GRaBS Expert Paper 7

assessing vulnerability to climate change and adapting through green infrastructure

By Zuzana Hudeková

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Assessing Vulnerability and Using Green Infrastructure

GRaBS

The GRaBS (Green and Blue Space Adaptation for Urban Areas and Eco Towns) project is a network of leading pan-European organisations involved in integrating climate change adaptation into regional planning and development.

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GRaBS Expert Paper 5

assessing vulnerability to climate change and adapting through green infrastructure

By Zuzana Hudeková

Summary

This Expert Paper puts urban areas under the spotlight and asks: what can cities and towns actually do to assess their vulnerability to climate change, and how can they use green infrastructure to adapt accordingly?

Urban areas face higher temperatures and an increase in extreme weather events as the climate changes. People, places and buildings will be vulnerable to the effects of these changes – this Expert Paper explains how to assess such vulnerabilities, using the framework set out by the Intergovernmental Panel on Climate Change. Annex C reports on a project carried out in Bratislava, Slovakia, which has investigated how to identify the population's vulnerabilities.

Finally, the Paper identifies how green infrastructure could help to reduce the impact of these vulnerabilities. Planning has an important role to play in creating a framework in which incremental changes will add up to an overall environment that helps people to be more resilient to increases in temperature.

1 Introduction

Urban green spaces, as they are traditionally perceived, are parks, residential green spaces, avenues of trees, and urban or municipal forests. They play a recreational role for inhabitants of urban areas. In the broader sense, green spaces and open spaces are understood as a continuous matrix of interlinked natural spaces between buildings and other urban infrastructure. This matrix links the built-up area to its natural hinterland and surrounding landscape. At the same time, there are also nodes in this matrix that operate as a network of interconnected elements. Green spaces can thus be considered as an integrated set of components within a system rather than as separate, disconnected areas (see Annex B). Depending on where a component is located in relation to other spaces, it can play various roles and fulfil various functions.[1]

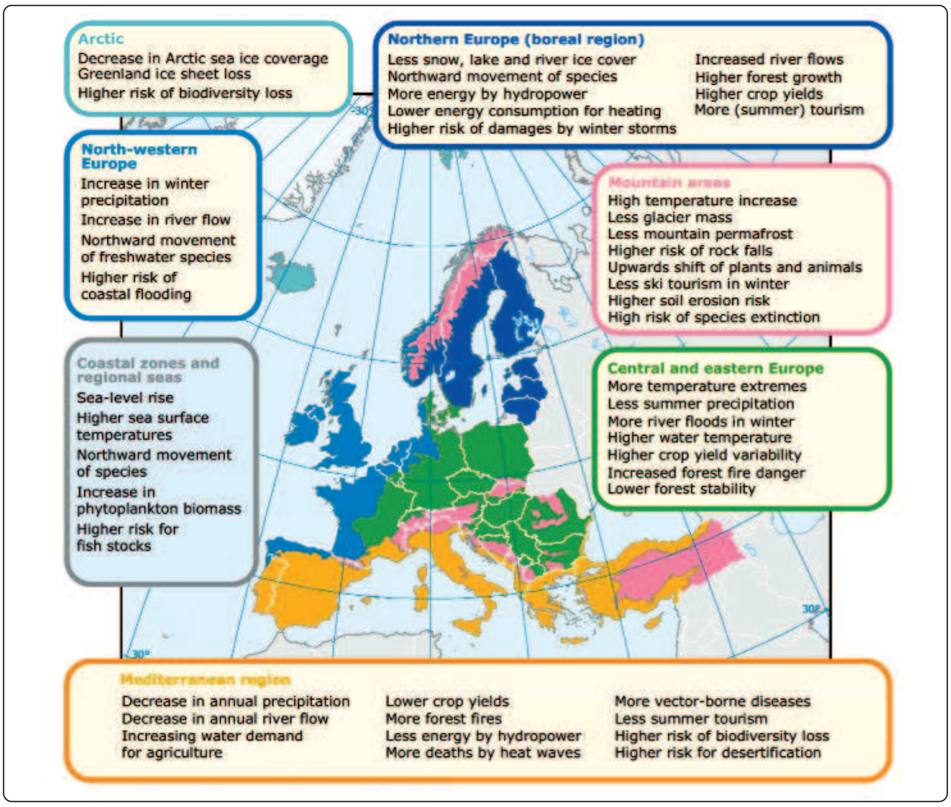
When defining the notion of 'green' or 'open' spaces, we are dealing with a broader notion of 'green infrastructure', a term which implies all the functions fulfilled by green spaces in urban areas. It is important to recognise that green infrastructure plays a role that is as vital as other types of infrastructure. When we consider climate change and its potential adverse consequences, the importance of green infrastructure grows.

1.1 Climate change, mitigation, and adaptation

Some consequences of climate change are already unavoidable, owing to previous greenhouse gas (GHG) emissions. The planet's average global temperature is now 0.7-0.8ºC higher than in the pre-industrial period. Even if GHG emissions were now already stabilised at year 2000 levels, it is estimated that the global temperature would still increase by 1.2ºC by the end of the 21st century compared with the pre-industrial period. An increase of 2ºC or more would lead to immense consequences in all areas of human life.[2]

1.2 How to respond to climate change?

There are two options in reacting positively to climate change: reduce GHG emissions (mitigation), and implement necessary adaptation measures in response to climate change's consequences. Mitigation is directly linked to the urgency with which we need to introduce adaptation measures, and to the scale of



Climate change – what we can expect in the major bio-geographic European regions

Source: European Environment Agency[4] their application. Successful mitigation of climate change would avoid increases in average temperatures in line with the IPCC worst-case scenarios. The higher the increase in average temperatures, the more significant will be the consequences – which will then require large-scale adaptation measures.

2
Consequences of climate change for urban areas

Climate change will affect all European regions, directly or indirectly – although to what extent will vary according to the location of an area and the adaptation measures it adopts. Consequences of climate change will be especially apparent in urban areas in the form of high summer temperatures and periods of drought and floods. Moreover, land use (and changes of use), uncontrolled urban growth, sealed surfaces and development on open spaces can all increase the risk of extremely high temperatures and floods, and can contribute to soil desiccation and shortages in drinking water supplies.

Summer heatwaves are considered to be the biggest problem for human health resulting from climate change. It is expected that their intensity, frequency and length will increase. It is estimated that in the EU countries an increase in temperature of 1ºC results in increases in mortality rates of 1-4%. During the 2003 heatwave, 70,000 people in 12 EU countries died from heat-related causes.[3] The EuroHeat project stresses the risk from the combined effect of air pollution and increased summer temperatures which exposes people to high concentrations of PM10 particulate matter and ground-level ozone – a risk that increases for people living in deprived areas.[3]

Urban environments differ from their natural surroundings in a number of ways, including average temperatures, humidity levels, and air and soil quality. It is expected that climate change will exacerbate these differences. The most important problems related to climate change in cities will include:

- increases in temperature (in the case of heatwaves, the heat in cities will be intensified by the urban heat island effect, whereby built-up environments absorb and retain more heat);
- significant reductions in relative air humidity;
- decreases in precipitation – with long periods of drought leading to a decline in soil quality (gradual desiccation, due, in particular, to increasing potential evapotranspiration and decreasing soil humidity);
- increases in storm precipitation and heavy rains, with greater likelihood of local flooding;
- windstorms and tornados;
- changes in natural ecosystems;
- changes in the geographic distribution of woody plants, and an unprecedented loss of biodiversity;[5] and
- landslides caused by intensive precipitation.

Climate change will affect almost all aspects of the environment. It will bring new challenges for living in cities, for the protection of human health, and for the conservation of biodiversity. Along with the projected adverse impacts set out above, it will be necessary to deal with problems with drinking water quality and new diseases.[6,7] Changes in natural ecosystems will affect the natural services that they provide.

3
Vulnerability to climate change, and the role of green infrastructure

The feeling or actual state of vulnerability encompasses, among other factors, concepts of potential loss; damage from or impacts of threats, risks and stress factors; uncertainty; and a lack of control or ability to manage. The starting point for understanding vulnerability to climate change is the IPCC (Inter-governmental Panel on Climate Change) definition set out on page 883 of the Fourth Assessment Report.[8] In the context of climate change, it is the most authoritative and widely quoted definition of vulnerability:

> ‘Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.’

This definition draws on three main concepts – exposure, sensitivity, and adaptive capacity:

vulnerability = function [exposure (+); sensitivity (+); adaptive capacity (-)]

- ***Exposure:*** Exposure means the 'degree to which a system is exposed to significant climatic variations'.[9] Changes in exposure are usually explored through climate models that show how, under certain assumptions, climate variables can change in time for a given area.

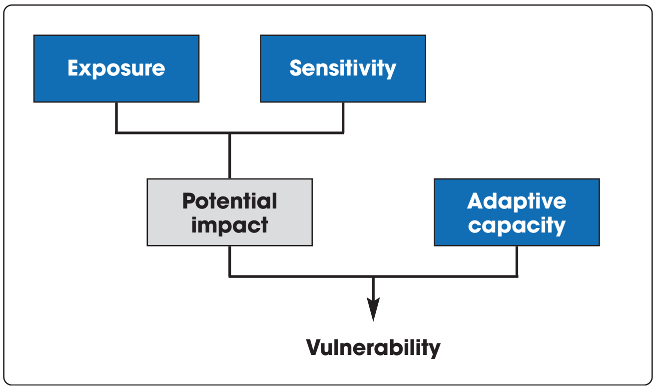
- ***Sensitivity:*** Sensitivity means the 'degree to which a system is affected, either adversely or beneficially, by climate-related stimuli'.[9] This takes account of the fact that different regions and groups will respond to the same event differently. When a region or a system is exposed to changes in climate, sensitivity determines the extent to which various receptors in the system are affected positively or negatively. An impact of climate change is a combination of the degree to which a system is exposed and the degree to which a system is sensitive to changes in climate variables (for example increased precipitation) and the consequences of these changes (for example increased occurrence of floods).

- ***Adaptive capacity:*** The third element of vulnerability according to the IPPC's definition is adaptive capacity – 'the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences'.[9]

3.1 How to measure vulnerability

After defining the system in question, a related challenge is how to measure vulnerability. When determining vulnerability it is necessary to bear in mind that we are measuring the vulnerability of 'something' (for example population, infrastructure, or natural ecosystems) to 'something' (such as flooding or a heatwave). Simultaneously, it is possible to evaluate current vulnerability as well as vulnerability to potential future threats that may result from climate change.[11]

An indicator of vulnerability can be provisionally defined as an observable variable indicating possible future damage that the system or subject in question faces.[12]



Conceptual relationship between exposure, sensitivity, adaptive capacity and vulnerability

Source: Adapted from 'Assessing vulnerabilities to the effects of global change: an eight step approach'[10]

3.2 What role is played by green spaces in calculating a city's vulnerability?

The vulnerability of cities depends to a great extent on how they have developed in the past and how they are developing now. Urban design, and especially the structure of a city, can increase the expected adverse impacts of climate change through the impermeability of surfaces and the urban heat island effect, which can also hamper the natural infiltration of rainwater.

The distribution, quantity and quality of green spaces and open spaces has a considerable affect on the vulnerability of:

- the population to extreme summer heat;
- natural ecosystems to long-term summer heat; and
- basic infrastructure, buildings and other services to flooding.

According to the IPCC:

- Assessing the vulnerability of the population to extreme summer heats means taking into account the distribution, quantity and quality of green infrastructure in a settlement.
- Assessing the vulnerability of natural ecosystems to long-term droughts means taking account of geographic mobility – the ability of species to move when droughts last.
- Assessing the vulnerability of basic infrastructure and other services to the threat of floods means taking into account not only the impact of a flood at any one location, but also the surrounding development density, the quantity and quality of green spaces, and the percentage of impermeable surfaces in public spaces.

Sensitivity means assessing:

- age, and physical and mental health (for populations);
- connectivity, health condition, and size (for ecosystems); and
- extent of the threat (for infrastructure and buildings).

Adaptive capacity is affected by various factors, such as:

- the availability of green spaces within a 300 metre walk, good healthcare, whether a heat plan exists or not, and access to climate change information (for populations);
- the scarcity of, and threats to, species, and/or insufficient diversity (for ecosystems); and
- the quantity of resources that can be invested in adaptation measures (for infrastructure and buildings).[11]

Annex C describes the findings of a pilot study in Bratislava that assessed the vulnerability of selected populations to extreme summer heat.

4 Using green infrastructure to adapt to climate change

Adapting to climate change means taking into account new threats and opportunities in our daily activities. The extent of our adaptation will depend on the success of mitigation measures.

In theory, it should be possible to see the success of mitigation measures through reductions in GHG emissions. However, any reduction will only be apparent in the long term, rather than immediately. When planning adaptation measures, it is also necessary to take into account these long-term impacts.

Although mitigation and adaptation measures have to be developed at all levels – local, national and international – adaptation measures are most important at the local level. Adaptation strategies should be focused on:

- coping with potential losses and risks;
- preventing consequences arising from the identified risks, or from reducing these risks;
- sharing responsibility for losses and risks; and
- utilising the potential opportunities of climate change.[13]

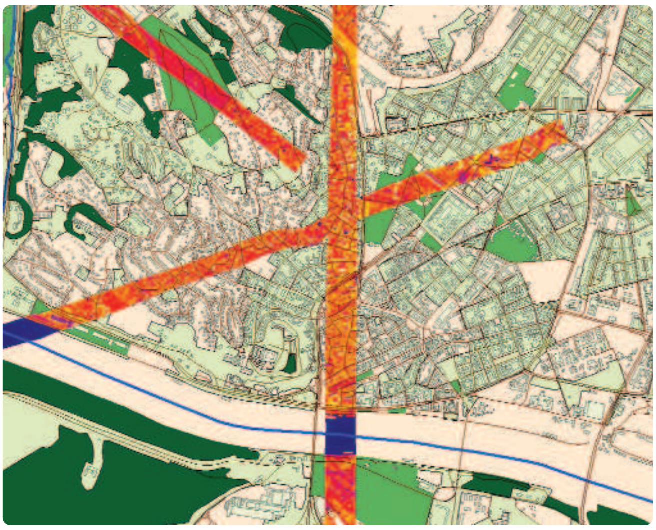
4.1 Alleviating summer heat through green spaces

Based on the results of a number of Slovak and other studies, large differences were detected in the temperatures of a place depending on the amount of green space (especially trees) that it contained. Measurements in 2006 confirmed that vegetation cover has an important effect on a microclimate. Measurements of selected indicators showed significant differences – for example, the difference in maximum temperatures was as much as 14.6ºC between an uncovered green space and a spot under the shade of a solitary tree (measured at ground level). A cooling effect was demonstrated on all surfaces with woody plants. Surprisingly high temperatures were measured on grass, comparable to the temperatures measured on asphalt surfaces such as roads and car parks.[14]

In Bratislava four aerial measurements were carried out over a total distance of 20 kilometres and a width of 200 metres. The temperature was recorded at a height of 2 metres by a ThermoVision camera. The measurements confirmed really big differences between temperatures in Bratislava, from 29.87ºC in the floodplain forests up to 42.06ºC around the Aupark shopping centre (see Annex C). The Aupark shopping centre is in the immediate vicinity of the Janko Král' Park – if it wasn't, the difference in temperature would have been even greater (large parks reduce temperatures in the surrounding areas up to 200-500 metres away).[15]

Cities and municipalities should:

- enable better air circulation throughout the day and night through urban design and the inter-relationships between vegetation and buildings;
- increase the amount of vegetation, especially in the built-up areas of urban centres (through planting trees along streets and in car parks, creating green dividing strips, and using alternative types of vegetation such as green roofs and climbing and vertical vegetation);
- increase the percentage cover of trees and woody plants to more than 60% (compared with lawns) if the infrastructure allows;
- prepare for changes in altitudinal vegetation zones due to increases in temperature – this will affect the



Using Thermovision mapping to record temperatures in Bratislava

selection of basic woody plants to be planted in urban areas, which should now include woody plants that are more resistant to summer droughts and avoid some invasive woody plants that are more rampant in higher temperatures; and
- keep tree vegetation in good condition.[5]

4.2 Green spaces and water management

Green spaces can help to mitigate adverse impacts of climate change on the water cycle, which are likely to include:
- a decrease in precipitation;
- deteriorating water quality caused by increasing temperatures; and
- long periods of drought.

In relation to water resources, Slovakia can expect that:
- one-third of the country will be highly sensitive and vulnerable;
- one-third will have medium sensitivity and vulnerability; and
- one-third will have low sensitivity and vulnerability.[16, 17]

Cities and municipalities should protect vegetation on the banks of waterways. Along with increasing the capacity of a water course to improve water quality, such vegetation provides protection against sedimentation and overgrowth due to the shielding of the riverbed. Vegetation also reduces the heating of water, and provides shielding and protection against erosion.

4.3 Green spaces and reducing flood risk

Vegetation helps to manage water resources in a number of ways:
- Trees very efficiently ‘capture’ precipitation, depending on size and species. Studies show that large trees catch 80% of precipitation and small trees 15%. Coniferous trees are more efficient, as broadleaved trees without leaves catch only 10%-30%.[18, 19] Catching rainwater reduces the amount infiltrating into the soil.
- Root systems help to distribute rainwater to lower layers of soil[20] and to groundwater.
- Through transpiration (evaporation of water from plant surfaces) plants draw water from the soil through their roots. Research shows that the volume of water that a plant transpires into the air is impressive: approximately 300 litres per day for a mature tree.[21] Ermák *et al.*[22] have confirmed evaporation of 65-140 litres per day by a mature apple tree during summer.
- If rainwater is caught in temporary polders it can be very effectively drawn up by woody plants which are resistant to water logging.

Separate green spaces can be used to catch rainwater through natural or artificial shallow depressions that catch water from surrounding terrain, roofs and car parks, or in the landscape through polders.

Forests and other natural spaces are extremely important in the hinterland of a city or a municipality, especially on sloping terrain.

Permeability is especially important in urban environments (see Annex A). A study in Manchester showed that increasing the share of green spaces by 10% would lead to a 5% reduction in rainwater run-off.[23]

Cities and municipalities should:
- introduce an ‘index of maximal impermeableness’ for particular surfaces according to their function (for example, parks and green spaces should not have underground structures such as car parks) in order to increase an area’s retention capacity (see examples in Annex A).

- set up systems to collect rainwater from roofs and terraces and distribute it to infiltration and collection polders or gardens – this would help to reduce the desiccation of the urban landscape and drain rainwater (on public municipal spaces permeable surfaces should be retained – this could also benefit a municipality financially as it would lead to reduced payments for rainwater infrastructure).
- increase vegetation using a range of green spaces, such as green roofs, climbing species, vertical gardens, and so on;
- implement measures to protect against local floods after heavy rain in the hinterland of a municipality – for example, in forest areas such measures could include longer rotation periods, banning clear felling, afforestation, and building polders;
- support planting balks, tufts and wind breakers on agricultural land surrounding urban areas.

4.4 Green spaces and reducing soil erosion and landslides

Green infrastructure helps to reduce:

- erosion caused by heavy rain; and
- landslides that are a consequence of climate extremes, and prolonged and heavy rain.

Cities and municipalities should:

- support the implementation of agricultural practices that help to reduce soil erosion, such as ploughing along level lines, revitalising balks, tufts and terraces, and planting vegetation on field paths; and
- support landscape management in surrounding areas that reduces erosion, such as longer rotation periods, banning of clear felling, afforestation, and building polders.

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Annex A

Standards for green infrastructure in selected EU countries

Sustainable urban development promotes the concept of a compact city. On the one hand, this calls for a greater number of smaller green spaces in urban areas, and on the other advocates the protection of landscapes around a city from overbuilding and fragmentation. Measures to increase the amount green spaces in a compact city might include small parks, green facades and roofs. Barcelona is a typical example: it is a densely populated territory (164 inhabitants per hectare) with a very low level of sealed surfaces per capita – 99.4% of inhabitants live within 300 metres of a green space.[A1, A2]

The proportion and accessibility of green areas and public spaces are included among indicators of sustainable urban development in various European policies (such as European Common Indicators, STATUS, TISSUE), and the access to open spaces, which is defined against a standard of living within 300 metres of a public space, can be measured and monitored.

In the **UK**, Planning Policy Guidance 17: *Planning for Open Space, Sport and Recreation* deals not only with green areas (regardless of how broadly they are defined) but also with open public spaces which provide space for recreation and are also valuable from visual and aesthetic points of view.

A standard of the National Playing Fields Association (NPFA, now known as Fields in Trust) is that an urban area should have 2.43 hectares of sporting areas and playgrounds per 1,000 inhabitants (known as the '6 acre standard'). In 2008 this standard was revised and re-issued under the title *Planning and Design for Outdoor Sport and Play*. It says that there should be 1.6 hectares of recreational green areas and 0.8 hectares of playgrounds for children per 1,000 inhabitants.

A number of British local authorities have adopted a standard of so-called amenity open spaces in the range 0.5-0.8 hectares per 1,000 inhabitants, which is to be applied as a guide for new development activities.

From the point of view of biodiversity protection there is a well known indicator of quality of life for urban inhabitants of 1 hectare of natural area per 1,000 inhabitants. A planning initiative in Chicago, USA (CitySpace) set an objective of ensuring a standard of 2 acres of open space (1 acre = 4,047 square metres) per 1,000 persons by 2010.[A3]

According to other approaches it is necessary to take into account not only the quantitative parameters of an area, but also how this open space is distributed within a city, i.e. the accessibility of open spaces from the most distant parts of a city. For example, the UK assesses the accessibility of open spaces by distance or by how long it takes a pedestrian to walk to a green space. Typical indicators are:

- playgrounds for small children – accessibility within 90 metres;
- playgrounds for children aged 10-13 – accessibility within 300 metres;
- playgrounds for children aged 14-18 – accessibility within 1,000 metres;
- sporting areas – accessibility within 1,000 metres
- parks – accessibility within 400 metres; and
- amenity open spaces – accessibility within 400 metres.

Accessibility of green spaces is generally used for particular categories of green areas according to their importance to a settlement:

- parks and public spaces of regional importance – accessibility within 8 kilometres (London Planning Advisory Committee (LPAC), 1992);
- parks of urban importance – accessibility within 3.2 kilometres (LPAC, 1992)
- parks of district importance – accessibility within 1.2 kilometres (Llewellyn Davies Planning with Environmental Trust Associates, 1992) or 2.5 kilometres (Dundee City Council, 1999 and Glasgow City Council, 1997).

Examples of other standards include Natural England's Accessible Natural Greenspace Standards:

- No person should live more than 300 metres from their nearest area of natural green space of at least 2 hectares in size.
- At least 1 hectare of local nature reserve should be provided per 1,000 head of population.
- There should be at least one accessible 20 hectare green space site within 2 kilometres of every home.
- There should be at least one accessible 100 hectare green space within 5 kilometres of every home.
- There should be at least one accessible 500 hectare green space within 10 kilometres of every home.

As well as quantity and accessibility, there also needs to be standards relating to the quality of green areas and open spaces, in order to maintain favourable environmental conditions in urban areas. In accordance with Freiraumplanerische Standards für die Baulandgestaltung (Standards for Open Spaces in New Development Activities), which are applied in the city of **Graz (Austria)**, various qualitative standards are applied according to the function of a territory – such as an impermeableness index, which is extremely important for rainwater management in the urban environment. It is calculated as a percentage according to the surface type:

- full permeability (0%) – vegetation surfaces on un-built terrain;
- semi-permeability (50%) – area covered by paving with extended open spaces in between, grass pavers, or porous paving in a gravel bed;
- impermeableness (67%) – area covered by paving in a sand bed; and
- impermeableness (100%) – area covered by asphalt or paving in a mortar bed.

The result is an average impermeability expressed as a sum of impermeability according to particular surface types in the given area:

$$\text{impermeability } \% = \frac{(x\,\text{m}^2 \text{ of area type A} \times \text{permeability factor A}) + (y\,\text{m}^2 \text{ of area type B} \times \text{permeability factor B}) + \ldots}{(x + y + \ldots)\,\text{m}^2 \;(= \text{total area of plot})}$$

The final calculation includes the area of green roofs (if there are any in the area in question), where the area of green roof is calculated as follows:

- thickness of soil layer 8-15 centimetres – calculated as 60% impermeability;
- thickness of soil layer 15-30 centimetres – calculated as 45% impermeability; and
- thickness of soil layer 30-50 centimetres – calculated as 20% impermeability.

In the **Swedish city of Malmö** a Green Space Factor was applied in building a new residential district called Västra Hamnen (Western Harbour). The Green Space Factor ensures that each plot has a certain amount of green space. Each particular type of green space is accorded its own factor value within the scale of 0 to 1.0 (impermeable surfaces have a value of 0.0, trees a value of 0.4, and green roofs a value of 0.8). New development has to achieve a Green Space Factor of at least 0.5 (see GRaBS Expert Paper 6,[A4] which considers the Green Space Factor in much greater detail).

Berlin has taken a similar approach, running a successful and comprehensive green factor programme called the Biotope Area Factor (BAF). BAF values for particular surface types are:

Surface type	Factor value
Sealed (built-up) surface	0.0
Partially sealed surface	0.3
Semi-sealed surface	0.5
Surface with vegetation unconnected to unmade ground (thickness of soil layer less than 80 centimetres)	0.5
Surface with vegetation unconnected to unmade ground (thickness of soil layer greater than 80 centimetres)	0.7
Surface with vegetation on unmade ground	1.0
Polders (surface) for infiltration of rainwater	0.2
Vertical greening	0.5
Green roof	0.7

The BAF standard requires values ranging from 0.6 (residential developments) to 0.3 (industrial facilities).

Slovakia's Standards of Minimal Services in Municipalities – covering guidance for spatial planning – was updated in 2009 and 2010. The previous version (dating from 2002) was used as a starting point, and successful standards from other countries were taken into account (such as those used in Graz and Mälmo). Consideration was also given to maintaining quality of

Table A1

Quantitative and qualitative standards for public parks in Slovakia

Green space category	Indicator	Standard for size of municipality, thousands of inhabitants								
		<1	<2	<5	5-10	10-20	20-30	30-50	50-100	>100
1 Parks, public gardens and green spaces	Minimum park area	unlimited	unlimited	5,000 m^2, & minimal width 25 m	5,000 m^2, & minimal width 25 m	5,000 m^2, & minimal width 25 m	5,000 m^2, & minimal width 25 m	5,000 m^2, & minimal width 25 m	5,000 m^2, & minimal width 25 m	5,000 m^2, & minimal width 25 m
	(m^2/inhabitant)	unlimited	unlimited	8-14	8-14	8-14	8-14	8-14	8-14	8-14
	(% of vegetation surfaces)	80%	80%	80%	80%	80%	80%	80%	80%	80%
	(% of coverage by woody plants)	60%	60%	60%	60%	60%	60%	60%	60%	60%
Parks, public gardens and green spaces – local level	(m^2/inhabitant)	unlimited	unlimited	8-14	8-14	5-7	5-7	5-7	5-7	5-7
	Accessibility within	unlimited	unlimited	unlimited	300 m	300 m	300 m	300 m	300 m	300 m
Parks, public gardens and green spaces – district level	(m^2/inhabitant)	unlimited	unlimited			5-7	5-7	5-7	5-7	5-7
	Accessibility within	unlimited	unlimited			1.2 km	1.2 km	1.2 km	1.2 km	3.2 km

life for inhabitants now and in the future (especially from the point of view of climate change) and protecting biodiversity in urban areas. An ecologically balanced settlement has more than 40% of its area covered by green spaces (in planning eco-districts in the UK there is a general rule that 40% of plots should be covered by green spaces).[A5] Drawing on various sources, it is possible to say that the average need for green spaces in a built-up settlement is around 75 square metres per inhabitant.

In the updated Slovakian guidance the green space standards are expressed in both quantitative (for example square metres per inhabitant) and qualitative (for example level of woody plant cover, percentage of vegetation surfaces, impermeability index) terms – see, for example, Table A1.

References

A1 *EEA Fast Track Service Precursor on Land Monitoring – Degree of Soil Sealing 100m (reference year 2006)*. European Environment Agency, 2010. In *The European Environment: State and Outlook 2010. Urban Environment*. European Environment Agency, 2010. www.eea.europa.eu/soer (Thematic Assessment: Urban Environment)

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A3 *Public Space Lessons: Adapting Public Space to Climate Change*. Commission for Architecture and the Built Environment, 2008

A4 A. Kruuse: *The Green Space Factor and the Green Points System*. Expert Paper 6. Apr. 2011. www.grabs-eu.org/news.php

A5 *The Essential Role of Green Infrastructure*. Eco-towns Green Infrastructure Worksheet. TCPA, 2008. www.tcpa.org.uk/data/files/etws_green_infrastructure.pdf

Annex B

Main types and categories of green infrastructure

Parks and other types of public parks and green spaces:
- Local level
- Zone level
- City level

Other green and open spaces:
- Playgrounds
- Botanic gardens and zoos
- Cemeteries
- Camp sites

Public spaces, roads and transport routes:
- Urban squares and spaces (local, zone and city levels)
- Pedestrian streets
- Residential streets
- Other roads
- Urban motorway corridors
- Car parks
- Cycle routes
- Railway lines and embankments

Residential open spaces:
- Private gardens
- Green spaces within blocks in low-rise residential areas
- Green spaces in multi-storey housing settlements
- Green roofs, roof gardens and balconies

Historic open spaces:
- Formerly private parks and gardens associated with historic buildings
- Historic public parks and gardens

Civic infrastructure spaces:
- Pre-school and school buildings and premises (from kindergartens to university centres)
- Hospitals and social care facilities
- Public and accommodation buildings (sites)
- Healthcare buildings (sites)
- Sporting facilities
- Recreational and spa centres
- Cultural and educational centres
- Trading and shopping centres

Urban peripheries:
- Left-over agricultural land
- Forests and woodlands
- Waste disposal and excavation areas
- Unplanned open spaces

Manufacturing and industrial facilities:
- Green spaces within a manufacturing facility
- Zone of isolation green space (pursuant to a type)

Annex C

Pilot assessment of the vulnerability of the population of Bratislava to extreme summer heat

Low-rise residential development – family houses and gardens in the Old Town (Staré Mesto) near the castle

Introduction

In accordance with the IPPC's definition of vulnerability from the Fourth Assessment Report (2007), which introduced three main concepts of exposure, sensitivity and adaptive capacity, the sum of exposure and sensitivity represents the potential impact, threat and damage caused by climate change:

vulnerability = function [exposure (+); sensitivity (+); adaptive capacity (-)]

A pilot project in Bratislava attempted to determine the vulnerability of the population to extreme summer heat. Selected indicators were assessed based on qualitative interaction in a matrix (see Figure C1). This resulted in a combination of matrix ranking and weighed analysis of performance, where Aa>Ab ... >Ba>Bb ... >Dd.

It is possible to rearrange the results as follows (see Figure C1):
Aa, ... = high value = A
Ac, ... = mid-high value = B
Bd, ... = mid-low value = C
Db, ... = low value = D

	a	b	c	d
A	Aa	Ab	Ac	Ad
B	Ba	Bb	Bc	Bd
C	Ca	Cb	Cc	Cd
D	Da	Db	Dc	Dd

Figure C1 Selected indicators were assessed based on qualitative interaction in a matrix

Sensitivity of the population to extreme summer heat

To assess sensitivity of the population to extreme summer heat, two basic indicators were selected (see Figures C2 and C3):

- age (which indirectly includes physical health), expressed as a percentage of the total number of the inhabitants in a section of the city; and
- density of the population.

By integrating these two pieces of information it is possible to calculate the sensitivity of the population of various parts of the city to extreme summer heat (see Panel A1).

	Value
More than 9%	A
5.6-9%	B
Less than 5.5 %	C
Less than 3%	D

Figure C2 Proportion of the population aged 75+

A: high value; B: mid-high value; C: mid-low value; D: low value

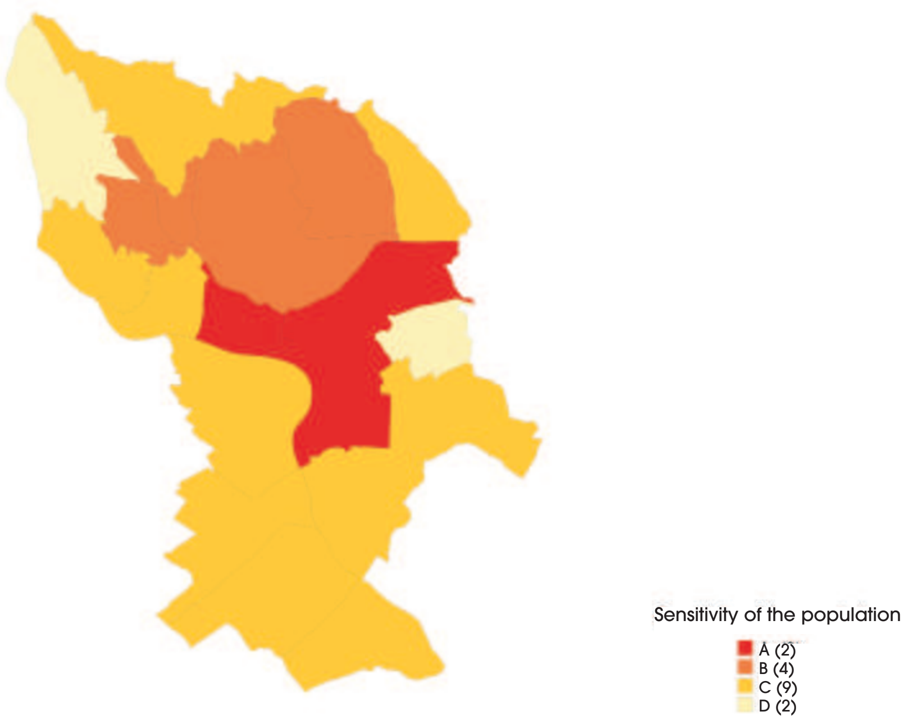
	Value
More than 2,000	a
Less than 2,000	b
Less than 1,000	c
Less than 100	d

Figure C3 Density of the population expressed as the number of inhabitants per square metre

a: high value; b: mid-high value; c: mid-low value; d: low value

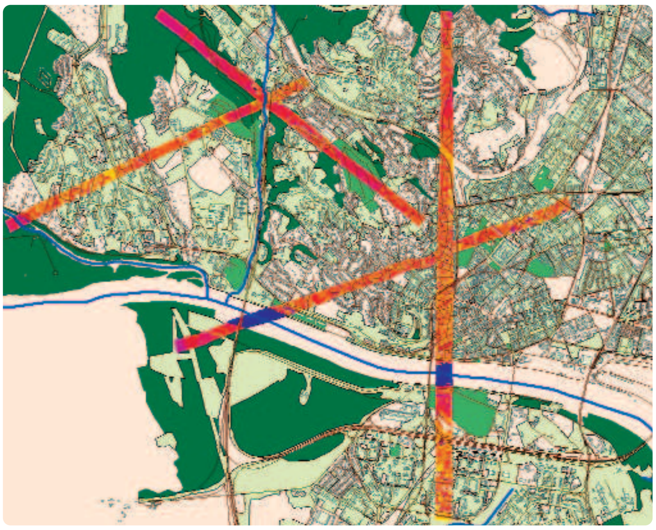
Panel C1
Sensitivity of the population to extreme summer heat

Name of the city district	Total number of inhabitants	Population aged 75+, percentage	Value	Density of population, inhabitants per m^2	Value	Sensitivity
Bratislava – Stare Mesto	40,828	10.6	A	4,302	a	A
Bratislava – Ruzinov	71,802	9.3	A	1,781	b	A
Bratislava – Raca	20,548	8.2	B	864	c	B
Bratislava – Nove Mesto	37,778	9.9	A	988	c	B
Bratislava – Lamac	6,722	7.9	B	1,006	b	B
Bratislava – Dubravka	34,725	6.0	B	3,978	a	B
Bratislava – Zahorska Bystrica	3,194	5.5	C	88	d	C
Bratislava – Vajnory	5,057	4.5	C	344	c	C
Bratislava – Rusovce	2,669	3.8	C	95	d	C
Bratislava – Podunajske Biskupice	21,207	3.7	C	488	c	C
Bratislava – Petrzalka	112,545	2.4	D	3,955	a	C
Bratislava – Karlova Ves	34,510	4.4	C	3,094	a	C
Bratislava – Jarovce	1,388	5.5	C	61	d	C
Bratislava – Devin	1,099	6.0	B	74	d	C
Bratislava – Cunovo	970	4.9	C	50	d	C
Bratislava – Vrakuna	19,866	2.9	D	1,876	b	D
Bratislava – Devinska Nova Ves	16,153	2.5	D	658	c	D



A: High value; B: Mid-high value; C: Mid-low value; D: Low value

Source: Statistical Office



Thermovision mapping of the city territory in four corridors – a total length of 20 kilometres and a width of 200 metres

Part of the historic centre of Bratislava (Staré Mesto – Bratislava's old town), displaying a clear lack of green infrastructure

Public space with a signifant amount of green infrastructure in Bratislava's old town (Staré Mesto)

Exposure of the population to extreme summer heat

The project examined the nature and extent of the extreme summer heat to which the Bratislava population is exposed, using data from Thermovision temperature mapping in four 200 metre-wide corridors, totalling 20 kilometres in combined length. The data thus obtained were also applied to other urban areas with similar amounts of green infrastructure.

Mitigation of summer heat using green spaces and green infrastructure reduces temperatures significantly. However, ambient temperature is a result of a number of factors – such as shielding by buildings, the number of nearby trees (grassed areas reach temperatures that are comparable to those recorded on sealed surfaces, especially during droughts) – and consequently it is also necessary to make a qualitative assessment of an area's green infrastructure (see Table C1).

Combination of low-rise development (family houses with gardens) and residential buildings with little green infrastructure, city district of Karlova Ves, Bratislava

Map of average temperatures in Bratislava's old town (Staré Mesto)

Table C1
Quantitative and qualitative assessment of green infrastructure and related temperatures according to type of land use

Type of urban landscape structure	Average temperature, °C	Quantitative assessment of green infrastructure – unsealed area as a percentage of total area	Qualitative assessment of green infrastructure – area covered by trees as a percentage of total area
Watercourses – Danube river	20.14	100	N/A
Forest (floodplain)	29.87	100	100
Parks – Horsky Park	30.36	90	90
Forest (oak-hornbeam)	31.15	100	100
Public spaces with high levels of green infrastructure (Hviezdoslavovo namestie)	32.37	60	100
Parks (Sad Janka Krala)	33.09	80	60
Cemetery (Jewish cemetery)	33.97	80	60
Social service facilities (PKO)	34.07	60	50
Educational and recreational parks (Zoo)	34.21	60	50
Other spaces	34.43	80	80
Non-forest woody vegetation	35.42	100	50
Public spaces with medium levels of green infrastructure (Namestie Slobody)	35.43	50	50
Public spaces with low levels of green infrastructure (Zupne namestie)	36.57	40	40
Mosaic structure	36.87	100	40
Parks (Presidential Park)	37.10	60	40
Grassy areas (natural, unmowed)	37.14	100	20
Gardens, garden areas (Devinska cesta)	37.81	60	40
Technical structures – railways	38.27	20	0
Technical structures – transport (Sitiny tunnel)	40.06	20	0
Public spaces with low levels of green infrastructure (Dlhe Diely)	40.32	20	10
Shopping and services facilities with low levels of green infrastructure (shopping centre, Aupark)	42.06	20	10
Grassy areas (mowed)	44.61	100	0

Table C2
Exposure of the population to extreme summer heat

Type of sealed area (settlement)	Average temperature, °C	Exposure
Residential structures with low levels of green infrastructure (Dlhe Diely)	39.33	A
Built-up sites with low levels of green infrastructure (residential, administrative facilities, Panenska ul.)	39.94	A
Built-up sites (administration, Zupne namestie, Kapucinska)	38.51	B
Historical centre with low levels of green infrastructure	38.57	B
Social services facilities and accommodation (Mlynska dolina, university colleges)	38.63	B
Residential structures with medium levels of green infrastructure (Petrzalka)	38.90	B
Residential structures with high levels of green infrastructure (Karlova Ves)	38.08	C
Low-rise residential development (family houses, gardens)	38.22	C
Low-rise development (family houses, gardens, Stare Mesto, Mudronova)	37.10	D
Low-rise development (family houses, gardens, Liscie udolie)	36.22	D

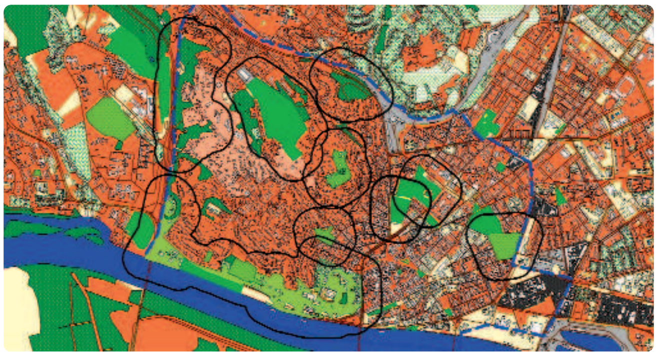
A: High value; B: Mid-high value; C: Mid-low value; D: Low value

Table C3
Potential impact on the population of extreme summer heat

Type of sealed area (settlement) and level of green infrastructure	Exposure	Sensitivity	Potential impact
Built-up sites with low levels of green infrastructure (residential, administrative facilities, Panenska ul.)	A	A	A
Built-up sites (administration, Zupne namestie, Kapucinska)	B	A	A
Historical centre with low levels of green infrastructure	B	A	A
Social services facilities and accommodation (Mlynska dolina, university colleges)	C	A	A
Residential structures with medium levels of green infrastructure (Petrzalka)	D	A	A
Residential structures with high levels of green infrastructure (Karlova Ves)	A	C	B
Low-rise residential development (family houses, gardens)	B	C	B
Low-rise development (family houses, gardens, Stare Mesto, Mudronova)	C	C	C
Low-rise development (family houses, gardens, Liscie udolie)	D	C	D

A: High value; B: Mid-high value; C: Mid-low value; D: Low value

Potential impact on the population of extreme summer heat in Staré Mesto (in terms of high value, mid-high value, mid-low value, low value)



Adaptive capacity of the population to extreme summer heat in Staré Mesto – inhabitants living in the 'buffer areas' of green infrastructure have a higher adaptive capacity and therefore lower vulnerability to extreme summer heat

The sum of exposure and sensitivity represents the potential impact and damage resulting from climate change. Staré Mesto, with high a sensitivity of the population, and Karlova Ves, with mid- to low sensitivity of the population, were selected as pilot areas.

Adaptive capacity of the population to extreme summer heat

The overall vulnerability of the population is affected by its capacity to adapt to extreme summer heat. The project assessed adaptive capacity using the presence of green infrastructure within a 300 metre walk as an indicator, expressed on an GIS map as a buffer area. However, it should be noted that public spaces with very low levels of green infrastructure (and therefore very high temperatures) can have a negative effect on adaptive capacity and can thus actually increase the vulnerability of the population.

Conclusion

Green infrastructure can very significantly affect the overall vulnerability of a population to extreme summer heat and influence its adaptive capacity.

I think what she means here is that there can be open space which is regarded as a 'buffer' area and that on a GIS map this might be seen as good but if it does not have GI then it can be counter-productive - ie just a huge concrete open space.

GRaBS Expert Paper 7

Assessing Vulnerability and Using Green Infrastructure

The GRaBS Project
GRaBS Expert Paper 7: Assessing Vulnerability to Climate Change and Adapting through Green Infrastructure
By Zuzana Hudeková

Zuzana Hudeková is Project Manager with the Regional Environmental Centre for Central and Eastern Europe, Bratislava, Slovakia (REC Slovakia).

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Town and Country Planning Association

17 Carlton House Terrace
London SW1Y 5AS
t: +44 (0)20 7930 8903
www.tcpa.org.uk