposed to hard surfacing such as concrete. It aids in the natural passage of water to the ground – helping reduce the risk of flooding.

6.1.22 Coastal storm protection

Green infrastructure can be used to protect infrastructure and agriculture close to the shore. It can protect against winds, sea spray and slow the speed and impact of waves and large tidal surges. Could include areas of woodland and marsh.

6.1.23 Water conveyance

Green infrastructure can transport water to areas which need water and also away from areas at risk of saturation or flooding. Examples include rivers and canals. Irrigation ditches in agricultural land are another example of water conveyance.

6.1.24 Pollutant removal from soil/water

Vegetation can remove pollutants from soil and water. For example, green infrastructure at the side of the road can clean contaminated road runoff (reducing concentrations of pollutants such as heavy metals), and certain plants can remove pollutants from contaminated soil.

6.1.25 Flow reduction through surface roughness

The speed and amount of water passing through a site can be reduced by vegetation. If the site has a varied green topography as opposed to hard standing, water will be retained onsite for longer, potentially helping to reduce flooding. Some types of green infrastructure perform this function more than others – for example, a woodland floor tends to be rougher than grass.

7 Appendix 2 Mapping Needs

When assessing "need" in a city a threshold is required to be able to assess those areas where there is a challenge to be dealt with, compared to those areas where there is no/less challenge.

For any of the challenges, there will be a continuum in the scale of the challenge to be faced. Choosing where to draw the line to identify the level at which the need is deemed to be a challenge can be complicated. However, it is necessary in order to be able to zone a city. It can get even more complicated if there are large areas of a city that face a particular challenge. In this instance a further refinement might be to identify areas of "greatest need".

For example, in a city with extensive flood risk, covering much of the city, greatest need maybe where flood frequency might be highest and/or where impact on businesses, homes and communities is deemed to be greatest.

For some challenges there may be guidance data that can be used to set these thresholds for need and greatest need. For example, for air quality we can use EU guidance on levels of NOx or PM2.5 to identify areas of need.

For other challenges and in identifying areas of greatest need, it may be that arbitrary, but informed, thresholds are used.

The following table explains how greatest need was mapped for some of the functions in work that was carried out by Mersey Forest team in Liverpool City Region[72]. If using this approach, cities will come up with their own thresholds based on local data and the expertise of the participants in the development of the RUP. Whilst some of the data described in the table below and the notes below the table are UK focused, the principles applied, the types of data and the approach taken are likely to be useful in other countries and municipalities.

FUNCTION	THRESHOLDS
Recreation - public	Reverse Access to Natural Green Space Standard score > 8 or percentage households without a car >70% or Index of Multiple Deprivation health score >2.5 or percentage population aged 0 - 15 >25% or main town centre
Recreation - private	Reverse Access to Natural Green Space Standard score > 8 or percentage households without a car >70% or Index of Multiple Deprivation health score >2.5 or percentage population aged 0 - 15 >25% or main town centre

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FUNCTION	THRESHOLDS
Recreation - public with restrictions	Reverse Access to Natural Green Space Standard score > 8 or percentage households without a car >70% or Index of Multiple Deprivation health score >2.5 or percentage population aged 0 - 15 >25% or main town centre
Green travel route	Population movement gradient >70°
Aesthetic	100m buffer of key gateways, 25m buffer of main roads, railways and canals
Shading from sun	Lower Layer Super Output Areas with population density >10,000km^{-2} in, 2014 or 2024, >500 population with limiting long-term illness, >30% population aged 65+ (male) or 60+ (female), or >25% population aged 0 - 15, 100m buffer of schools, main town centres
Evaporative cooling	Urban Lower Layer Super Output Areas with >500 population with limiting long-term illness, >30% population aged 65+ (male) or 60+ (female), or >25% population aged 0 - 15
Trapping air pollutants	Population density >5,000km^{-2} in 2014 or 2024 and Core Biodiversity Areas, both within 100m of motorways or A roads
Noise absorption	Population density >5,000km^{-2} in 2014 or 2024 within 30m of motorways, A roads or railways
Habitat for wildlife	Core Biodiversity Areas, Connectivity Zone
Corridor for wildlife	Connectivity Zone
Soil stabilisation	Slope >4° or Flood Zone 3 or 'sandy' soil
Heritage	50m buffer of existing heritage functionality
Cultural asset	Population density >7,000km^{-2} in 2008, 2014 or 2024
Carbon storage	Everywhere equal
Food production	Best and most versatile agricultural land
Timber production	5km buffer of potential timber station sites
Biofuels production	1km buffer of areas with energy use >50GWh/km^2

FUNCTION	THRESHOLDS
Wind shelter	Average wind speed >5.5m/s at 10m above ground level
Learning	Population density >7,000km^{-2} in 2014 or 2024, 100m buffer of educational establishments
Inaccessible water storage	Upstream of urban historic flooding
Accessible water storage	Upstream of urban historic flooding, 100m buffer of most multifunctional green infrastructure, 100m buffer of best and most versatile agricultural land
Water interception	Upstream of urban historic flooding
Water infiltration	Upstream of urban historic flooding
Coastal storm protection	Population density >1,000km^{-2} in 2014 or 2024 within 500m of the coast
Water conveyance	Downstream of urban historic flooding, best and most versatile agricultural land
Pollutant removal from soil/water	Best and most versatile agricultural land
Flow reduction through surface roughness	Upstream of urban historic flooding

Figure 25 Thresholds for identification of need.

The reverse Access to Natural Green Space Standard (ANGSt) score was calculated as follows.

- Estimated population figures for 2014 (last census) were obtained from the Office for National Statistics.
- Housing projection figures for 2014 and 2024 were obtained from Merseyside Information Service and used to estimate population figures for those years.
- Focal statistics calculations were run on population densities for each of the three years to each of the four distances quoted in the ANGSt[73] documentation (300m, 2km, 5km and 10km).
- The twelve resulting datasets were added together with equal weighting.

[73] http://publications.naturalengland.org.uk/file/83065 - Presents the findings of a project which looked at English Nature's natural greenspace standards model in order to determine whether its validity could still be supported, how local authorities were managing greenspace policy and how the standards might be promoted effectively in the new and changing policy environment. The project aimed to build on work published in English Nature Research Report No. 153, Accessible Natural Greenspace in towns and cities – a review of appropriate size and distance criteria (1995).

The population movement gradient used a hydrological model as an analogy for the movement of people through the city region. Centres of population (both present and future) were made analogous to mountain peaks, and destinations (schools and centres of employment) were made analogous to low points in the terrain. A surface was interpolated and areas of greatest slope were considered to be where the greatest numbers of people would want to travel. This implies a bias towards short-range travel, which is the primary role of green travel routes.

8 Appendix 3 - Further information about zoning in New York

From 1916 onwards New York was engaged with a process of urban renewal that attempted to address public health, housing and transport issues following extensive periods of immigration. This prompted the rise in influence of Robert Moses who promoted the new urban typology of "tower-in-the-park" locating high density housing in urban the urban core of New York (Yunda & Jiao, 2019). Although associated with the promotion of ecological, i.e. in Staten Island Greenbelt and Richmond Parkway, Moses remains associated with planning for vehicular access and zoning across New York City (Nugent, 2016).

Robert Moses (1888–1981) was an urban planner and public administrator who worked in New York City and for the State of New York between the 1920s and the 1960s. Moses is considered the architect of the motorised city laying out plans to locate an extensive highway system in the heart of New York. He was responsible for the planning and construction of a great deal of the metropolitan area's modern transportation infrastructure, public housing and urban renewal projects, and projects including the UN Headquarters, Lincoln Center, and the World's Fairs of 1939 and 1964 (Ross, 2019).

The legacy of Moses in New York can be seen in a spatially unequal distribution of resources. Although he and his team zoned for the provision of housing, transport infrastructure and recreational facilities, i.e. parks across the city, there is a view that a greater proportion and a high quality set of resources were located in affluent and "white" neighbourhoods (i.e. of the 255 playgrounds zoned in New York only 1 was located in Harlem, a high density working class and African-American neighbourhood (Checker, 2011). Zoning was therefore used to manage the location of resources and for some commentators to limit access to essential urban infrastructure. This was discussed by Charles Abrams who noted that:

"…the kind of "order" that Moses's vision of urban renewal created: displacement of the poor, rampant discrimination against minorities, and homogeneity of neighbourhood" (Walker, 2012:315).

Moses subsequently worked Sao Paulo, Brazil, where the promotion of zoning via "industrial facilities, offices, hosing, leisure and other public and private concerns" across the city, and helping to create one of the most congested articulations of urban form in Latin America (da Silva Leme, 2010:519). However, as in New York aspects of ecological zoning were included in these plans including a renewed purpose of the city's canal to help structure zoning, and a continuous network of public and quasi-public spaces within the city. The articulation of these plans though were subsumed within the drive to promote automative movement across the city.

Checker, M. (2011) Wiped Out by the “Greenwave”: Environmental Gentrification and the Paradoxical Politics of Urban Sustainability. City & Society, 23, 2, 210-229.

da Silva Leme, M.C. (2010) Transforming the modern Latin American city: Robert Moses and the International Basic Economic Corporation. Planning Perspectives, 25, 4, 515-528.

Nugent, P. (2016) From the Richmond Parkway to the Staten Island Greenbelt: The Rise of Ecological Zoning in New York City. Journal of Planning History, 16, 2, 139-161.

Ross, E.S. (2019) Moses, Robert. In: Orum, A.M. (Ed.). The Wiley Blackwell Encyclopaedia of Urban and Regional Studies. Wiley

Walker, P. (2012) Charles Abrams vs. Robert Moses: Contested Rhetorics of Urban Housing. Rhetoric Review, 31, 3, 289-308.

Yunda, J.G. & Jiao, J. (2019) Zoning changes and social diversity in New York City, 1990–2015. Journal of Urbanism: International Research on Placemaking and Urban Sustainability, 12, 2, 230-243.

9 Appendix 4 Bringing together function and needs mapping with the Eklipse framework (based on work for Liverpool City Region)

The following table provides some guidance, based on the Pinch Points and Assets work carried out in Liverpool City Region, on how function and need might be mapped in a city or municipality against indicators in the Eklipse Framework. This type of mapping has been used to inform local policy and project delivery and influenced other strategies. However, these are simply examples, local knowledge and data may mean that different approaches are taken.

As described in the main document, it is essential that robust data and methodologies for mapping and analysing data are used.

CHALLENGES	TYPE OF INDICATORS	KPI NAME	Example of mapping Green Infrastructure **Function**	Example of mapping Green Infrastructure **Need**
CHALLENGE 1: Climate mitigation & adaptation	**Carbon savings per unit area** (environmental, chemical) **Carbon storage and sequestration in vegetation and soil**	**Ton C02 CARBON REMOVED per Ha**		
	Temperature reduction (environmental, physical)	**TEMPERATURE DECREASE**	**Evaporative cooling**	**Urban Lower Layer Super Output Areas with >500 population with limiting long-term illness, >30% population aged 65+ (male) or 60+ (female), or >25% population aged 0 - 15**
	Energy and carbon savings from reduced building energy consumption (environmental, physical)	kWh savings per year	Wind shelter	
	Other	**SPECIES MOVEMENT**		**Use of condatis or similar**

CHALLENGES	TYPE OF INDICATORS	KPI NAME	Example of mapping Green Infrastructure **Function**	Example of mapping Green Infrastructure **Need**
			Corridor for Wildlife/Habitat for Wildlife	**connectivity mapping**
CHALLENGE 2: Water Management	**Physical indicators**	RUN-OFF COEFFICIENT		
		FLOOD PEAK REDUCTION	Water interception/water infiltration/coastal storm protection	Upstream of urban historic flooding/ Population density >1,000km-2 in 2008, 2014 or 2024 within 500m of the coast
		DROUGHT RISK REDUCTION	inaccessible water storage/accessible water storage	Upstream of urban historic flooding, 100m buffer of most multifunctional green infrastructure, 100m buffer of best and most versatile agricultural land
		ABSORPTION CAPACITY (m^3/m^2)	Water interception/water infiltration/coastal storm protection	Upstream of urban historic flooding, 100m buffer of most multifunctional green infrastructure, 100m buffer of best and most versatile agricultural land
		ABSORPTION CAPACITY (m^3/tree)	Water interception	Upstream of urban historic flooding
		WATER SLOWED DOWN FROM SEWER SYSTEM	water conveyance/Water interception/water infiltration/coastal storm protection	Downstream of urban historic flooding, best and most versatile agricultural land
		TEMPERATURE REDUCTION		

CHALLENGES	TYPE OF INDICATORS	KPI NAME	Example of mapping Green Infrastructure **Function**	Example of mapping Green Infrastructure **Need**
		INTERCEPTED RAINFALL	Water interception/water infiltration/coastal storm protection	Upstream of urban historic flooding
	Spatial	GREEN AREAS IN FLOOD RISK		
		AREA (Ha) EXPOSED TO FLOOD RISK		
	Chemical indicators (water quality)	NUTRIENT ABATEMENT (COD)	Pollutant removal from soil/water	Best and most versatile agricultural land (we think this a weak criteria)
		NUTRIENT ABATEMENT (BOD)	Pollutant removal from soil/water	Best and most versatile agricultural land (we think this a weak criteria)
		NUTRIENT ABATEMENT (SST)	Pollutant removal from soil/water	Best and most versatile agricultural land (we think this a weak criteria)
	Socioeconomic indicators	POPULATION EXPOSED TO FLOOD RISK DRINKINGWATER PROVISION		
		IRRIGATION WATER PROVISION		
		WATER REMOVED FROM THE WATER TREATMENT		
		SAVINGS IN TREATMENT OF STORMWATER		
CHALLENGE 4: Green Space Management	**Social indicators** (benefits)	GREEN SPACE DISTRIBUTION (m2/capita)	recreation private/Public	Reverse Access to Natural Green Space Standard score > 8 or percentage households without a car >70% or Index of Multiple

CHALLENGES	TYPE OF INDICATORS	KPI NAME	Example of mapping Green Infrastructure **Function**	Example of mapping Green Infrastructure **Need**
				Deprivation health score >2.5 or percentage population aged 0 - 15 >25% or main town centre
		GREEN SPACE DISTRIBUTION (km cycle lane/capita)	recreation private/Public	
		GREEN SPACE ACCESSIBILITY	recreation private/Public	
		PEOPLE LIVING WITHIN 300 m TO GREEN AREAS		
		PEOPLE LIVING WITHIN 10KM TO GREEN AREAS		
		RECREATIONAL VALUE		
		ELDERLY PEOPLE LIFE QUALITY		
		GREEN INFRASTRUCTURE CONNECTIVITY	Green Travel routes	Population movement gradient >70°
		CONNECTIVITY PERCEPTION		
		GREEN AREAS SUSTAINABILITY		
		FOOD PRODUCTION	Food production	Best and most versatile agricultural land
	Environmental (biological)	POLLINATOR SPECIES INCREASE	Habitat for wildlife	Core Biodiversity Areas, Connectivity Zone
		FLORAL RESOURCES INCREASE	Habitat for wildlife	Core Biodiversity Areas, Connectivity Zone
		PLANT SPECIES INCREASE	Habitat for wildlife	Core Biodiversity Areas, Connectivity Zone
		INSECTIVORE INCREASE	Habitat for wildlife	Core Biodiversity Areas, Connectivity Zone

CHALLENGES	TYPE OF INDICATORS	KPI NAME	Example of mapping Green Infrastructure **Function**	Example of mapping Green Infrastructure **Need**
CHALLENGE 5: Air Quality	**Social** (physiological)	DEATHS RELATED TO POLLUTION AND CONTAMINATION		
		ANNUAL MEAN LEVELS OF FINE PM2.5 PARTICULES	Trapping air pollutants	Population density >5,000km^{-2} in 2008, 2014 or 2024 and Core Biodiversity Areas, both within 100m of motorways or A roads
		ANNUAL MEAN LEVELS OF FINE PM10 PARTICULES	Trapping air pollutants	Population density >5,000km^{-2} in 2008, 2014 or 2024 and Core Biodiversity Areas, both within 100m of motorways or A roads
		NOx TRENDS		
		Sox TRENDS		
		VOC TRENDS		
		MEAN LEVELS OF EXPOSURE TO AIR POLLUTION		
		POLLUTANT REMOVED BY VEGETATION	Trapping air pollutants	Population density >5,000km^{-2} in 2008, 2014 or 2024 and Core Biodiversity Areas, both within 100m of motorways or A roads
		AIR QUALITY PARAMETERS CO		
		AIR QUALITY PARAMETERS O3		

CHALLENGES	TYPE OF INDICATORS	KPI NAME	Example of mapping Green Infrastructure **Function**	Example of mapping Green Infrastructure **Need**
		AIR QUALITY PARAMETERS C6H6		
		AIR QUALITY PARAMETERS ICA		
	Economic	Run-off mitigation	Water interception/Water infiltration	Upstream of urban historic flooding
		Energy savings		
		Increase in property value		
		GI val to calculate the value of air quality improvements		
		Value of air pollution reduction		
		Total monetary value of urban forests including air quality		
CHALLENGE 6: Urban Regeneration	**Spatial**	GREEN SPACE QUANTITY		
	Socio-cultural indicators	BENEFITS FROM INTERVENTIONS		
	Economic	ENERGY SAVINGS RELATED TO GREEN INFRASTRUCTURE		
CHALLENGE 7: Participatory Planning and Governance	**Social**	OPENNESS		
		PARTICIPATORY LEGITIMACY		
		SOCIAL LEARNING	Learning/heritage	Population density >7,000km^{-2} in 2008, 2014 or 2024, 100m buffer of educational establishments
		CITIZEN PERCEPTION	Cultural Asset/heritage	
		URBAN FARMING ACTIVITIES	food production	

CHALLENGES	TYPE OF INDICATORS	KPI NAME	Example of mapping Green Infrastructure **Function**	Example of mapping Green Infrastructure **Need**
CHALLENGE 8: Social Justice and Social Cohesion	**Social justice**	CRIME REDUCTION		
	Social cohesion	GREEN INTELLIGENCE AWARENESS (EDUCATIONAL ACTIONS)	learning/cultural asset/heritage	Population density >7,000km^{-2} **in 2008, 2014 or 2024**
		GREEN INTELLIGENCE AWARENESS (INHAB. ATTENDED)		
CHALLENGE 9: Public Health and Well-being	**Psychological indicators** (Relaxation and restoration, sense of place, exploratory behaviour, socializing).	NOISE REDUCTION	Noise reduction	Population density >5,000km^{-2} **in 2008, 2014 or 2024 within 30m of motorways, A roads or railways**
	Health indicators related to ecosystem service provision (Buffering of noise and air pollution, reduced heat, exposure to microflora).	WALKING AREA INCREASE	Green travel route	Population movement gradient >70°
		CYCLING AREA INCREASE	Green travel route	Population movement gradient >70°
		HEALTH QUALITY PERCEPTION		
CHALLENGE 10: Potential of economic opportunities and green jobs	**Economic**	SUBSIDIES		
		TAX REDUCTION		
		JOB CREATION		
		LAND AND PROPERTY PRICE CHANGE		
		NEW BUSINESSES		
		CONSUMPTION BENEFITS		
		JOB CREATION		

Table 13: Mapping Need and Function against Eklipse Framework work indicators.

10 Appendix 5 Further examples of challenge mapping

Valladolid

The following section provides examples from Valladolid of mapping that can be used as the basis for zoning. The selection shows the range of mapping that might already be available in towns and cities to help with zoning. It also shows the variety of mapping that might be considered in developing zoning.

Water management: Mapping for water management is likely to feature in most work to zone for Nature Based Solutions. The following maps show areas of the city that are at risk of flooding. NBS can be used in conjunction with traditional engineering to help reduce flood risk, these maps help to identify where the risks are likely to be in the city.

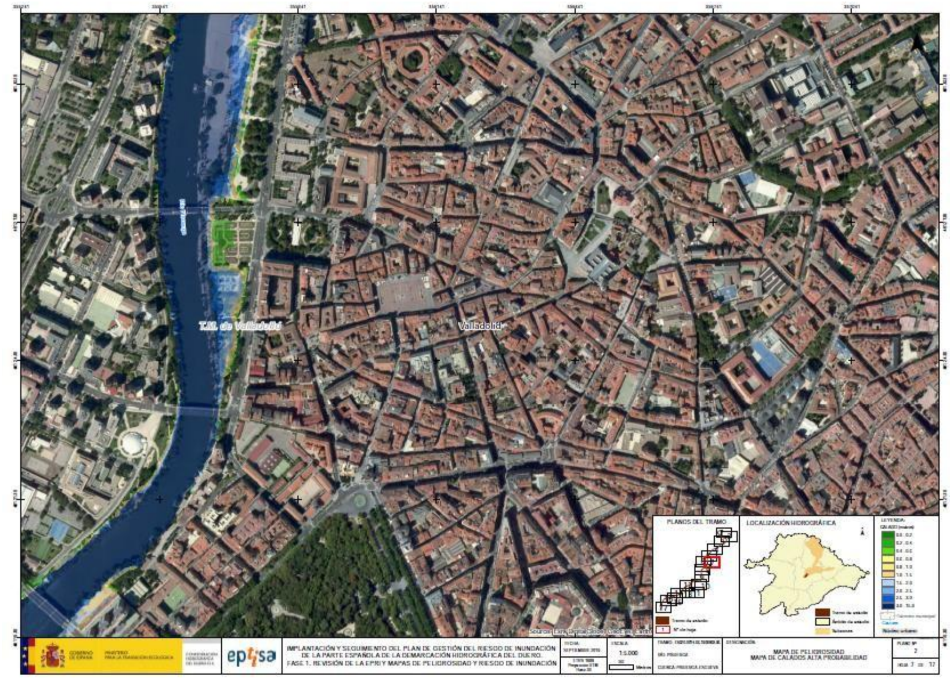

Figure 26: "Pisuerga river in Valladolid". Flood Hazard and Risk Maps. 2019. River Duero Basin

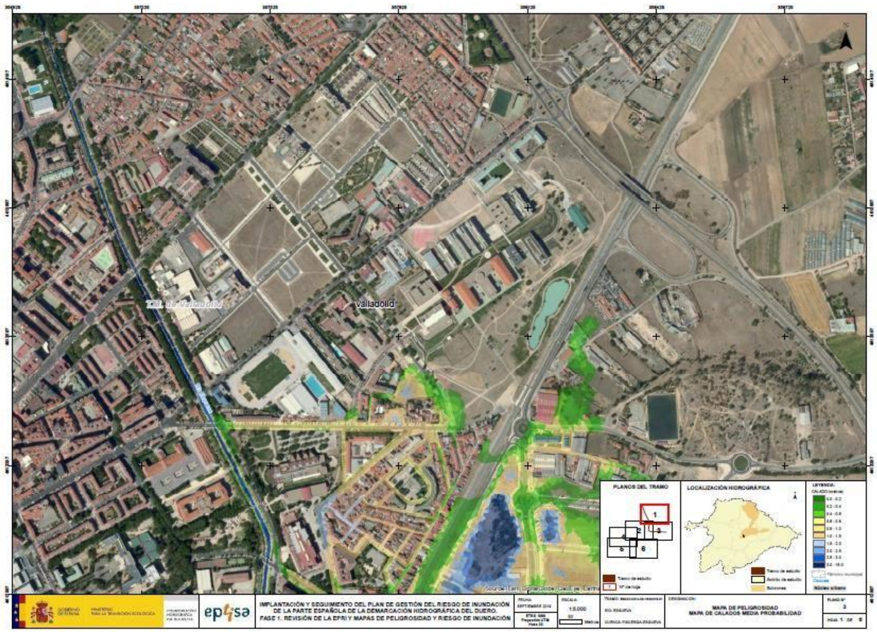

Figure 27: “Esgueva river in Valladolid”. Flood Hazard and Risk Maps. 2019. River Duero Basin.

Sustainable Mobility: Increasing focus on active travel will mean that walking and cycling networks will also feature in many RUPs. Mapping suitable routes, perhaps linking areas of housing to amenities such as shops and schools as well as places of work can help to focus the role of NBS to support active travel. In the following maps new bike and walking route are identified.

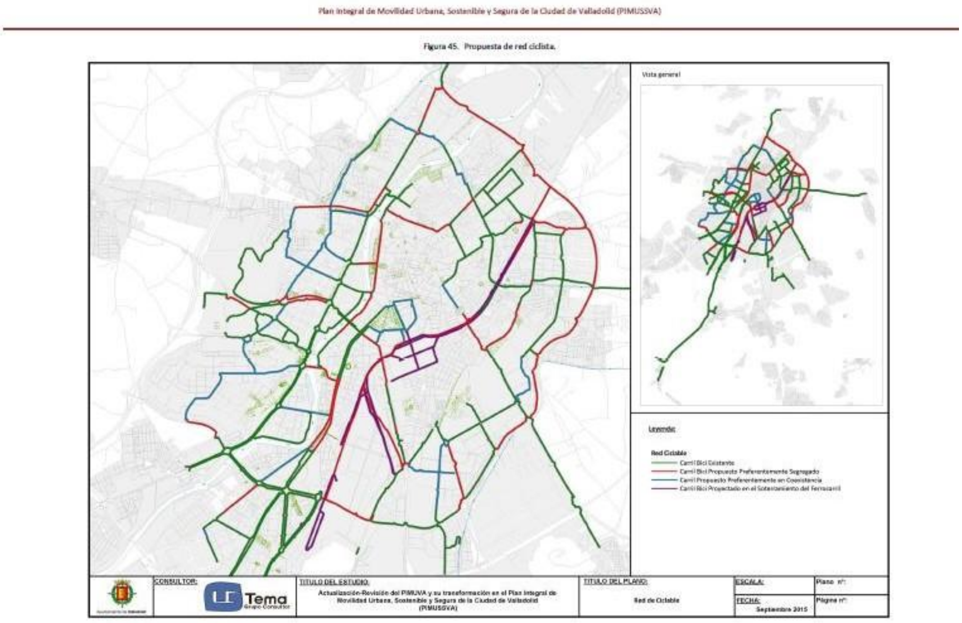

Figure 28: "Proposed bike lane network". Comprehensive Plan for Sustainable Mobility of Valladolid. 2015. Valladolid City Council.

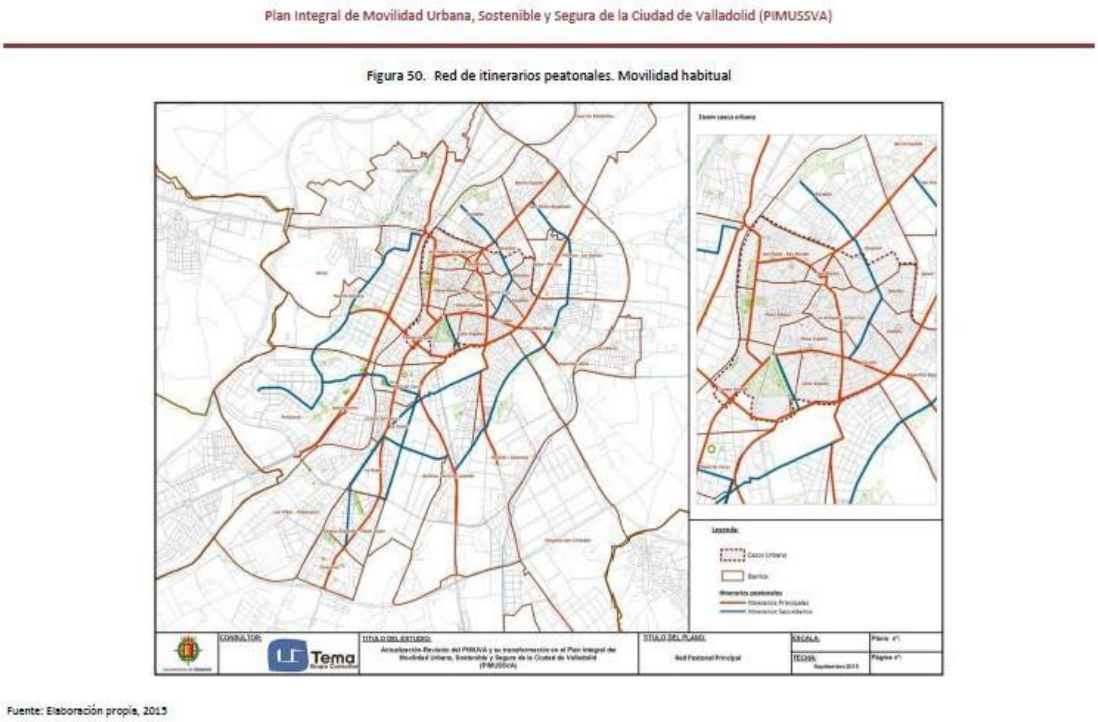

Figure 29: "Walking areas". Comprehensive Plan for Sustainable Mobility of Valladolid. 2015. Valladolid City Council.

An update to these Sustainable Mobility Plans is currently in progress. This new program is named "Valladolid Ciudad Verde: Red de vías sostenibles" or "Valladolid Green City: Network of sustainable roads". The programme aims to increase cycle lanes and pedestrian walkways in the city. This highlights the need to stay closely aligned with key partners who may be updating plans and policies. Decisions about NBS should be based on the most up to date information available.

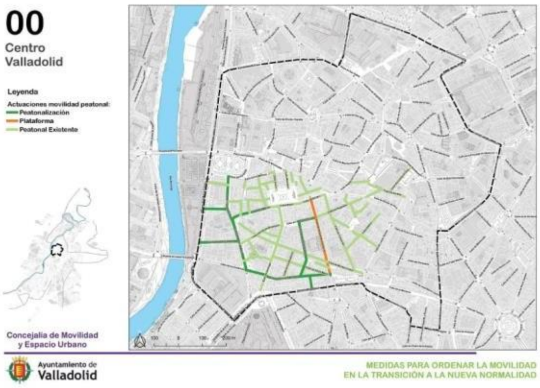

Figure 30: Valladolid Green City: Network of sustainable roads. Pedestrianisation of the city centre streets. May 2020

Noise map:

Mapping of noise in a city can help to target NBS that can reduce noise, improving the quality of place and wellbeing of residents.

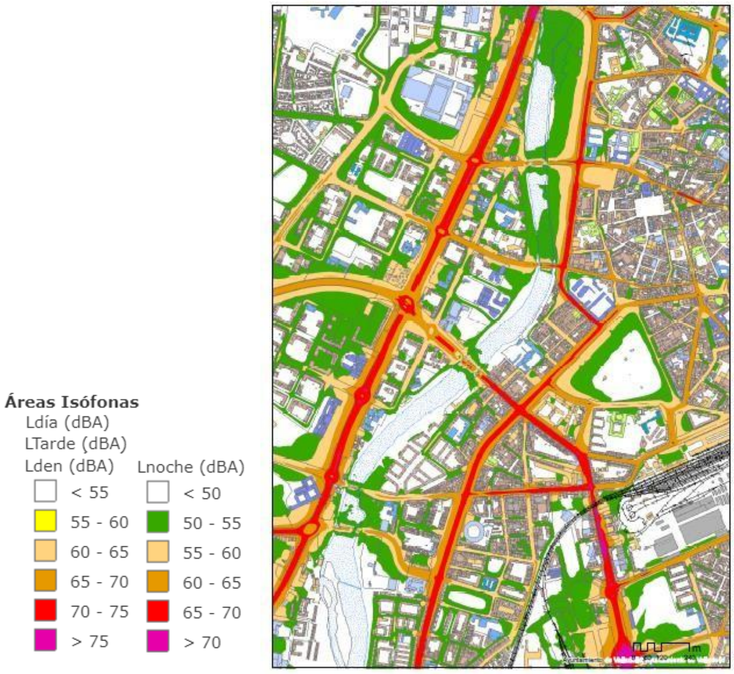

Figure 31 Light noise levels in Valladolid city centre". Noise map of Valladolid. 2018. Valladolid City Council.

Fear Map

This map identifies the risk areas in Valladolid, where the gender perspective is included in the urban planning policy of the city. The initiative includes specific strategies that improve the safety of its inhabitants and, especially, women.

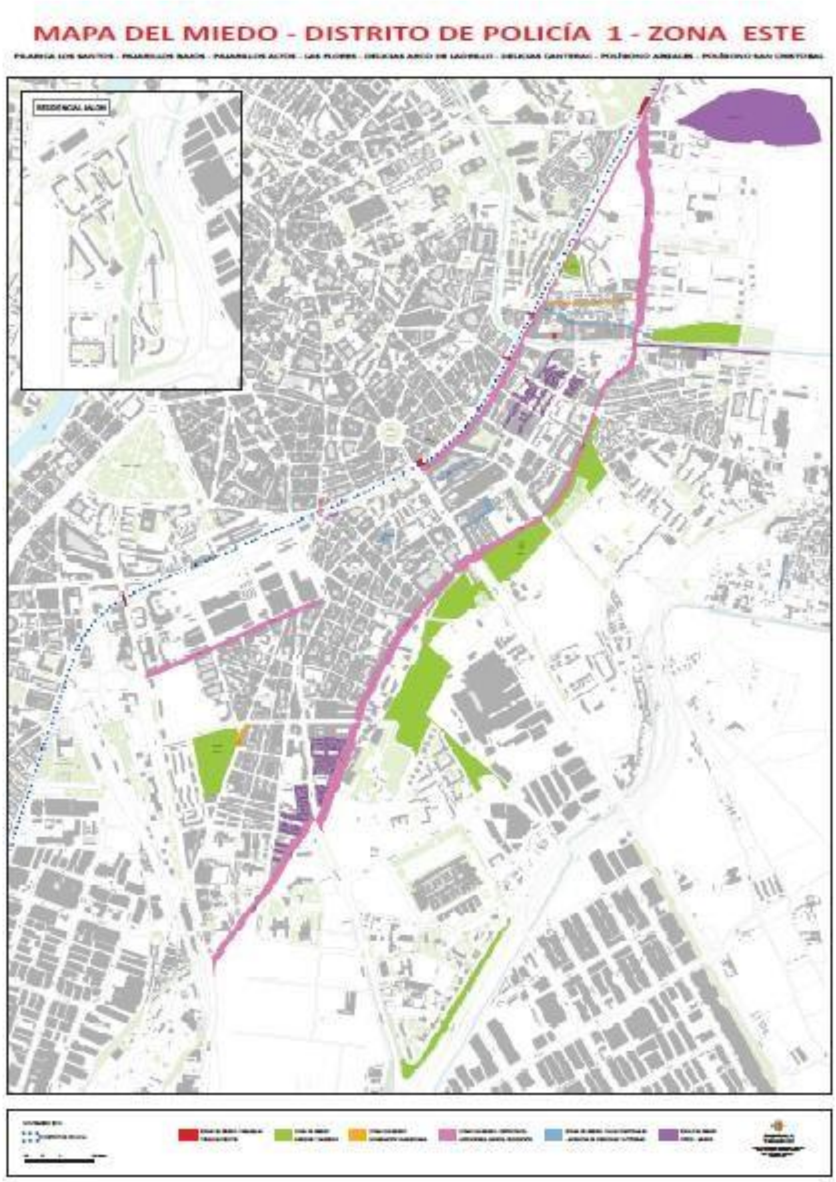

Figure 32: “Fear map”. 2019. Valladolid City Council -> Suggested view, page 5, City Centre.

Legend: Red (Walkway, tunnel, bridge), Green (park, garden), Orange (bad illumination), Pink (Elevator, wall, vegetation), Blue (Low people and activity presence), Violet (Other).

Vitoria-Gasteiz

Another example mapping from Sustainable Transport and Public Space Plan of Vitoria-Gasteiz (PMSEP) promotes sustainable transport ways avoiding the private vehicle through different measures:

- Restructuring of the bus network in coordination with the tram.
- The expansion of pedestrian areas, creating a safe and functional network of bicycle lanes.
- Configuration of a network of urban trails.

The Master Plan for Cycling Mobility and the Master Plan for Pedestrian Mobility foresee reforms of major roads and streets.

The network of urban trails and bicycle lanes offers a high potential to be part of an Urban Green Infrastructure, introducing naturalisation and promoting green measures that guarantee its functionality both physically and ecologically.

One of the most ambitious proposals is the reorganisation of the private vehicle network through a superblock-based urbanisation model, in which pedestrian and cycling transport will be preferred. This measure will suppose a reduction in traffic and the recovery of a more accessible, comfortable public space, continuous and safe in which it is possible to apply new greener urban designs.

Figure 33: Planning for Sustainable transport with urban green infrastructure.

Ludwigsburg

Ludwigsburg has a GIS System for the municipality. There are two versions of the System. One version is accessible for Public and one is only for internal use. The public version is available here: https://klima.ludwigsburg.de.

For the preparation of the RUP in Ludwigsburg one important basis will be the climate analysis (see Stadtklimaanalyse 2019 in the public version) these map shows which parts of the city are expected to show heat stress. In these areas NBS will become more important. Mapping also shows the danger of flooding (see Umwelt --> Wasserschutz --> Hochwassergefahrenkarte).

Using an internal GIS System, the city can use multiple layers of data to identify areas in the city with challenges. The internal GIS System also contains information about the land owners of different parts of the city and we information about special development plans for specific areas (zones). Both sets of information are important for the identification of locations for NBS.

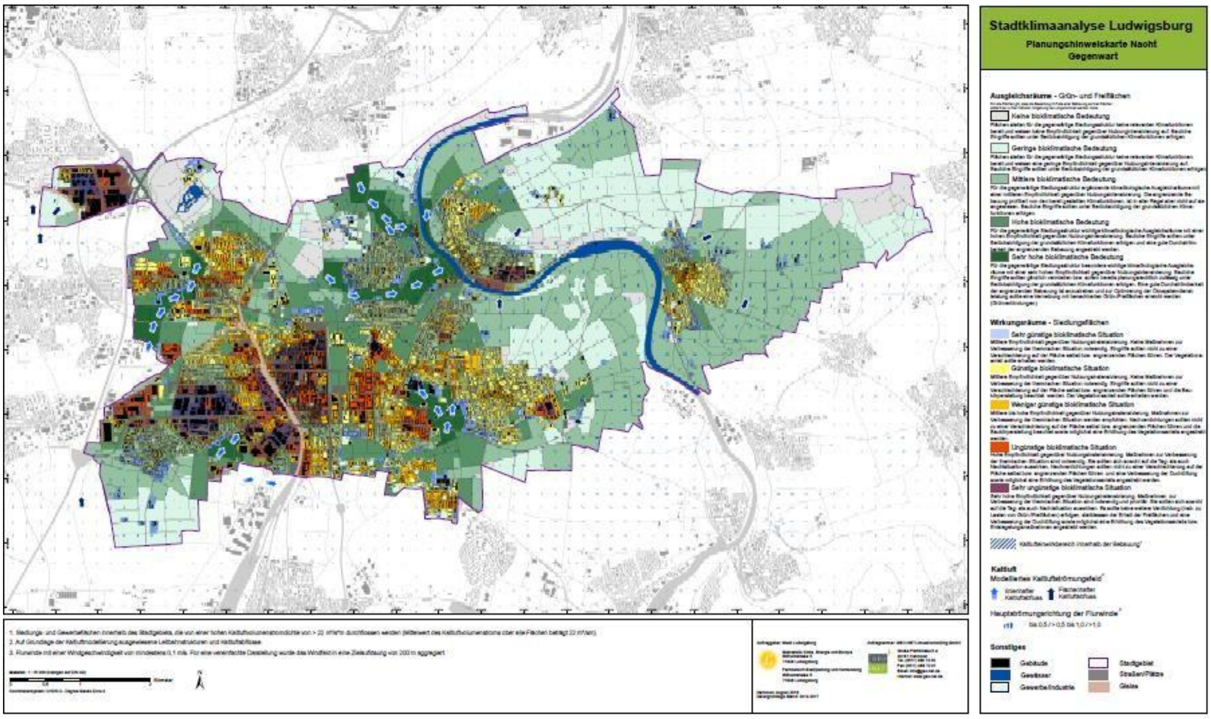

Figure 34: Extract Climate Analysis Map, Ludwigsburg, situation at night.

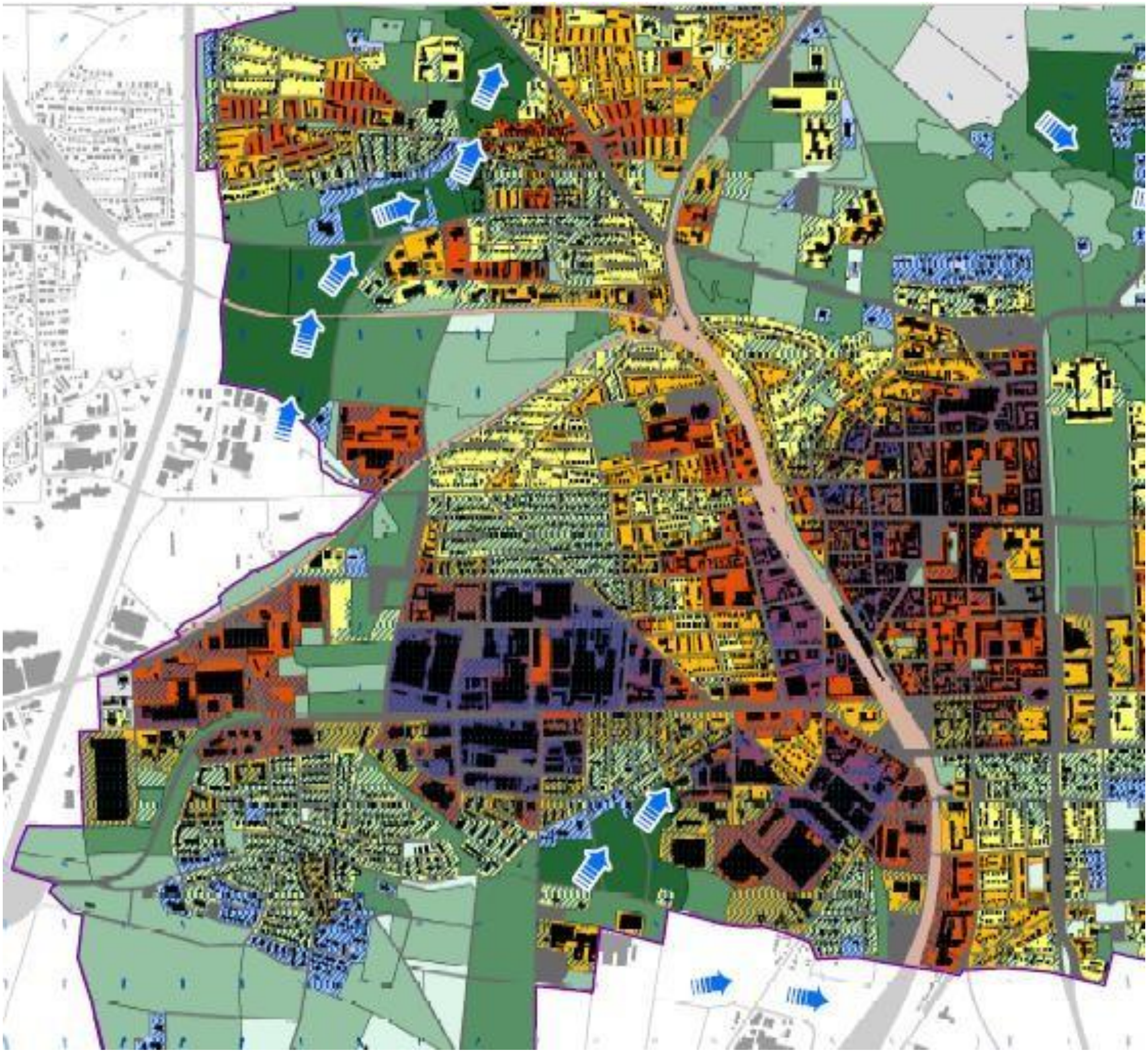

Figure 35: Extract Climate Analysis Map, Ludwigsburg, situation at night.

MANTOVA - Zoning for climate adaptation

Mantova has also mapped challenges related to climate change using cutting edge technology. Approaches developed during the development of Climate Adaptation Guidelines aimed to define assessment methodologies for vulnerability to the impacts of heat waves and extreme weather events (heavy rains). To ensure this, numerous assessments were carried out to gather data through new information technologies (ICT). This work was supported by IUAV University of Venice. Specifically, to make up for the lack of information such as soil permeability, temperature, etc., innovative data (provided by AeroDron S.r.l.) has been used. The provided data was taken from a survey with latest generation drones, which produced 4-band orthophotos (RGBI) with a 20 cm per pixel definition and the height of the urban elements, also with a of 20 cm per pixels definition (Digital Surface Model, DSM).

The city wanted to look at quantitative assessments of vulnerability, as they can effectively answer questions, such as "how resilient is it?", "which part of the territory is the most vulnerable?".

Mantova analyzed the presence or absence of green infrastructure in the city as one of the quantitative indicators for resilience of the urban fabric in a changing climate. Particularly in response to extreme precipitation, thanks to the filtering and absorption properties of the soil, the permeable surfaces significantly contribute to the water collection and to prevent its rapid flow outflow in urban areas.

The initial phase of the work was therefore based on the production of an atlas of surfaces, that is an organized geo-database, with various vector data, which classify the different surfaces of the city into "permeable surfaces" and "waterproof surfaces". Non-permeable surfaces have been further classified into:

- gravel
- concrete / asphalt
- bare soil (green and artificial materials-free)

This further classification helped to define the useful variables for assessing vulnerability with respect to extreme meteoric events.

The starting data, obtained with aerial photogrammetric survey, made it possible to have a remote-sensing analysis, which classified the surfaces every 20 cm. The analysis, possible thanks to new geo-spatial instruments, allowed the creation of different shape files for use in Arc GIS, typologically correct, essential for the assessment of vulnerability of the two considered impacts, but not available from the existing information base.

The new layers created were:

- surface with vegetation (including green ground and trees)

- buildings
- waterproof surface (gravel, red roof tiles, concrete, asphalt)
- surface temperature
- kWh roofs
- kWh ground surfaces
- Sky View Factor

Once the information levels necessary for the assessment of the vulnerability have been identified and their production process completed, all the useful information was included in a new geo-database, having as its geometric structure the census boundaries of Istat 2011 and the ability to structure and analyze data using commands in SQL.

Using the Istat database (INSTITUTE OF NATIONAL STATISTICS), further assessments were made, concerning the assessment of "social" vulnerability. The new indicators were:

- total population
- sensitive young population (<10 years)
- sensitive elderly population (> 65 years)

The geo-database is like a single entity, organized in a series of rows, which correspond to the different geometric extensions of Istat and a sequence of columns (definable as fields), containing the values relating to the information produced for that geometric Istat extension.

For each row, therefore for each portion of territory, data shows the quantity of vegetation in m^2, the percentage of vegetation in reference to the area, m^2 of waterproof surface, m^2 of buildings, average kWh / m^2 per roof, average kWh / m^2 per any horizontal surface on the ground, surface temperature and Sky View Factor (SVF).

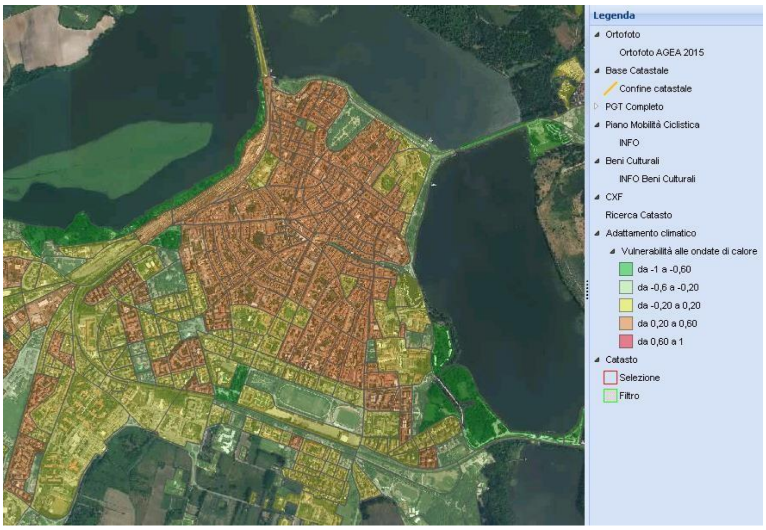

Figure 36: Heatwave vulnerability.

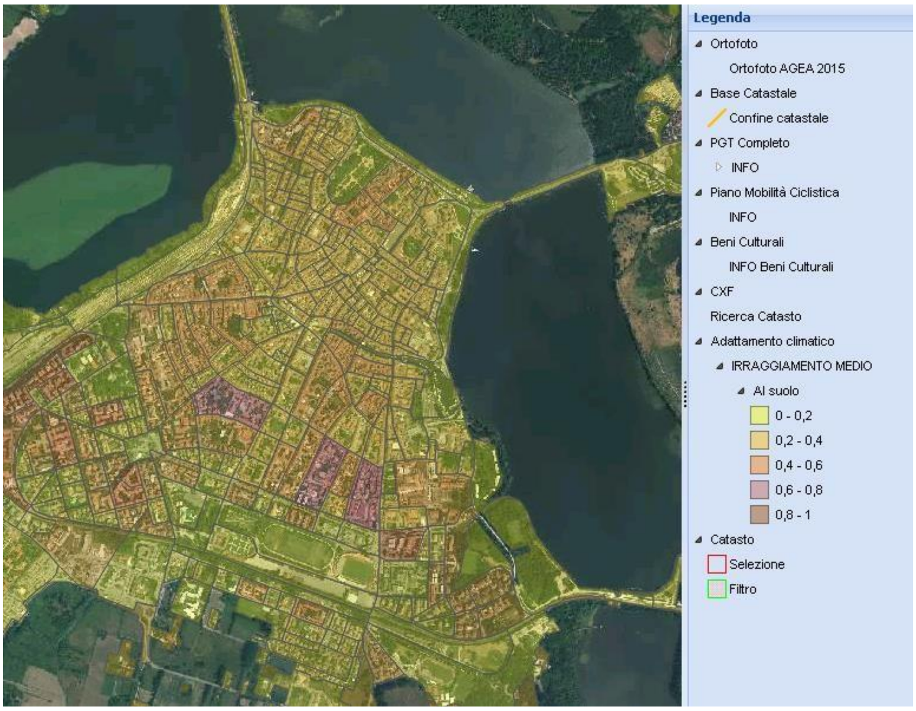

Figure 37: Ground potential radiation.

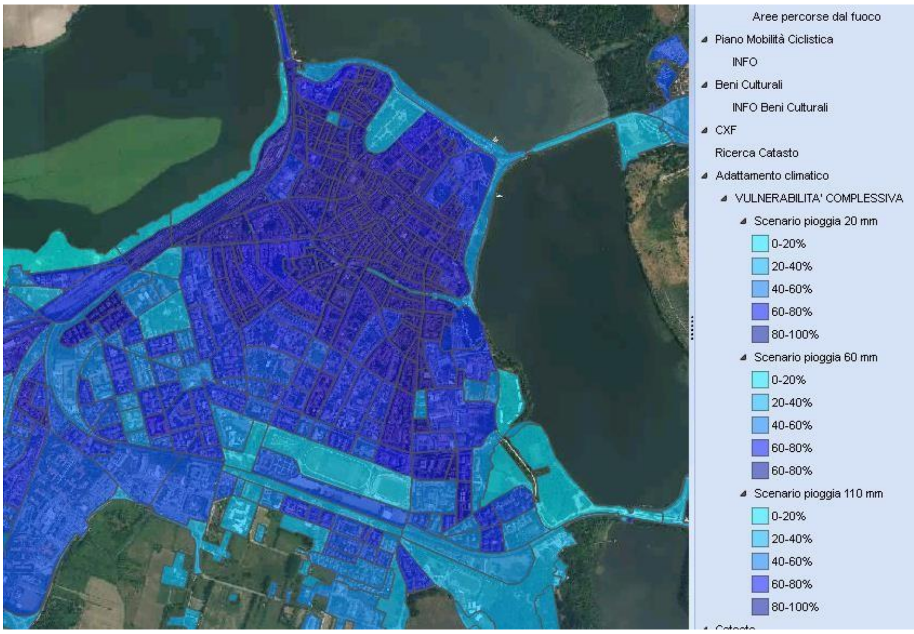

Figure 38: Run off vulnerability.

This data can be used to help zone the city and assist in the selection of NBS.