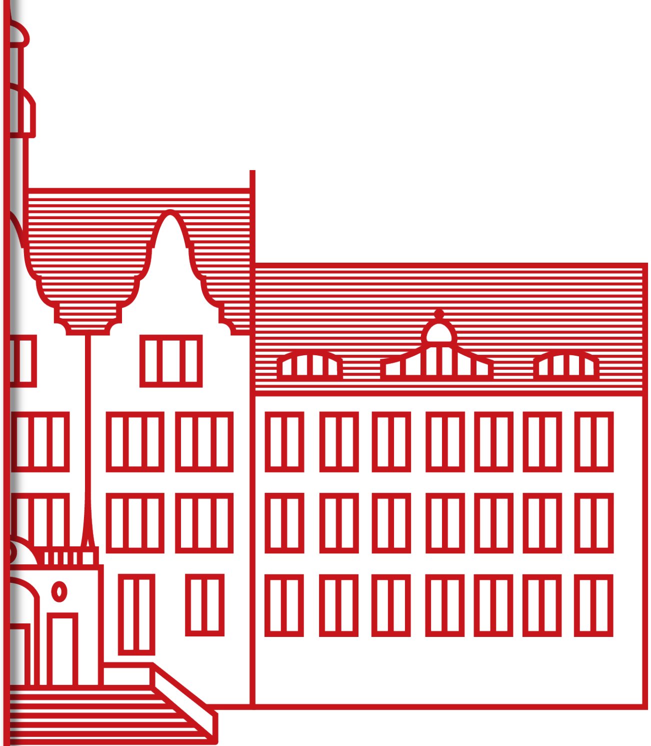
Impetus

Co-funded by the Erasmus+ Programme of the European Union

Innovative Measurement Tool towards Urban Environmental Awareness

MANUAL

https://impetus.aau.at/



Project Partners

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1 Introduction

In European cities the threats of climate change become crucial for city development and human safety. Even though cities are becoming more and more experienced with new approaches to local adaptation planning, there are still clear barriers such as:

- limited availability of up-to-date data about local conditions,
- lack of awareness and civic attitude of ignorance towards climate change and its impact on wellbeing and local conditions in our streets and neighborhoods, lack of public interest, and finally,
- lack of interdisciplinary approaches and public actions to solve local problems and the inability to select the optimal solutions from the set of alternatives.

These barriers can be removed by introducing a new holistic, interdisciplinary approach based on a combination of technical and engineering skills, art & design and social sciences, supported with IT solutions and storytelling.

The aim of the IMPETUS project is to:

- create awareness about climate change related vulnerabilities and challenges at local level among target groups,
- integrate the challenges of climate change in the curricula of different faculties and disciplines of EU HEI's to increase awareness as well as to equip students & staff with innovative methodology combining social, technical and visual ones for acquiring data about climate vulnerabilities.

In order to create awareness about the vulnerabilities like drought, heat stress, floods of our neighbourhoods and cities, vulnerable locations should be visited and vulnerabilities should be assessed, measured and captured on photo and video clips and shared on social media. All data on neighbourhood conditions that can be easily acquired and shared with target groups, stakeholders and practitioners on platforms and social media support the dialog and motivate for the participation in monitoring, planning and development processes. Thus target groups of the project are:

- students, researchers, teaching staff of Water management, Civil and Environmental Engineering, Urban planning, Transport planning, Architecture, Arts and communication and Social sciences;
- civil servants and decision makers;
- experts, specialists, practitioners involved in any wide range adaptation or mitigation activities;
- citizens of the urban areas

Within the IMPETUS project we developed a set of tools which help to collect data on the urban environment and condition and improved the database where all the data can be collect and presented (Figure 1.1).

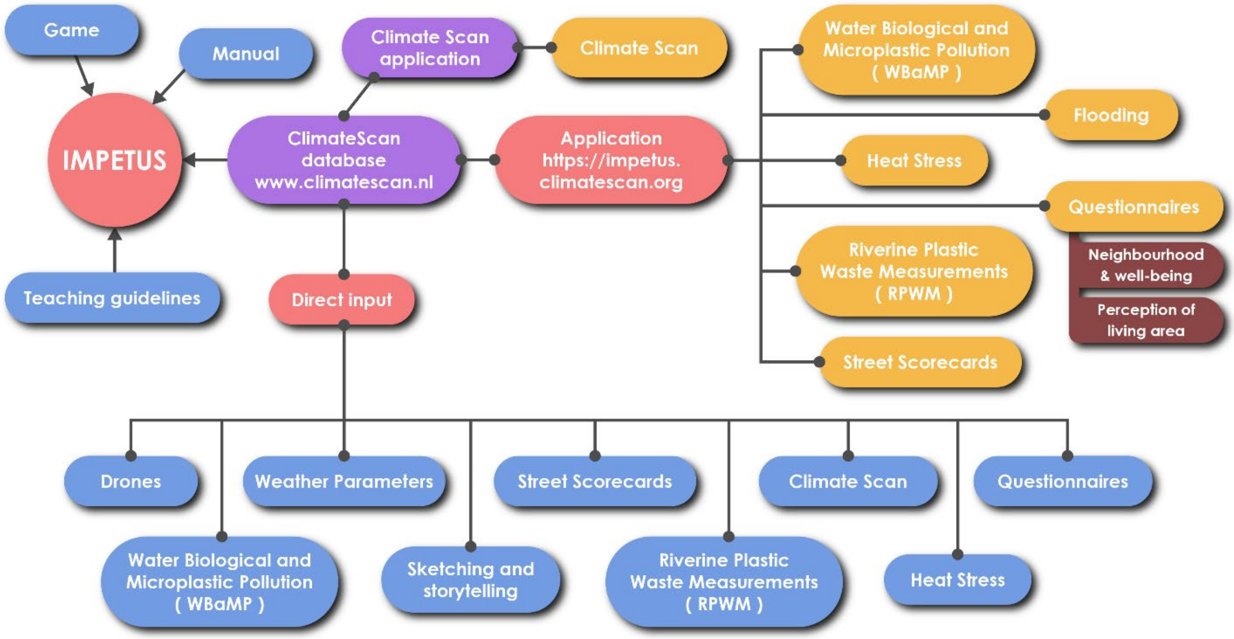

Figure 1.1. The set of didactic tools developed/improved within the projects and paths for input data into the database ClimateScan.

The spine of the IMPETUS project is the database ClimateScan https://www.climatescan.nl/ . This is a narrative map, which can be accessed either via computer or by using the application ClimateScan on mobile phone. Not only various data such as photos, text, video, measurements results can be added but also they can be used for different purposes such as citizens involvement into the design process or public discussions, student studies based on case studies etc. and various analysis.

Using the narrative map, one should remember that there is no reviewing process of the data. On one hand this may be the significant limitation for the usage of them. On the other hand, the analysis based on the statistics or on well described cases are valuable enough to give the knowledge on the problems and solutions in different cities. All depends on the quality of data.

All the instructions and supportive materials, how to collect various data are located at https://impetus.aau.at/outputs/ in folders.

Folder: ClimateScan

The methodology is used to identify problem areas and solutions in your city or neighbourhoods. Students are to collect data on problems related to climate change and to assess how adaptive the analysed area is by creating its DNA. This assignment is based on field research as well as online research.

You can use the tools and methodologies to measure the following pollutants and hazards. You can do it manually using prepared, ready to print templates (see the instructions) or using the dedicated IMPETUS application https://impetus.climatescan.org.

Folder: Application

This app is for collecting data in the form of questionnaires (IMPETUS activities) that are easy to answer and they do not require much time. Information about how to conduct measurements is always provided to make the procedure easier for non-experts.

The available via app measurements are as follows:

- Water Biological and Microplastic Pollution (WBaMP),
- Flooding,
- Heat Stress,
- Riverine Plastic Waste Measurements (RPWM),
- Street Scorecards,
- Questionnaires.

This app is connected with the ClimateScan databse, so users must create an account under www.climatescan.nl first. This app uses GPS location to identify the region that the measurements are conducted. All the information on how to use the IMPETUS application you will find here.

Folder: Water Biological and Microplastic Pollution

Water biological and microplastic pollution was developed to assess the level of the biological pollution and microplastic pollution of the water in open water tanks (lakes, streams, rivers, retency ponds and NbS solutions as well as sea water). It is based on simple, easy to get tools and the analysis results in calculating the pollution index value describing the level of the water pollution.

Folder: Flooding

Flooding is based on simple methods and tools for measuring parameters such as: precipitation, infiltration, surface runoff and water level. These parameters affect the flood index, which you will use to assess the risk of flooding in the analysed area.

Folder: Weather Parameters

Weather parameters measurement methodology helps to learn how to measure the temperature and presents the correlation with the surface temperature and air temperature.

Folder: Heat Stress

Heat Stress presents the solutions for the field survey focusing on an urban area, or street(s), that can provide important knowledge on the local urban environment and increased understanding of the role played by different urban attributes. Overall, usual aims are to appraise ambient conditions, namely with respect to air temperature and relative humidity and to assess the risk of heat stress through, e.g., the calculation of the Heat Stress Index.

Folder: Riverine Plastic Waste Pollution

Riverine plastic waste pollution was developed from the methodology for scanning plastic pollution in the marine environment and adopted to the inner city water (streams, rivers...) to tackle the influx of plastics. It determines the amount and composition of riverine plastic litter on a riverbank using a random subsample.

Folder: Street Scorecards

Street Scorecards is the tool that helps to assess the climate adaptive measures at the street level and attaches climate adaptation labels to street segments and streets, is accurate and is easy to use by residents and communities to self-assess streets and neighbourhoods, would be very valuable to identify the least adaptive streets and raise awareness about climate adaptation among the members of the community.

Folder: Geo-Questionnaire

The research on human behaviour can be conducted by interviews, discourse analysis, open-ended questionnaires, documents, participant observation, and others. This questionnaire is to collect data on the citizens' well - being and neighbourhood environment.

Apart from the mentioned above, tools based on sketching, remote sensing techniques were developed.

Folder: Sketching & Storytelling

To diagnose the problems, hazards, pollutants in different places, see symptoms of climate change, you can use the set of dedicated sketching booklets, which will help you do efficient visual description and storytelling with your sketches. All you need is the (digital) pencil and the time to have a closer look to detect details.

Folder: Drones measurements

This methodology requires sensors and any vehicles to carry the sensor. The drones are dedicated but also you can do measurements with the sensor mounted to the bicycle. The steps for the visualisation of the results using free GIS software is also presented.

To make the education easier and motivate students to work, we prepared teaching guidelines with the set of templates and the game to make the learning process interesting.

The game's purpose is to learn about the topics shown during a Climate Cafe by playing an online game. The short synopsis of the game is that the player participates in a fictional Climate Cafe in the town of Ecopolis. The tasks range from answering quizzes to solving minigames (in the style of match 3, simons says, hidden object puzzles and many more). The game design does not have a typical win situation with high scores, but is more an interactive story where the player will learn something, so even giving wrong answers will not lead to a game over. The game will always try to show the player the correct answer, including the explanation.

Folder: Teaching Guidelines

These guidelines include the basic knowledge on innovative didactic methods and templates for teachers and students to help organise the group work, prepare the assignments, presentations or assess them. These methods were used during IMPETUS teaching/learning activities.

Project Partners

Gdańsk University of Technology (Gdańsk Tech) – https://pg.edu.pl/en
Gdańsk University of Technology (Gdańsk Tech) is the largest technical university in the Pomeranian Region and one of the oldest technical universities in Poland. The first inauguration of the academic year took place on 4th October 1904. Today The university employs over 2600 staff, including nearly 1200 academic teachers (113 titular professors, 165 associate professors and 651 assistant professors). One measure of the university's achievements in research and development is the yearly contribution of over 2000 publications, of which nearly 300 appear in the world's most renowned scientific journals on the ISI list and more than 40 are scientific monographs and academic textbooks. The impressive premises of GUT are occupied by 9 faculties, which offer Bachelor's, Master's and Doctoral studies conducted in full time and part time systems in many areas of science and

technology. GUT provides its students with vast access to information resources localized in specialist departmental computing laboratories, as well as two open laboratories in the Information Technology Centre. GUT is home to the Information Academic Computer Centre in Gdansk (CI TASK). Civil and Environmental Engineering, which will be the Lead Partner, is one of the oldest and the largest faculties at GUT. It has full academic rights – a privilege to grant BSc, MSc, PhD and DSc degrees. At the moment there are almost 200 academic teachers delivering courses for over 4600 students. The faculty conducts daily and extra-mural courses in Civil Engineering, Geodesy and Cartography, Environmental Engineering, and Transportation.

Hanze University of Applied Sciences (HUAS) – https://www.hanze.nl/eng
Hanze University of Applied Sciences (HUAS), Groningen, has establishments in Groningen, Assen, Leeuwarden and Amsterdam with approximately 26.000 students and more than 50 professorships. The HUAS distinguishes itself from other colleges by the emphasis on internationalization and the direct link with businesses in the Dutch Northern region. Research is of an applied nature and concentrated in six so-called Centres of Applied Research and Innovation. Our research group 'Spatial Transformations and Water' belongs to the Research Centre for Built Environment ('NoorderRuimte'). This research centre develops and shares expertise about area development in the north of the Netherlands, thereby functioning as a knowledge broker for business, industry and the not-for-profit sector in the Northern part of the Netherlands and beyond. The research group specifically focuses on climate adaptation, urban water management and heat stresses.

Rotterdam University of Applied Sciences (RUAS) – https://www.rotterdamuas.com/
Rotterdam University of Applied Sciences (RUAS) is one of the major Universities of Applied Sciences in the Netherlands. The university is divided into eleven schools, offering more than 80 graduate and undergraduate programmes in seven fields: art, technology, media and information technology, health, behaviour and society, education, and of course, business. Currently around 30,000 students are working on their professional future, studying at our university. The School of Built Environment focusses on the strategy, design, construction and (socio-) economic factors in the development of sustainable and resilient cities and works on research to contribute to building the most sustainable and durable harbour city in the world. The School of Built Environment comprises of 7 bachelor and 2 master programmes, all departments operate in the fields of Technology and Business. They are strongly connected to one another, which reflects the professional work field. Due to this professional connection they cooperate closely both from an organisational and content point of view. With nearly 300 staff members, the School of Built Environment offers education to around 3500 students. The combination of bachelor and master programmes, together with the research opportunities at the Research Centre for Sustainable Port Cities, make the School of Built Environment an interesting partner for various cooperative ventures.

University of Coimbra (UC) – https://www.uc.pt/en
University of Coimbra (UC) is a reference in higher education and R&D in Portugal, due to the quality of the courses taught at its eight colleges and to the advances achieved in pure and applied research in various scientific domains and on technology related areas. UC pursues a policy of continuous improvement in several areas, ensuring high standards of teaching and research, as well as being an active participant in the development of the corporate world. The continuous technological development promoted by UC's different R&D units addresses the challenges involved in the design, operation and regulation of technologies, bringing together teachers from different scientific disciplines with a long experience in teaching, research, technology transfer and

consultancy in different areas in the context of technology. The offer in technological research makes UC an undeniable reference in R&D in Portugal, which highlights the excellence of work developed by the R&D units of UC, in particular CISUC (Centre for Informatics and Systems), CIEPQPF (Chemical Process Engineering and Forest Products Research Centre), CMUC (Centre for Mathematics of the University of Coimbra), CQ (Centre for Chemistry of University of Coimbra), CFE (Centre for Functional Ecology) and IBILI (Institute of Biomedical Research on Light and Image), besides the Associated Laboratories: CNC (Centre for Neuroscience and Cell Biology), ADAI (Association for the Development of Industrial Aerodynamics), LIP Coimbra (Laboratory of Instrumentation and Experimental Particle Physics). The University of Coimbra is in constant search for improvement and enhancement of knowledge, research and technology, contributing decisively to the improvement of science, technology and to the enhancement of knowledge through R&D collaborations dues to H2020 projects and PT2020 projects. The administrative and financial procedures regarding project implementation run in the Support Project Office of UC'S Administration, that assigns a competent member of the staff to each project with accountable and legal competencies. UC has a large and long experience in participating in European and other international projects (as well as national projects). UC stands out also on technology transfer being involved in the promotion of several initiatives, like IPN Incubator and Biocant, and in the creation of diverse technological spin-offs, as Active Space Technologies, Artscan, Crioestaminal, Critical Software, Feedzai, InfoGene, Inogate, iNovmapping, ISA Intellicare, Luzitin, Move Mile, Sensebloom, SPI and Take The Wind, amongst others.

The University of Applied Sciences of the Grisons FHGR – https://www.fhgr.ch/en/

The University of Applied Sciences of the Grisons FHGR is a practice-oriented institution for study and research with around 1,700 students. The research group consists of researchers from the Institute of Multimedia Production in the Department of Applied Future Technologies. The research activities focus on developing visualization for mobile devices with sketching as rapid prototyping method. To apply all means of ideation in the digital production chain of smart phones and any smart devices to communicate for the media, for corporate communication and for science visualization is on scope. Fast adoption to emerging technologies and devises are a field of special interest in research. The sketching method of Sketch&Draw is developed to educate students in technical degrees to draft visually. This approach is unique and proved over nine years. The method is based on algorithm derived from classical sketches used by scientist in the past and adopted to today's devices and needs. Furthermore, the research reaches out to visual storytelling and narrative design. The blending borders from visualizations to moving and interactive images and visualization up to 3d objects need to be developed for the mobile and desktop applications. Scientific visualization and communication in multimedia application in 2D and 3D information artefacts is a main focus. Scientific visualization and communications were realized for the Government of Switzerland in the field of special planning, sustainability and health. There are two units that deal with convergent newsroom for media, political communication and corporate communication: 1) The institute conducts a research on multimedia educational resources in the field of MINT education.2) The department conducts technical expertise and research projects in cooperation with business entities and innovation development units and the government of Switzerland. The production zone at the University is equipped with all the needed facility for multimedia production and measurement tool.

The Alpen-Adria Universität Klagenfurt (AAU) – https://www.aau.at/en/

Since its foundation in the year 1970, the Alpen-Adria Universität Klagenfurt (AAU) has successfully established itself as a distinctive voice reinforcing the canon of Austrian universities, as a globally networked research institution, and as a hub for the acquisition, exchange, and transfer of knowledge across the entire Alps-Adriatic Region. Along with the universities of Graz, Innsbruck, Linz, Salzburg, and Vienna, it is one of the six state universities offering a broad spectrum of subjects. The scientific achievements of the AAU advance the university's growing national and international visibility. The AAU contributes to finding solutions for today's vast challenges by pooling and strengthening various research fields. The establishment of the profile-enhancing research initiatives Energy Management & Energy Technology, Sustainability, Self-organizing Systems and Visual Culture allows holistic approaches and yields excellent research results. The projects carried out at the AAU serve as important impulse generators for the business location Carinthia. More than 10,000 students attend the Alpen-Adria Universität for the purposes of study and research, including around 1,800 students from abroad. Approximately 1,500 members of staff strive to produce outstanding achievements of the highest quality in the realms of teaching, research and university administration. In total, 35 departments spread across the university's four faculties serve as sites of work and research at the AAU. In addition, several specialized centres contribute to shaping the university's specific portrait. The research group Transportation Informatics (TIG) which represent AAU is mainly involved in MACHINE LEARNING, DATA SCIENCE and NEURO-COMPUTING based modelling, simulation, optimization and control in the frame of selected TRANSPORTATION related COMPLEX SYSTEMS, which are: intelligent traffic systems, autonomous and/or networked vehicles, intelligent mobility & logistics systems, and advanced driver assistance systems.

2 ClimateScan

2.1 Introduction

Climate change has a big impact on the livability in our cities. European cities are increasingly experiencing periods of high temperatures. The local climate is affected and outdoor human thermal comfort increases. The urban heat islands effect shows that the temperature in cities is several degrees higher compared with their surroundings (van Hove et al., 2015). This could be a risk to human health as growing urban populations exacerbate the heating effects of climate change. In addition to this, climate change has resulted in periods of heavy precipitation that occurs more frequently and more intensely than before (Stocker et al., 2013). A larger percentage of precipitation has come in the form of intense single-day events. Heavy precipitation may result in urban flooding. Urban flooding is a major problem in many parts of the world and is one of the most natural disastrous events which takes place every year (Eldho, Zope, & Kulkarni, 2018).

2.2 EU Green Infrastructure strategy

In order to stay livable, cities need to adapt to the changing climate. In fact, cities are increasingly taking action to be better prepared for the impacts of climate change and especially urban floods, heat stress and drought. Cities should also invest in nature based solutions to tackle water and heat risks (Global Commission on Adaptation, 2019). The European commission has formulated a Green Infrastructure (GI) strategy to enhance Europe's (Urban Green Blue Grids) natural capital. Ecosystem-based approaches are strategies and measures that harness the adaptive forces of nature. They are among the most widely applicable, economically viable and effective tools to combat the impacts of climate change according to the European Commission (European Commission, 2013). In addition to addressing the impacts of climate change Green Infrastructure features in urban areas creates a greater sense of community, strengthens the link with voluntary actions undertaken by civil society, and helps combat social exclusion and isolation Ecosystem-based approaches are strategies and measures that harness the adaptive forces of nature. They are among the most widely applicable, economically viable and effective tools to combat the impacts of climate change (European Commission, 2013).

2.3 Urban Green and blue spaces to combat effects of climate change

The world has recorded the hottest decade on record (2010-2020) during which the title for the hottest year was beaten 8 times. Implementing nature-based solutions on a larger scale would increase climate resilience and contribute to multiple Green Deal objectives. Blue-green (as opposed to grey) infrastructures are multipurpose, "no regret" solutions and simultaneously provide environmental, social and economic benefits and help build climate resilience (European Commission, 2021). Developing urban green spaces and installing green roofs and walls is mentioned will help to adapt in a cost-effective way. In 2018, an estimated 55.3 percent of the world's population lived in urban settlements. By 2030, urban areas are projected to house 60 percent of people globally (United Nations, 2019). All these people will be directly affected by the impacts of climate change. One of the solutions that has been suggested to make cities more resilient is Urban Green infrastructure (UGI). Urban green and blue spaces and green infrastructure are very effective to combat the effects of climate change and tackle water and heat risks. A common method to evaluate such contributions is to measure the ecosystem services (ES) provided by the vegetation or water bodies present in urban green and blue spaces (UGBS) that constitute the UGI. (De Manuel, Méndez-Fernández, Peña, & Ametzaga-Arregi, 2021). The European commission initiated the Climate ADAPT project to raise awareness and increase the expertise of how green and blue infrastructure can help new and existing mixed use urban development adapt to projected climate scenarios of key bodies responsible for spatial planning and development (Climate ADAPT) https://climate-adapt.eea.europa.eu. The challenge is now how to integrate these measures in our cities and to assume directive roles in their implementation. The Urban Green Blue Grids toolbox was developed by the climate ADAPT project to help in the realization of green-blue urban grids and to illustrate and explain the synergetic potential of the various measures for the themes water, heat, biodiversity among others (Urban Green Blue Grids). https://www.urbangreenbluegrids.com/measures.

European cities need to adapt and to implement green and blue solutions. To share best practices and example worldwide, the website ClimateScan was launched
(Climate Scan) https://www.climatescan.org.

ClimateScan is an interactive narrative web-based map application for international knowledge exchange on blue-green projects around the globe. It focuses mainly on the topics surrounding the areas of urban resilience, climate proofing and climate adaptation. Over the past few years, more and more adaptive measures for climate change are being implemented by urban areas worldwide. The objective of climate scan is international knowledge exchange on climate adaptation projects through an interactive web-based application (Restemeyer and Boogaard 2020).

2.4 Measurement description

ClimateScan web page enables you to browse different green and blue solutions, or other measures in different categories. You can both:

- gain information on measures in any areas including in your locality,
- upload the measures to the interactive website with exact coordinates. The measures will appear on the world map (Figure 2.1).

Similarly, you can select one of eight categories and browse the measures from around the globe that are uploaded by practitioners worldwide. One of the categories is problem areas. Here you can upload areas that are characterized by a certain climate-change related problem like heat stress, drought, urban flood or areas that lack adaptive measures (Figure 2.2).

Climatescan.nl has proven to be a successful instrument with over 5000 international projects in the area of climate adaptation. The tool is used in various international Climate Cafés (climatecafe.nl), workshops and projects and meets the demands of various stakeholders.

Practitioners can investigate any area and visit successful projects and upload pictures, movies and descriptions to the climate scan website. Students and young professionals can also visit problem areas and upload pictures and movies to the website. After identifying a problem site, they can look for best practices on the ClimateScan website elsewhere in the world that are presented on the map. (Figure 2.3).

There are 7 focus topics.

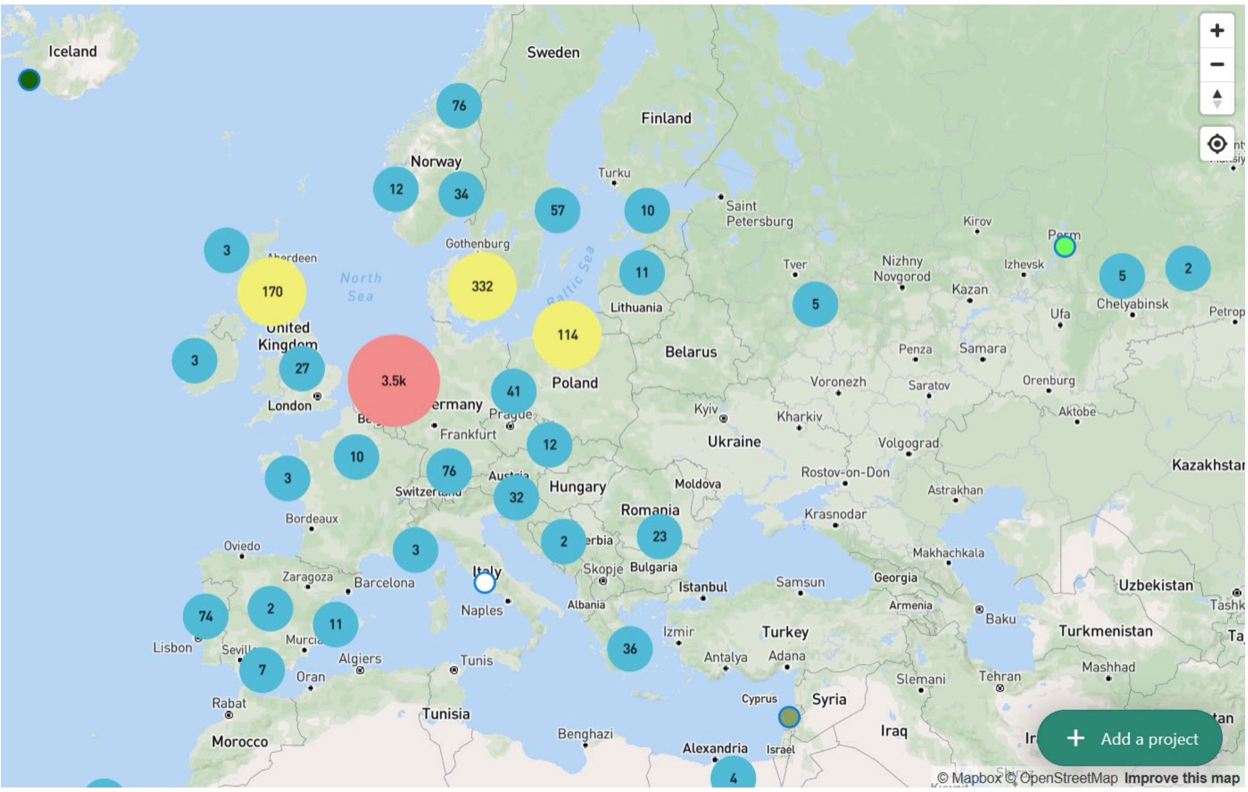

Figure 2.1. Climate adaptation projects in Europe.

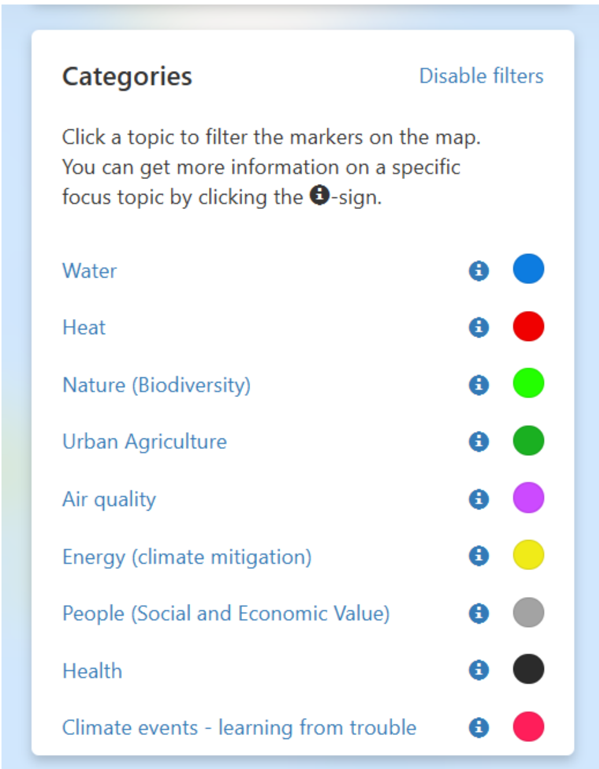

Figure 2.2. Categories.

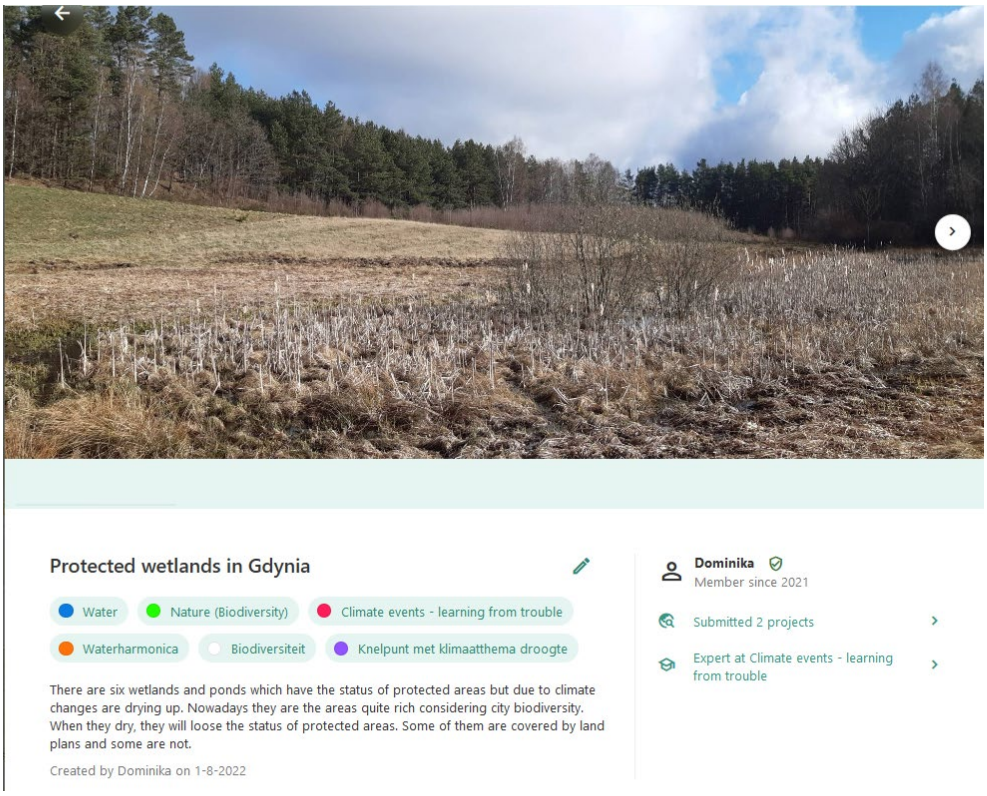

Figure 2.3. Project details.

Data collection & methodology

To add the information to the webpage you need to follow these steps:

1. Download the ClimateScan app on your smartphone or go to the website www.climatescan.org, to the tab "join us" and create an account and log in.
2. Start a new project. Visit blue-green measures in your city as shown in Table 2.1 (or another measure that you would like to upload). Open the app (see Figure 2.4) and click the GPS button. The coordinates of the project are now registered. Create a project title, write a description, select a category. Upload 3-5 pictures from different angles of the measure. Upload each 5-10 blue green measures in your city or neighborhood.
3. Identify blue-green infrastructure measures in your city or neighborhood, gather the information about them, do your measurements, take photos and upload all to the ClimateScan. Before you go outside, prepare yourself. Browse measures from locations around the globe at www.climatescan.nl. (Figure 2.2, Table 2.1). The website shows thousands of examples from around the world. You can also zoom into your city and see what measures are uploaded near your location. If you don't know what blue-green infrastructure measures are, visit the website https://www.urbangreenbluegrids.com/measures/ and click the tab 'water' or 'heat'. You can find multiple measures with a description at the website. Or you can use the NbS solution description in the IMPETUS Manual.
4. Identify problem areas in your city or neighborhood, take photos and upload to the ClimateScan.
5. Collect online details about the problem areas or blue-green infrastructure measures and finalize the text at the website for each measure/problem location.
6. Discuss the results. Find out why this measure is taken and the benefits of this measure. What can planners learn from this measure? Can it be implemented elsewhere?

Table 2.1. Blue green measures.

• Bioswale • Green roofs • Rain Gardens • Permeable pavement • Constructed Wetlands • Vertical green (walls) • Green roofs • Type of vegetation in/around the measure	• Park • Playground • Parking space • Photo of surroundings • Age of the measure • Data added with desk research • Designs and dimensions of the measure • Potential secondary functions of the measures

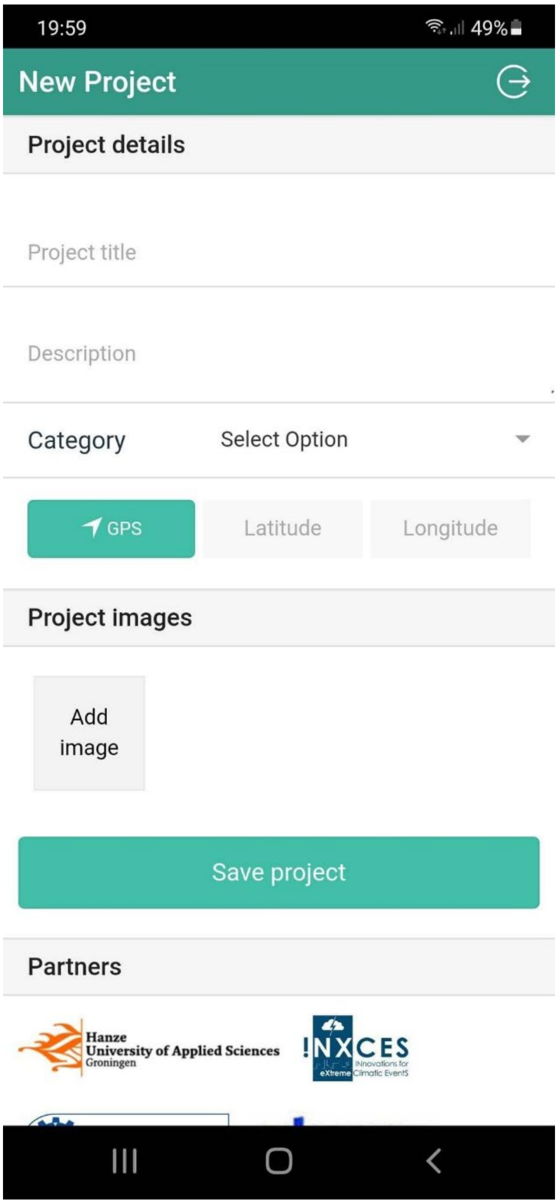

Figure 2.4. ClimateScan app in the app store, start of a new project interface.

If you need help use these tutorials as inspiration:

- 1 min tutorial app ClimateScan: https://youtu.be/VnTYWVU8hPA
- Tutorial ClimateScan desktop: https://www.youtube.com/watch?v=W11ktLkmsRg

ClimateScan activity – new project

The goal of this task is to identify problem areas in your city or neighborhood. Students are to collect data on problems related to climate change and to assess how adaptive the analyzed area is. This assignment is based on field research as well as online research.

Before the fieldwork students are asked to do research on the climate change effects and problems described in local newspapers. Look for the recent incidents of floods, or heat problems, or playgrounds without any shadow, or other environmental problems which can be uploaded to ClimateScan. The next step is field research and taking pictures of places where the problems appear or the solutions were applied to decrease the risk of hazards:

- pictures of water pollution in water bodies in your area - locations that show signs of water pollution (plastic waste, general waste, chemical pollution, other sources of water pollution).
- pictures of locations with (potential) heat stress at public squares and playgrounds - locations such as public squares, school playgrounds, playgrounds general, public places to sit and relax that do not have shadow from trees. The places are exposed to the sun that could result in heat stress in the summer months, and lack of cooling for the public.
- pictures of (lack of) neighborhood / spatial quality - litter in public space, vandalism/graffiti in public space other problems with signs of lack of climate adaptation

Visit the problem locations in your city or neighbourhood. Open the app (see Figure 2.5) and click the GPS button. The coordinates of the project are now registered. Select on your smartphone the 'problem area' in the tab 'category'. Create a project title and write a description. Upload each 5-10 problems in your city or neighbourhood.

The next step is to describe the project and add the verified information illustrated by your photos. Open each item that you uploaded and add (if possible) the following details (see Figure 2.5):

- add a title
- add an additional category
- add a summary
- edit or add images
- edit or add video's
- edit or add files
- edit or add website links
- edit or add your research data
- edit or add a polygon (if applicable)

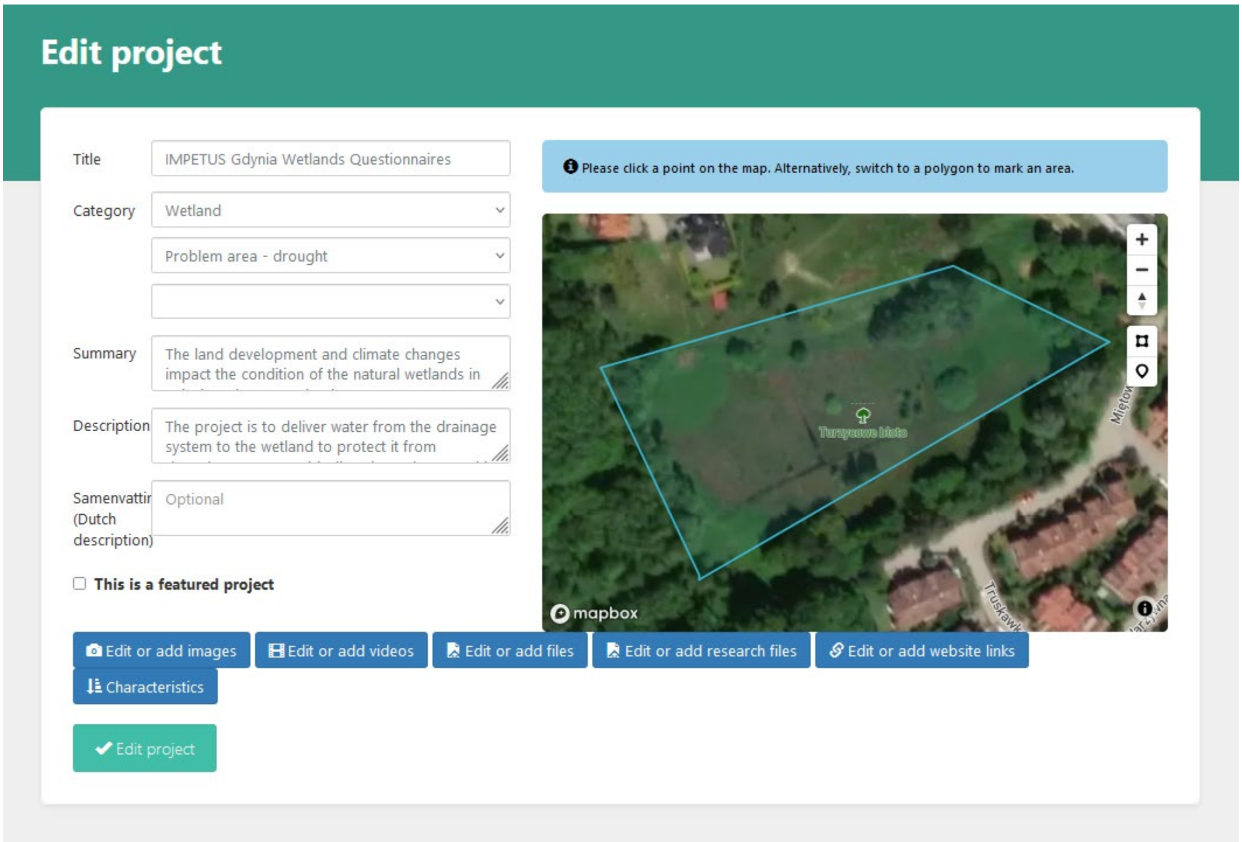

Figure 2.5. Interface for edition of the project data.

DNA of a city

DNA of the city is the visualization of the data that help to get a clear picture of what kinds of measures have been implemented in the city (Figure 2.6).

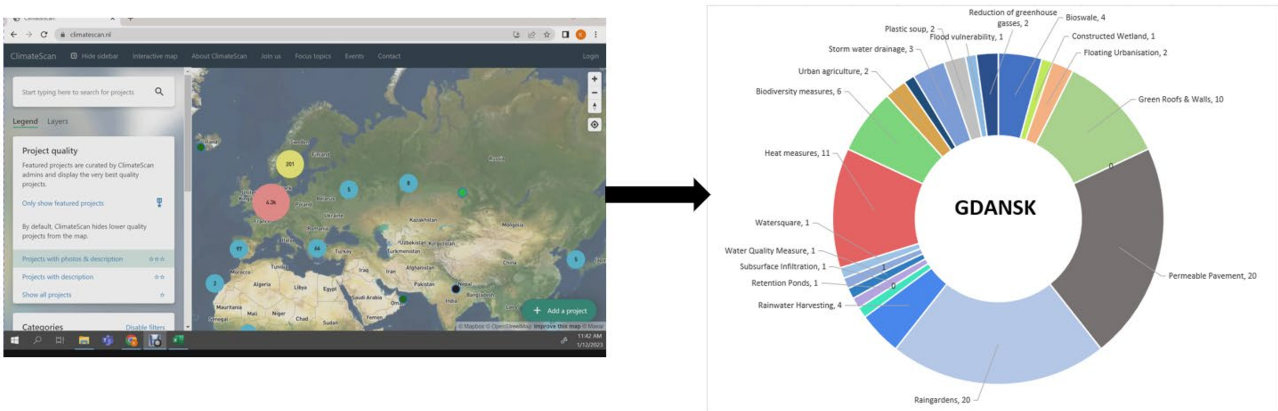

Figure 2.6. Gdańsk DNA.

To create the final report on measures the following steps should be followed:

Step 1: Go to ClimateScan website (www.climatescan.nl)

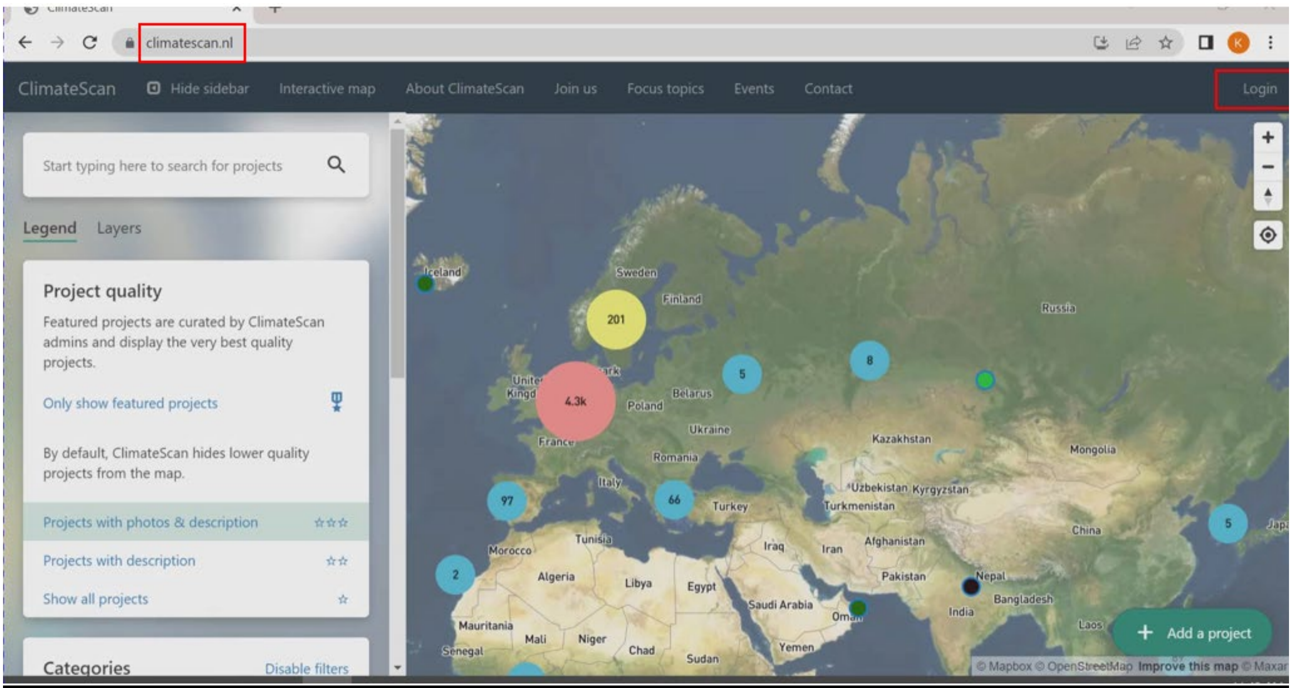

Figure 2.7. The home page of ClimateScan website showing the map viewer and general information. Navigation through the website is possible by clicking the options buttons on the top of the screen.

Step 2: Zoom in the area of interest and make a list with all the existing projects from ClimateScan in that area

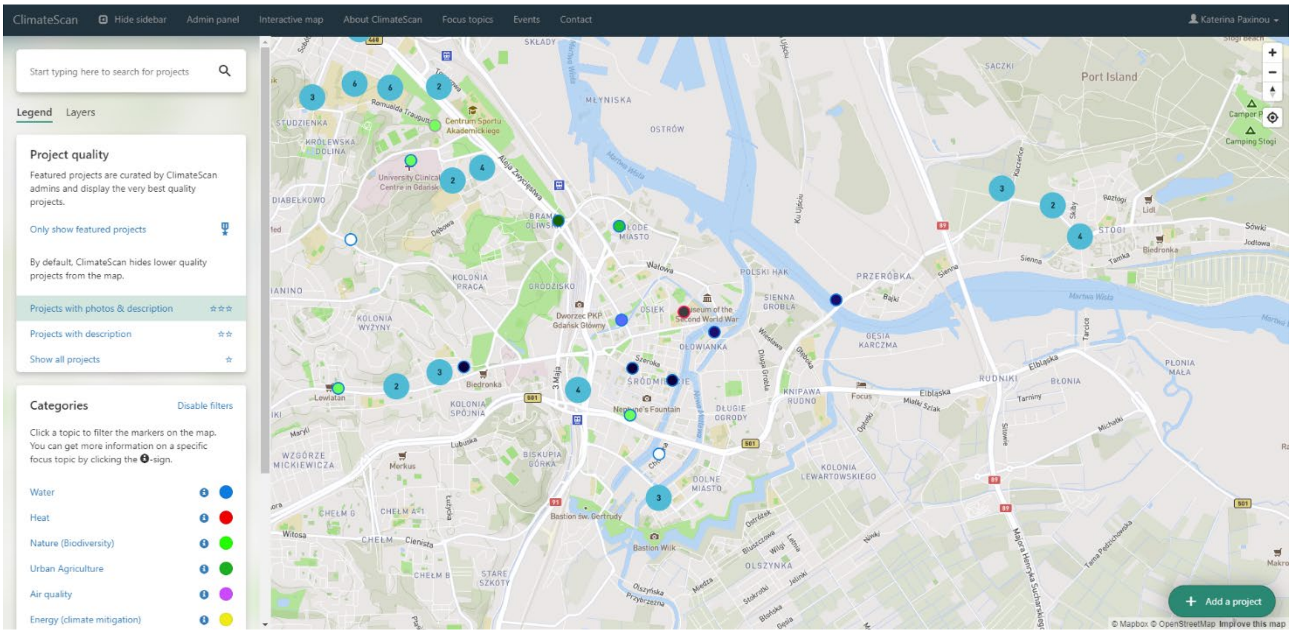

Figure 2.8. By zooming in the map viewer of ClimateScan you can click on specific projects and see more details about this project.

When zooming in the area of interest one can click on specific projects that have been created in that area. When clicking on a project you can see more information about this project from the details panel that pops in the screen as shown in Figure 2.9. The details panel contains among other features, pictures and/or videos, text description with more information about this project and in which category the project is listed on.

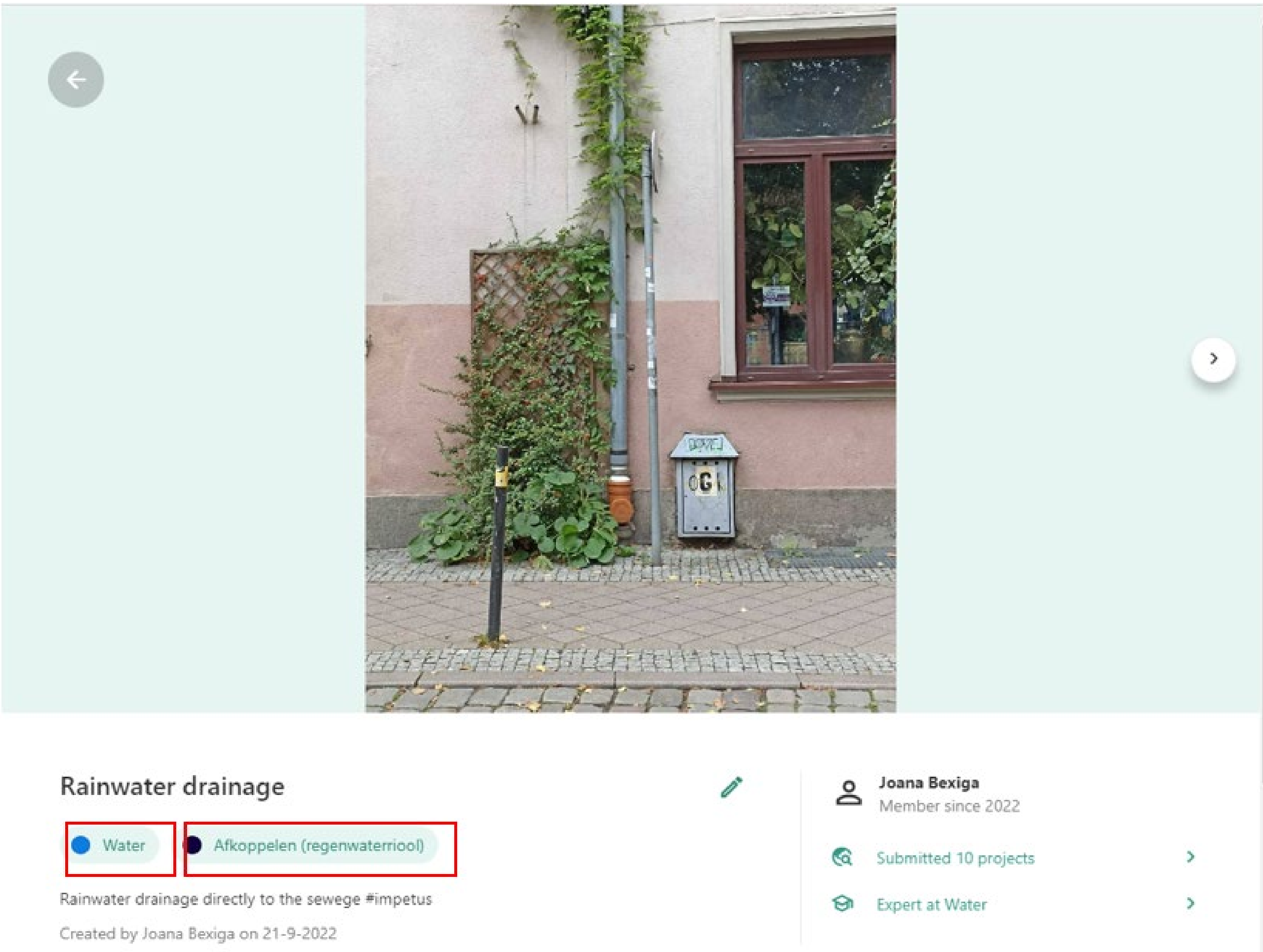

Figure 2.9. When clicking to see the details of a project you can see in which category the project is listed (red squares on the Figure) among other information about this project.

Step 3: Create a list with the existing ClimateScan projects on an excel file

Write down in excel (.xlsx) all the different categories from ClimateScan that projects have been created on the ClimateScan website. You can see in which category every project is listed by looking at the project details as it is explained in Step 2. The list on the .xlsx format should look like the one in Figure 2.10.

City : Gdansk	
Measure Type	Nr
Bioswale	4
Constructed Wetland	1
Floating Urbanisation	2
Green Roofs & Walls	10
Gully Free Roads	0
Permeable Pavement	20
Raingardens	20
Rainwater Harvesting	4
Retention Ponds	1
Water Storage	0
Subsurface Infiltration	1
Water Quality Measure	1
Water Conservation Measures	1
Watersquare	1
Heat measures	11
Biodiversity measures	6
Urban agriculture	2
Energy measures	1
Storm water drainage	3
Plastic soup	2
Flood vulnerability	1
Reduction of greenhouse gasses	2

Figure 2.10. The list in excel format (.xlsx) has information on the project categories for the area of interest and the number of projects listed in that area.

Step 4: Create a doughnut chart with the listed projects

Select the two columns in excel and click on "Insert" → "Insert Pie or Doughnut Chart" → "Doughnut". The doughnut chart should appear on the screen like in Figure 2.11. Information is not very clear on the chart yet. Let's fix the chart to look more understandable and clear.

1		
2		
3	City : Gdansk	
4	Measure Type	Nr
5	Bioswale	4
6	Constructed Wetland	1
7	Floating Urbanisation	2
8	Green Roofs & Walls	10
9	Gully Free Roads	0
10	Permeable Pavement	20
11	Raingardens	20
12	Rainwater Harvesting	4
13	Retention Ponds	1
14	Water Storage	0
15	Subsurface Infiltration	1
16	Water Quality Measure	1
17	Water Conservation Measures	1
18	Watersquare	1
19	Heat measures	11
20	Biodiversity measures	6
21	Urban agriculture	2
22	Energy measures	1
23	Storm water drainage	3
24	Plastic soup	2
25	Flood vulnerability	1
26	Reduction of greenhouse gasses	2
27		
28		
29		
30		

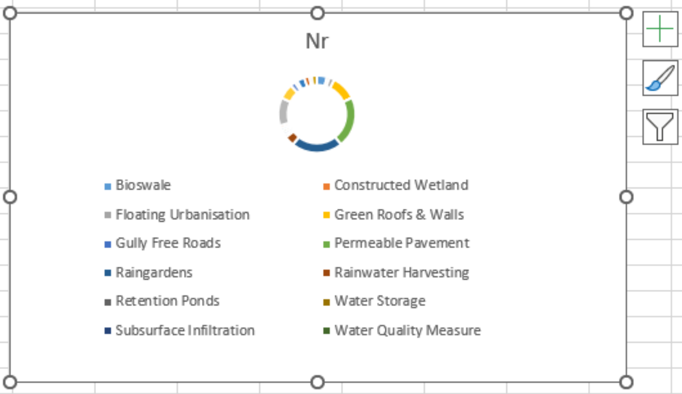

Figure 2.11. This is how the DNA of the city looks in the beginning after creating the doughnut chart. After fixing the chart to look more clear it will get to the final form of Figure 2.6.

Step 5: Go to Format Data Labels

When clicking on the plus (+) sign on the top right corner of the doughnut chart (Figure 2.11) the format labels panel opens up. Choose the "Category Name" and "Value" attributes to be visible as it is shown in the Figure 2.12.

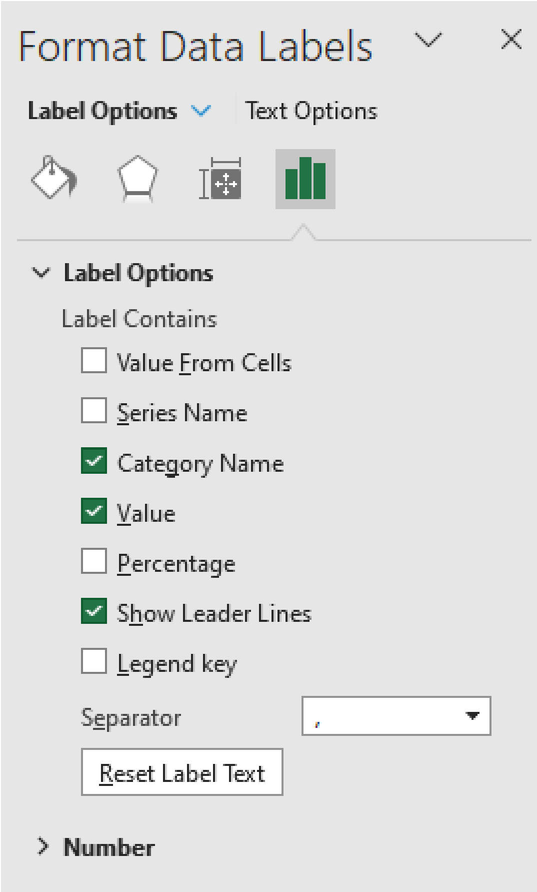

Figure 2.12. The Format Labels panel opens up when clicking on the plus (+) sign that you see on the top right corner of the doughnut chart.

Step 6: Click on the "Series Options" (icon in the red circle of Figure 2.13) and click on "Series "Nr"".

There, select the doughnut hole size to be 50% as it is presented in Figure 2.14.

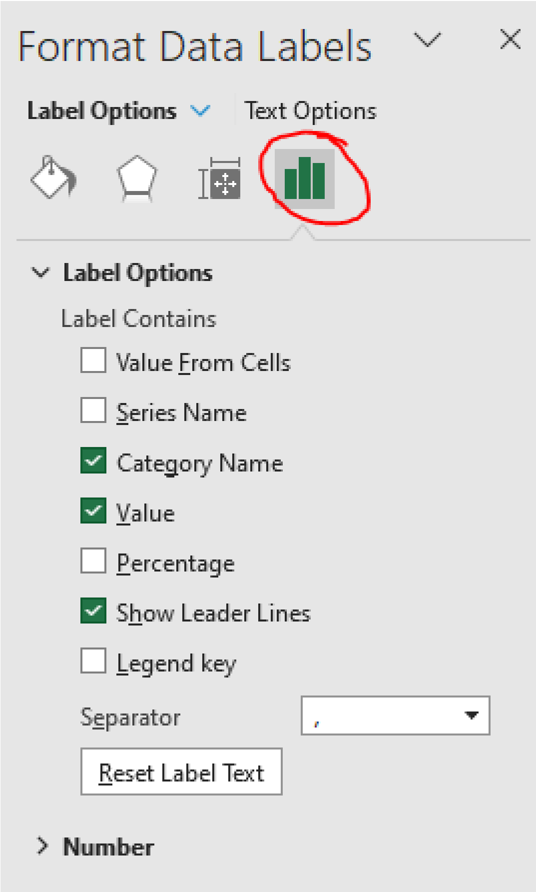

Figure 2.13. Click on “Series Options” to open up the Label options panel.

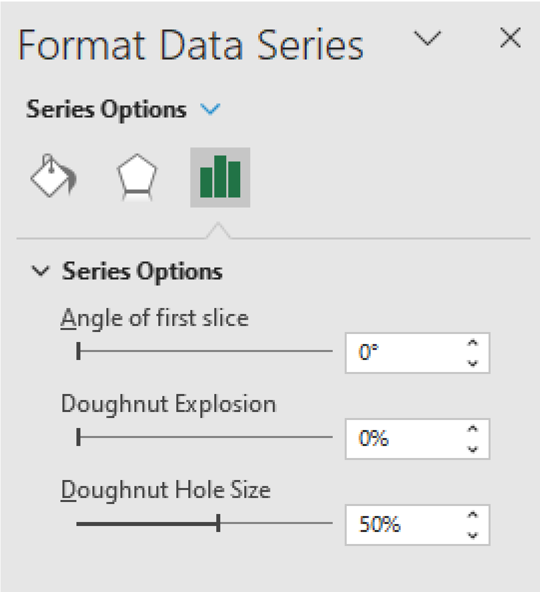

Figure 2.14. Click on the “Series Options” to open up the Series Options panel and adjust the doughnut hole size.

The DNA of the city chart should look something like Figure 2.15 by this step. Information is still not understandable. Insert a textbox in the center of the doughnut hole and write the name of the study area (Figure 2.16).

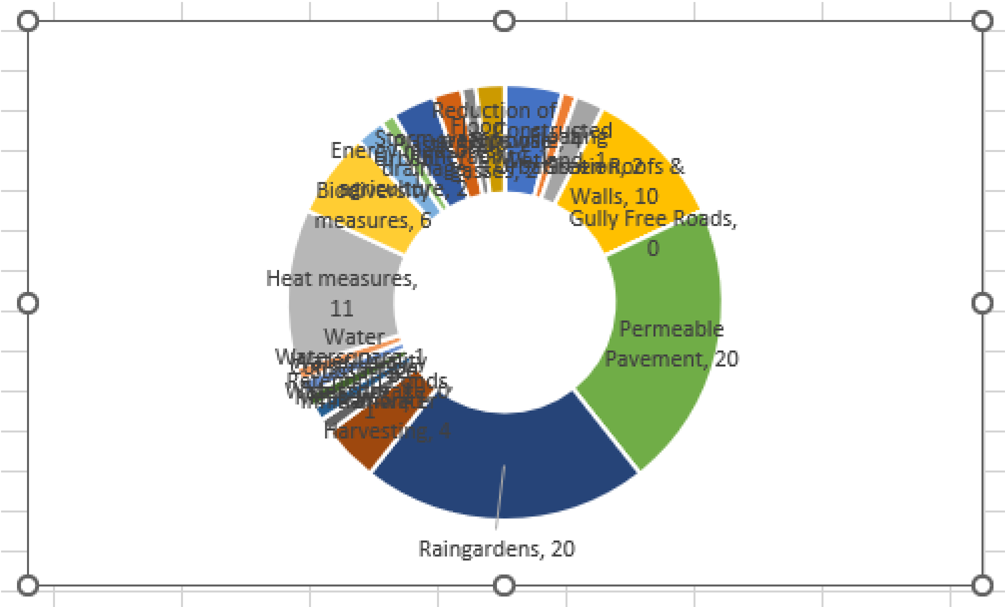

Figure 2.15. After adjusting the hole size of doughnut chart the DNA of the city looks something like this.

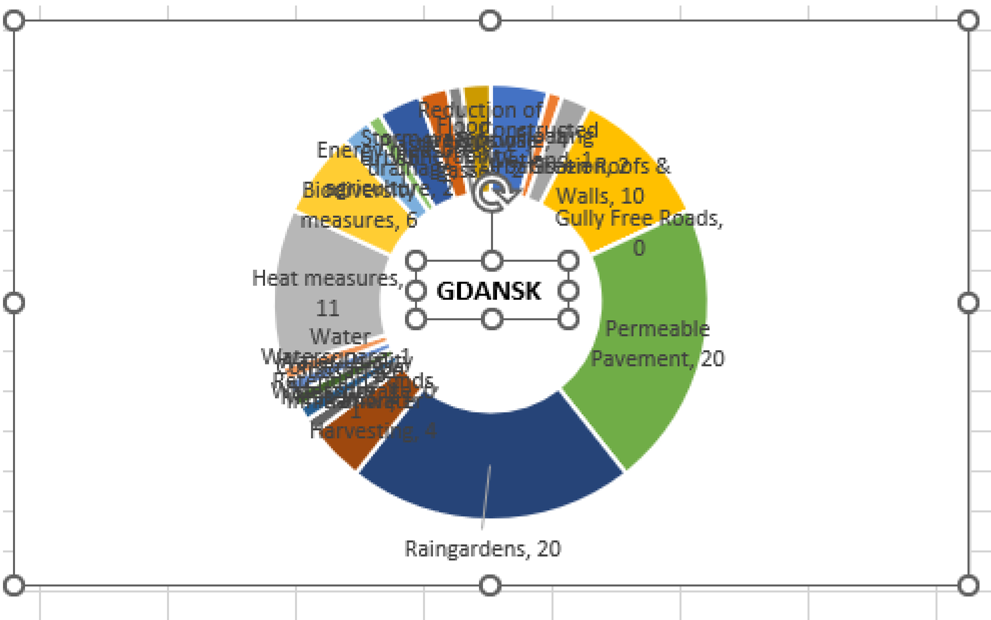

Figure 2.16. Insert a textbox on the center of the doughnut hole to name the DNA of the city.

Adjust the size and the position of the text box by dragging it in the desired position while holding pressed the left click of the mouse to appear on the center of the doughnut hole. Then, select each name category by clicking on it and drag it outside of the chart in the white canvas area of the chart while holding the left click pressed (Figure 2.17).

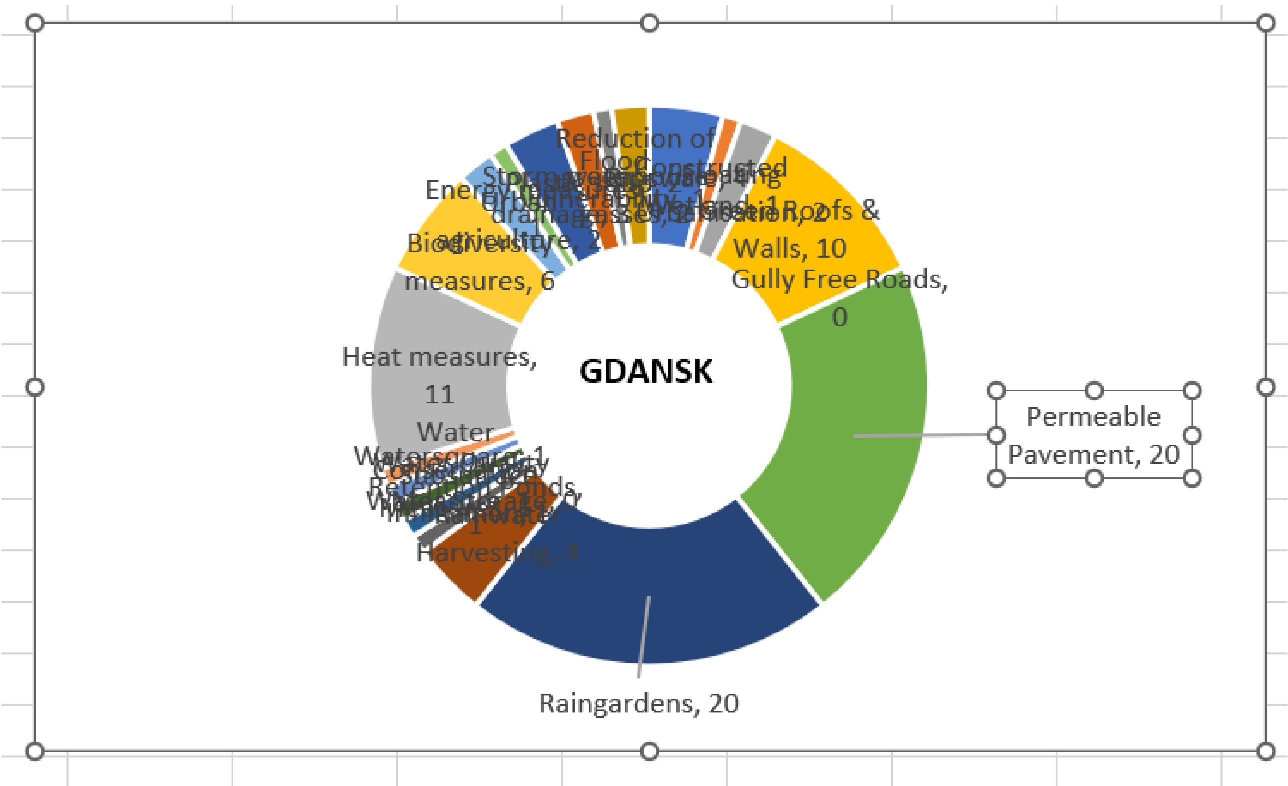

Figure 2.17. Drag each category name outside of the chart area in the white canvas around.

After adding the name of the city in the center of the doughnut hole and dragging all the category names outside of the chart area the DNA of the city is complete and look similar to Figure 2.18.

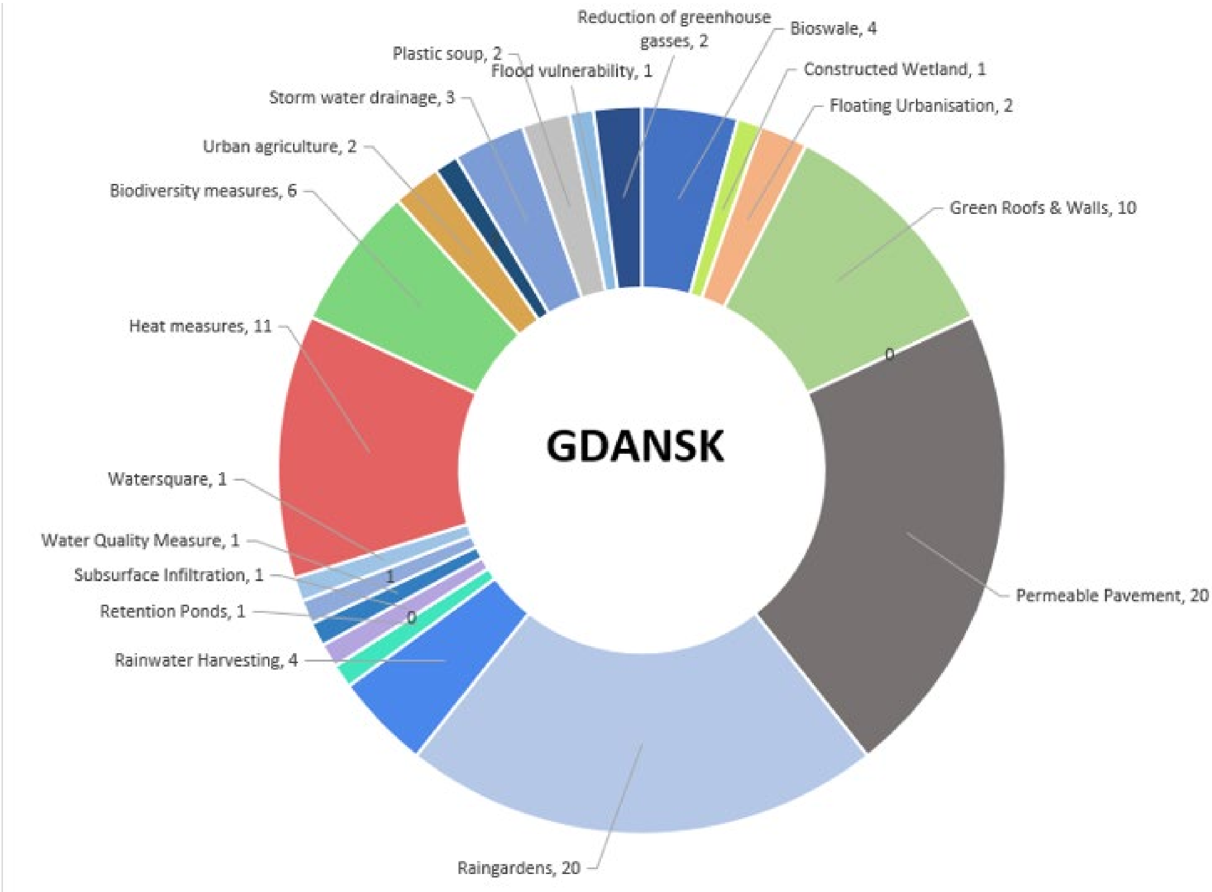

Figure 2.18. After following all the previous steps the DNA of the city should look like this (Gdansk DNA, 2023).

Then it is easy to compare the applied measures at the area at different years or how the citizens or other bodies are engaged in the city scanning (Figure 2.18 and Figure 2.19).

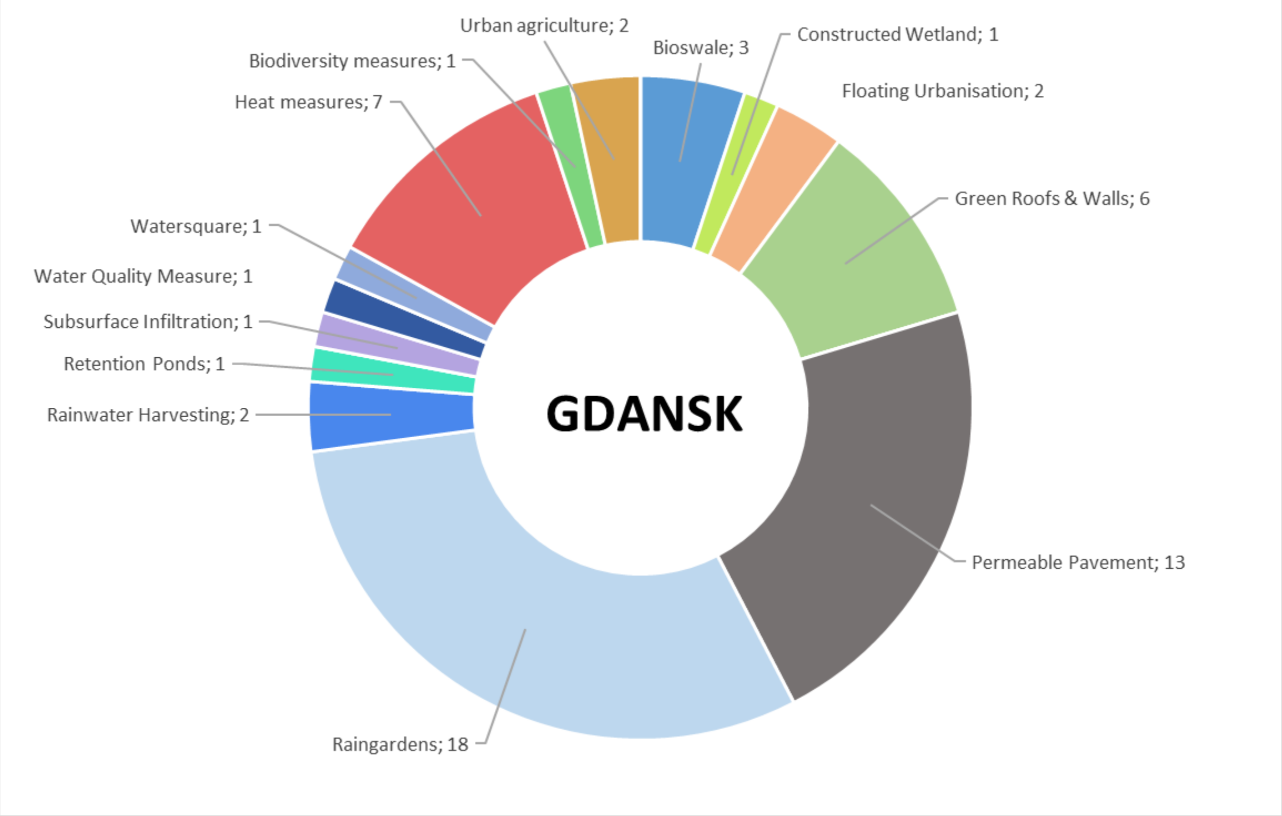

Figure 2.19. Gdańsk DNA 2021.

ClimateScan can give the feedback on the amount of various solutions implemented and described by the database users. These data are as complete and their reliability is based on the users, who scan the city, describe solutions and give the input to the database climatescan.nl. But still they are valuable for the analysis and gaining knowledge on relations between city development, NbS, city climate change problems and strategies to cope with them. Thus, the template of the report on mention above issues was developed which can guide students in processing simple analysis and looking for the solutions among NbS measures to adapt the analysed area. The best results can be achieved considering small neighbourhoods (streets, small districts) but also depending on the amount and value of the data, it can be also used for the cities. In the Tylor-made solutions–report template.doc two cities were presented: Groningen and Gdańsk.

2.5 External materials

See: https://impetus.aau.at/outputs/

Folder: ClimateScan

- ClimateScan instruction.pdf
- Tylor-made solutions-report template.doc

2.6 Literature

Boogaard, F.C.; Venvik, G.; Pedroso de Lima, R.L.; Cassanti, A.C.; Roest, A.H.; Zuurman, A. ClimateCafé: An Interdisciplinary Educational Tool for Sustainable Climate Adaptation and Lessons Learned. Sustainability 2020, 12, 3694.

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3 The IMPETUS application

3.1 Purpose of this app

This measurement tool developed under the IMPETUS project aims to raise urban environmental awareness by reducing the friction in participating in citizen science projects concerning the environment. Anyone can contribute to the research community regarding environmental issues by using this app to collect measurements and other relevant data through small experiments and questionnaires (IMPETUS activities). All activities are designed to be answered without being an expert in this field and without requiring much time. All necessary information for the experiments is shown directly in the app and described so that the procedure can be effortlessly completed for non-experts.

The available measurements (IOs) are:

- Water Biological and Microplastic Pollution (WBaMP),
- Flooding,
- Heat Stress,
- Riverine Plastic Waste Measurements (RPWM),
- Street Scan Scorecards,
- Questionnaires about Neighbourhood & Well-being and Perception of Living Area.

3.2 Operational Guidelines & Prerequisites

- This app uses the database of "ClimateScan", so users must create an account under www.climatescan.nl first. Then they can log in to the app using the credentials (email, password) of their ClimateScan account.
- This app uses GPS location to identify the region where the user is conducting the measurements. It asks for permission to access and save GPS coordinates. Users shall grant access if they want to find their location automated and, in that way, faster on the map. The location module collects the data as anonymously as possible (the app saves no additional user data, only the coordinates of the tracked place) and no additional tracking data without the user's approval. If the users do not grant access to the location permissions, they need to give the location of their measurements on the map manually.
- This app runs only online, so the users must have internet access while they use it, and no data is saved local on the device except for some needed cached data of the session.
- Users should not refresh the app because this will automatically change the session and, therefore, will automatically result in a log-out of the user!

3.3 Instructions (How-to use the app)

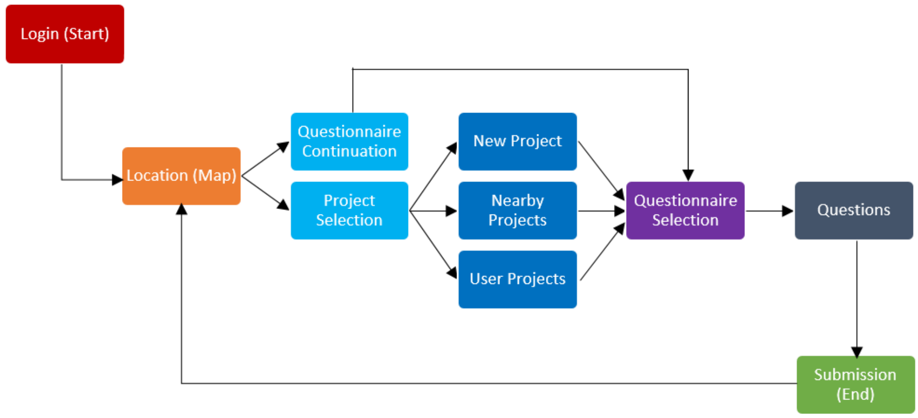


Figure 3.1. flowchart of the app from login to submission

Steps to follow:

1. Login page: Starting page

This is the starting page of the app. The users should fill in the form with the email and password of their **ClimateScan** account. By clicking the button "Let's Go", the user can proceed to step 2.

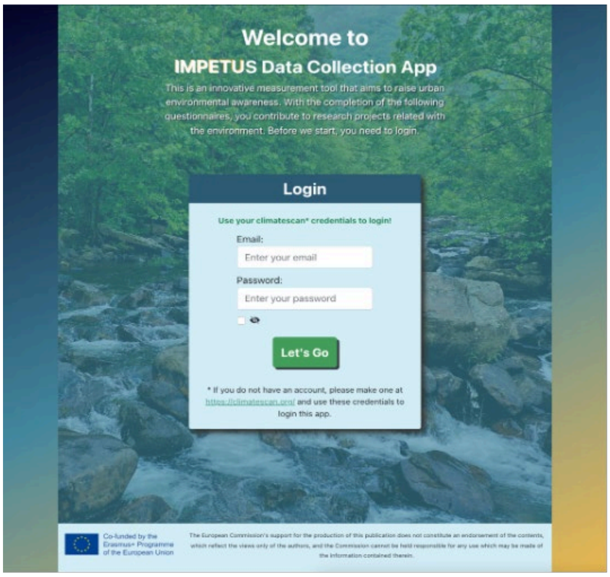


Figure 3.2. login screen

2. Information page

After a successful login, the user will see information with instructions on how to use the app and what steps to follow. By clicking the "Let's Start" button, the user will start the data collection and continue to the 1st step, the location of interest.

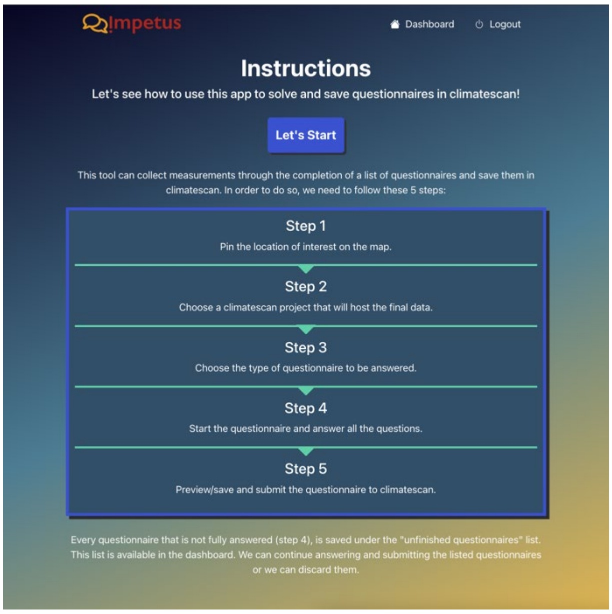


Figure 3.3. instruction screen

3. Location page (1st step)

The app asks the users to give the location of the conducted measurement area. The location shown on the map is the user's location if the user grants permission to use the GPS location of the user's device or the city of Groningen (in the Netherlands) by default. If access is not granted, the user can change the location manually by moving the pin to the appropriate place on the shown map. The selected GPS coordinates are saved by clicking the "Next Step" button, and the user can proceed to step 2 – the project selection.

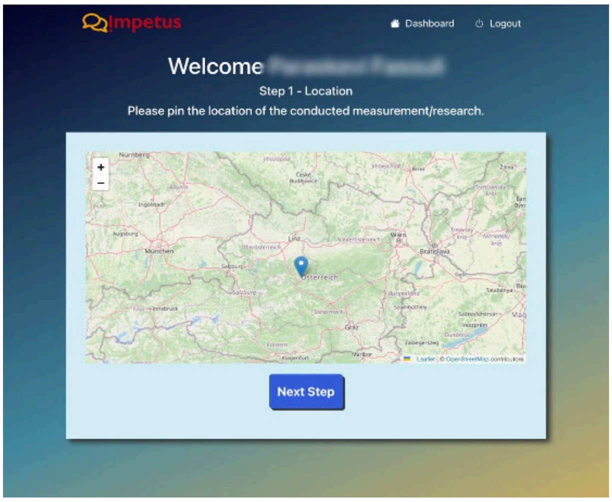


Figure 3.4. location selection screen

4. Dashboard page (2nd step)

After saving the location of the place that the measurements are conducted, the user will see the dashboard page where he can choose between two options (step 4.1 or step 4.2).

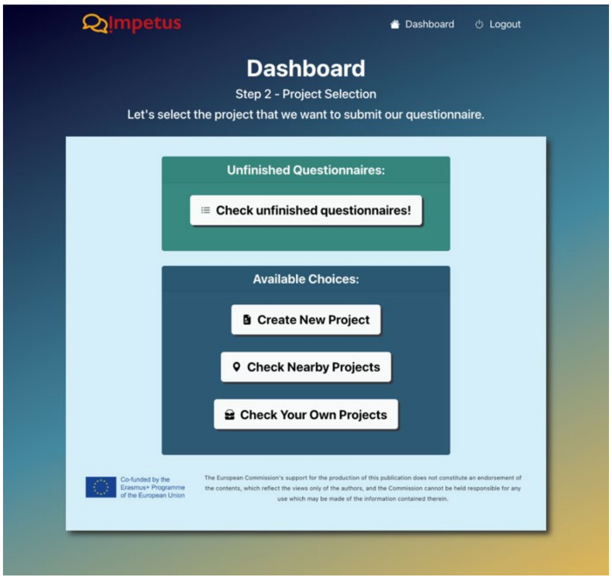


Figure 3.5. dashboard screen

4.1. Questionnaire continuation (Option 1)

By clicking "Check unfinished questionnaires", the user can see a list of all the questionnaires not finished. The list shows all questionnaires still open to be submitted to ClimateScan. The data are saved on the app server and stay there till they get finished or deleted by the user.

Finished questionnaires are submitted to ClimateScan and deleted from the app server and, therefore, cannot be changed afterwards! By selecting one from the list, the user can continue to fill it up and finally submit it to the ClimateScan server. On this screen, there is also the option of deleting one if the user does not want to finish it. Be aware that deleted data cannot be restored.

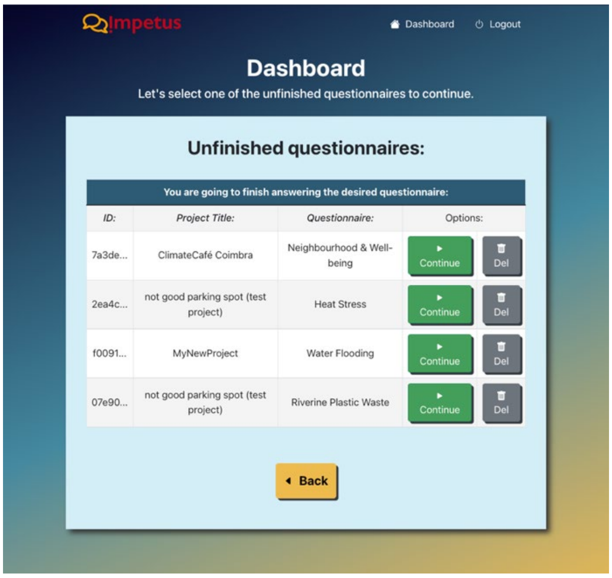


Figure 3.6. Questionnaire continuation interface.

4.2. Project Selection (Option 2)

The users can also start a new questionnaire by choosing between the three options described in detail in 4.2.1, 4.2.2, or 4.2.3. Please notice that newly created projects from this app will use the pin coordinates from step 1 as the location. Polygon areas are available only through project creation directly in ClimateScan.

4.2.1. Create a new project (Option 1)

By clicking the "Create New Project" button, the users will see a form that asks for a project title, a category, and a short description. All fields are mandatory! By filling it in and clicking the "Continue" button, the users will create a new project. This project is saved on the app server and not in ClimateScan until the users submit a questionnaire under it, which happens in the next step (step 3, described in detail in chapter 5, "Questionnaire Selection").

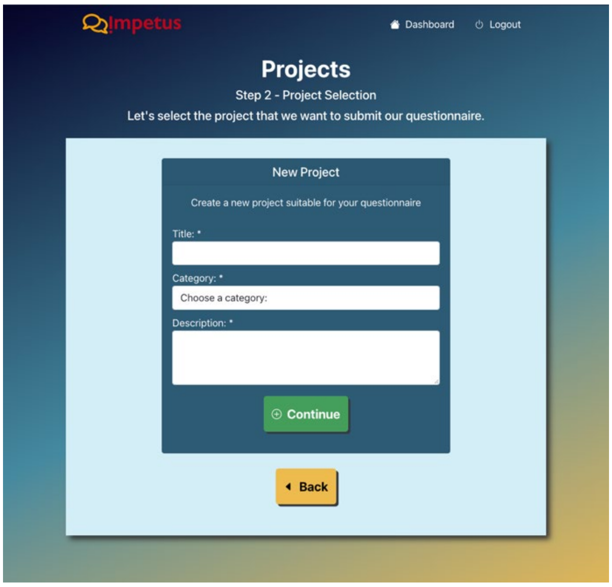


Figure 3.7. "Create a New Project" screen

4.2.2. Select a nearby project (Option 2)

By clicking the "Check Nearby Projects" button, the user will see a list of the ten nearest projects available nearby the GPS / pin location the users selected in step 1. These projects already exist in ClimateScan. The list shows the project's title and the distance from the user's location. By clicking the "Select" button, the users will choose the selected project to add a questionnaire to it, which can be selected in the following screen (step 3, described in detail in chapter 5, "Questionnaire Selection").

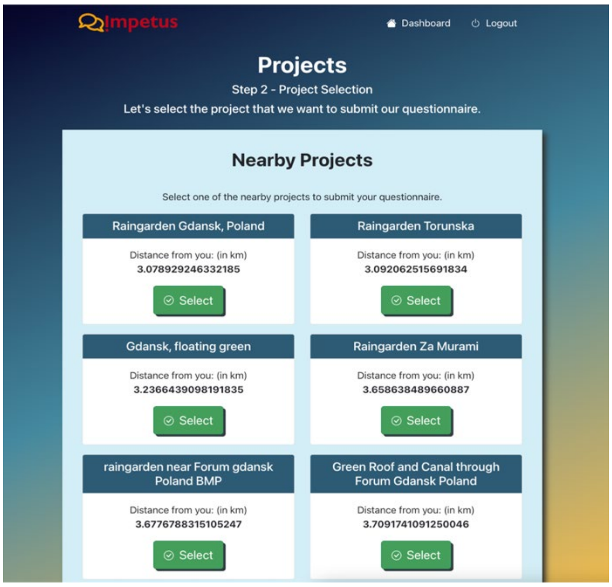


Figure 3.8. "Check Nearby Projects" screen

4.2.3. Select one of your own projects (Option 3)

By clicking the "Check Your Own Projects" button, the users will see a list of the projects that the users have already created before in ClimateScan. If the users have created a project without linking a questionnaire, for whatever reason, this project can also be foudn in this screen. Additional to the ability to select those "unfinished" projects, the option of deleting them is given on this screen. The list contains the title of the project, the category it belongs to and a link to check them directly in ClimateScan. By clicking the "Select" button, the users will be able to add a questionnaire to this project, proceeding to step 3. (described in detail in chapter 5, "Questionnaire Selection").

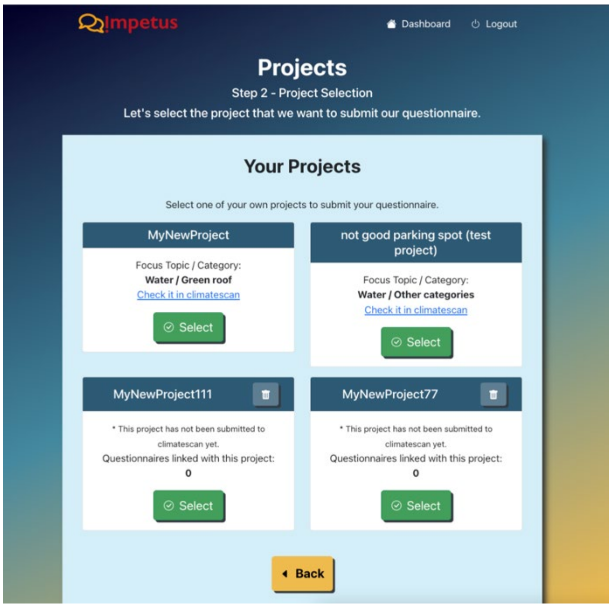


Figure 3.9. "Check Your Own Projects" screen

5. Questionnaire Selection (Step 3)

After selecting the appropriate project to submit a questionnaire, the users will see a list of the available questionnaires they can choose to fill out.

- Water Biological and Microplastic Pollution (WBaMP),
- Flooding,
- Heat Stress,
- Riverine Plastic Waste Measurements (RPWM),
- Street Scan Scorecards,
- Questionnaire about Neighbourhood,
- Questionnaire about Well-being and Perception of Living Area.

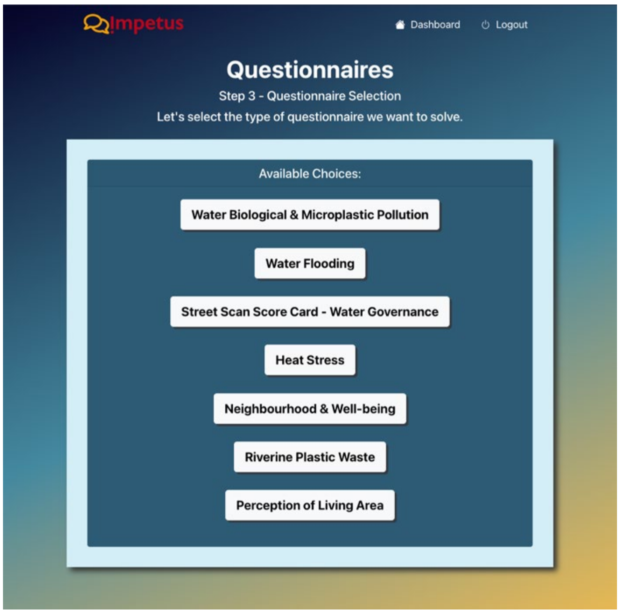


Figure 3.10. questionnaire selection screen

A summary screen shows the users the selected information until this point to ensure that everything is selected as wished. There is the option to make the answered questionnaire publicly available under the selected project **in ClimateScan** or to keep it private under the selected project and therefore only visible for the users themself and the group of scientists in ClimateScan with administrator rights. The users can start the questionnaire by proceeding to step 4.

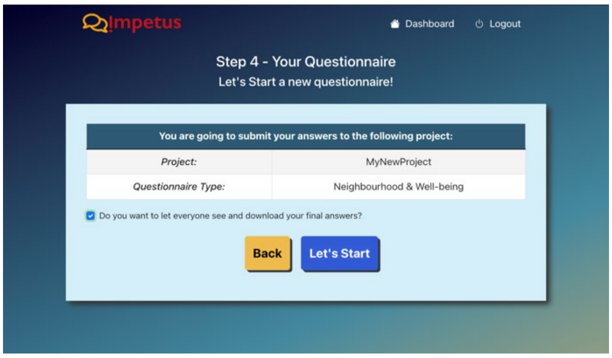


Figure 3.11. summary screen before start of the questionnaire

6. Questionnaire

This step is the actual questionnaire. The users can answer the questions shown one by one. The answer is saved by clicking the "Next" button, and the next question is shown. By clicking the "Back" button, the users can see the previous question, including the given answer. If an image is asked to be uploaded, the users can see a preview of the selected image to ensure it is correct. When a new measurement is asked, the users can see relevant information and instructions on measuring safely and correctly.

At the end of the questionnaire, the user automatically goes to step 5 – the preview.

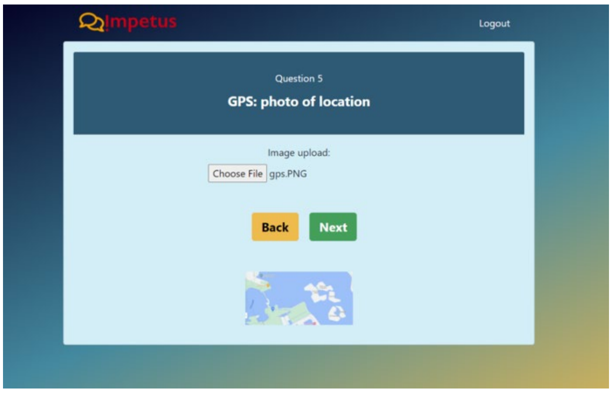


Figure 3.12. Example of the image upload screen

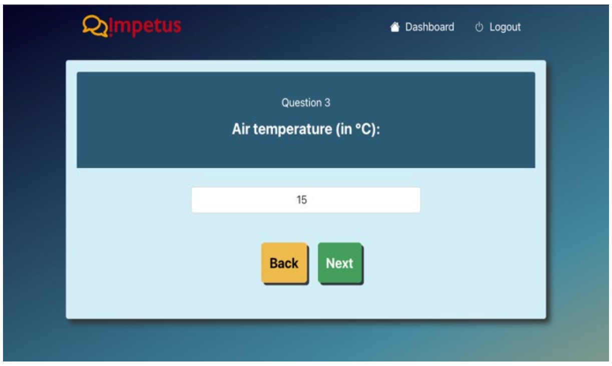


Figure 3.13. Example of a text / value input screen

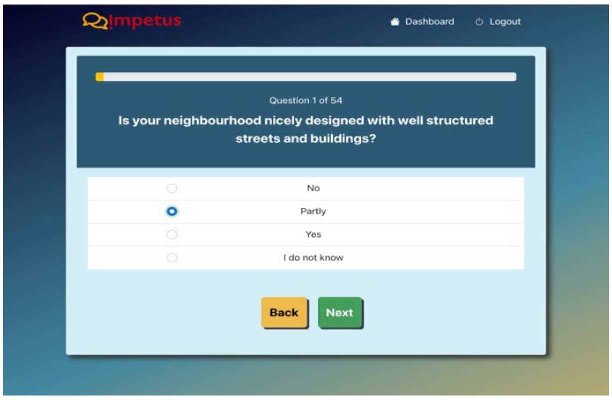


Figure 3.14. Example of a choice selection screen

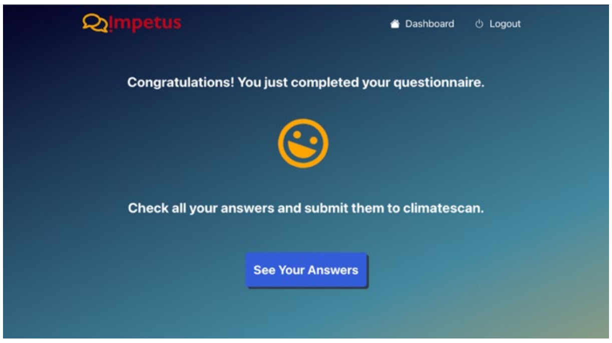


Figure 3.15. questionnaire end screen

7. Submission of results

In the preview panel, the users can see all the answers given on the questionnaire. Additionally, there is also a "Save" button to save the answer locally on their device. The "Submit Your Answers" button sends the answers to ClimateScan under the selected project. It also deletes all the data from the app server if ClimateScan acknowledges the reception of the data.

The users can also start a new questionnaire or push these answers to the "unfinished questionnaire" list by clicking the "Dashboard" button or the "Logout" button.

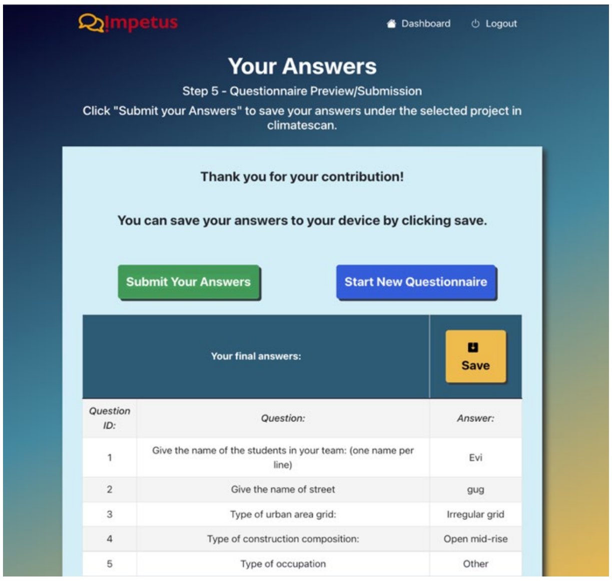


Figure 3.16. preview of the answers screen with possibility to save and submit

The link to the app can be found at the IMPETUS website (https://impetus.aau.at) or directly under https://impetus.climatescan.org/. The link to the GitHub repository containing the app's source code can also be found at https://impetus.aau.at.

See: https://impetus.aau.at/outputs/

Folder: The IMPETUS application

- The IMPETUS application instruction.pdf

4 Water biological and microplastic pollution

4.1 Introduction

The main aim of the IMPETUS IO1 MP WATER BIOLOGICAL AND MICROPLASTIC POLLUTION is to find simple measurement tools for easy classification of the water pollution index.

Currently, there is a lack of measurement instructions for citizens to evaluate the quality of the water bodies. Only qualified staff and researchers are able to measure the basic parameters of the water such as pH, conductivity, total suspended solids, color, turbidity or dissolved oxygen. On the other side, we are faced with a growing awareness of the inhabitants on environmental issues, climate changes, and surface waters such as lakes, ponds, streams, rivers pollution problems.

General knowledge on:

What is biological pollution?

Untreated domestic and industrial wastewaters discharged into water bodies. The heavily polluted water bodies can contain very high concentrations of nutrients, heavy metal and organic pollutants. The high nitrogen (N) and phosphorus (P) concentrations have a definite ecotoxicological effect on the extent of eutrophication when entered into e.g. lake water (Yin et al., 2018).

What is microplastic pollution?

Recent studies assume that microplastics fall within the range of 5 mm - 1 μm. Microplastics contamination of the environment is considered a potential threat to human health and can exist for hundreds of years in nature because they are not decomposable in any way. Despite plastic being widely used for a long time, it is only recently that its by-product microplastics have become a central topic of discussion around the world. This is not because they are good for society, but mainly because of their potential impact on the above- ground and underground environment. Therefore, a review of the potential impact of microplastics on the environment is necessary (Chia et al., 2021).

Relation between biodiversity, human health, climate changes and water pollution

Cities as well as different water bodies are becoming increasingly vulnerable to climate change. Following changes also affect biodiversity due to growing urbanisation, therefore inhabitants well-being and air quality severely decreased. More frequent flooding due to an increase in cloud bursts, or drought, forces action to be taken within already heavily urbanised areas where there is a competing demand for different land usage (Boogaard et al., 2020).

4.2 Expected results

A simple methodology for the classification of water using a defined water pollution index of any water reservoir, which can be used by nonprofessional researchers has been developed. Using this method one can:

- achieve knowledge of the impact of parameters on the surface water quality,
- gain practical knowledge how to evaluate real water during real-time monitoring,
- understand the connection with water surrounding and its influence on the condition of the basic water parameters.

For the skills achieved can be included:

- know how to measure the basic parameters of the surface water,
- know how to make a basic evaluation of the surface water condition,
- ability to do measurements with safety precautions,
- ability to use of theoretical knowledge in practical work,
- ability to find and use tools to replace laboratory equipment.

4.3 Measurement procedure

Field investigation – location of the sampling area

Open area with water reservoir (standing or flowing).

Easy and safe access for sample collection (4 possible locations for sample collection).

Prior the measurements, there is a need to:

- investigate the reservoir field,
- analyse the reservoir type (natural/artificial),
- analyse the catchment area (urban/rural),
- the reservoir bed needs to be evaluated (entrenchment),
- investigate of the potential sources of pollutants
- investigate the potential impact of human activities (discharges, solid waste).

For gathering information, the preferable method is to walk along the water body, if safety precautions are not allowed for field investigation you can use google maps and satellite photos.

Figure 4.1. Example of the sampling location – Slupia River dam (Photo: Barbara Śniatała).

Safety precautions

1. Please dress appropriately to the weather conditions.
2. Make sure that you understand the measurement procedure, *if you don't – ask your teacher before proceeding with the activity.*
3. *Perform only those experiments authorised by your teacher.*
4. Make sure that the water level is not above 30 cm (hardened bottom, safety access with galoshes).
5. Team of two persons at least is recommended.
6. Do not enter places that are not allowed.
7. ***Do not move away from the group without informing the teacher.***

Equipment

Measurements are based on simple methods and measurement equipment, which is avaible at our houses:

disposable gloves, galoshes, 4 glass beakers / jars (well washed), string, white paper, (coffee) filter, funnel, stopwatch, smartphone with camera, thermometer, (universal indicator paper, compact precision portable meter for students).

Figure 4.2. Example of equipment for measurements.

When the place is selected **describe sampling conditions.** Use Excel file:

Folder: Water biological and microplastic pollution / INDEX data sheet.xls

The following data should be added to the excel file:

1. **Season**
   a) spring
   b) summer
   c) autumn
   d) winter

2. **Time of the day**
   a) morning (8.00am – 11.00am)
   b) noon (11.00am – 2.00pm)
   c) afternoon (2.00pm – 4.00pm)
   d) evening (4.00pm – 8.00pm)

3. **Air temperature (put the temperature)**

____

4. **Precipitation events (past 48h) (choose one dominant option)**
   a) what type? (rain / snow)

   ____

   b) intensity? (drizzle / heavy rain)

   ____

Describe basic information about water body:

1. Type of reservoir (choose one of the options)

a) standing water
   type (natural / artificial)

   ____

b) flowing water
   type (lake, pond, sea / reservoir)

   ____

2. Type of the catchment

a) urban (centre of the city, close to main street)

b) semi-urban (outskirts of the city)

c) rural (close to agriculture areas)

d) semi-rural (scattered housing)

e) other

3. Type of reservoir entrenchment

a) none (natural course is maintained)

   ____

b) partly – what type? (fascine, gabions, concrete)

   ____

c) full – what type? (fascine, gabions, concrete)

   ____

d) other

   ____

4. Potential sources of the pollutants (give comments)

a) are there any discharges, connection with pipes?

____

b) are there any connections with other water bodies?

____

c) nearness of an industrial plant (what type?)

____

d) other

____

Methods for measurements

Organoleptic / Colorimetric method

Organoleptic method (sensory method) – quality assessment via senses – sight, smell, taste, and touch. The advantage of this method is its availability, the disadvantage – the subjectivity of the assessment.

Colorimetric method – a technique consisting in comparing the color of the analysed solution with the color of the reference solution. The reference solution is a solution of known concentration.

Parameters of the sample – color, turbidity, suspended solids, odour.

Results are described with words after observation / smelling of the sample.

Microplastic pollution and other suspended solids

Suspended solids are measured with simple filters (e.g. coffee filter) and funnel. Additionally, the time of filtration could be measured to define the amount of suspended solids. To evaluate the character of the suspended solids, the observation of the filter is recommended (for qualified staff – microscope observation).

Note! *Organoleptic method (sensory method) – quality assessment via senses – sight, smell, taste, and touch. The advantage of this method is its availability, the disadvantage – the subjectivity of the assessment.*

Sampling

Figure 4.3. Preparation for sampling.

Collect the samples with a glass beaker / jar. How deep: surface water or deep water, how far from edge: approx. 1 m. Preferable place for sampling is a bridge across the stream.

- **I.** Make sure that place is safe.
- **II.** Make sure that water level is not above 30 cm (hardened bottom, safety access with galoshes).
- **III.** Do not take measurements alone. Team of two persons at least is recommended.
- **IV.** Tie a string around the well washed jar.
- **V.** Holding a string immerse the jar in water.
- **VI.** Pull the jar out of the water and start observation. Jar should be filled to ¾ volume, next close the jar and shake for 30 s.
- **VII.** Immediately after sample collection, carefully smell the water inside the jar and describe the following parameter.

Answer a question and put score from brackets to table in excel file (water index page).

6. Odour quantity (intensity analysis)

- no odour (1)
- perceptible (2)
- intensive (3)

7. Odour quality (description analysis)

- plant (e.g. soil, grass, cucumber, flower, aromatic) (1)
- putrid (e.g. musty, mould, faecal, hydrogen sulphide – rotten eggs) (2)
- specific (e.g. chemical, petroleum, phenol, kerosene, tar, gasoline) (3)

Note! *Water bodies which are clean should have no odour or perceptible smell all others could indicate anaerobic decay or pollution which disqualify water in terms of its quality.*

- **VIII.** Put the jar on the white paper with text and compare your sample with images.

8. Turbidity

- no turbidity < 3 NTU (1)
- acceptable turbidity 3 – 6 NTU (1)
  (e.g. if you can read an instruction, or see fingerprints through the sample)
- turbid 6 – 15 NTU (2)
  (e.g. if you cannot read and instruction, or can see palm without fingerprints through the sample)
- very turbid / no visibility > 15 NTU (3)
  (e.g. if you cannot see anything though the sample)

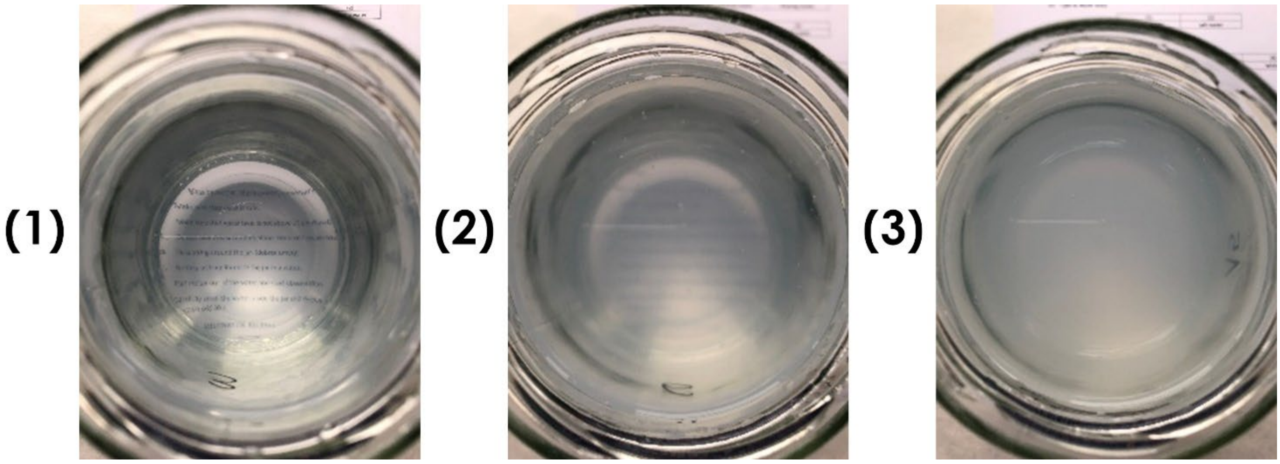


Figure 4.4. Examples of the turbidity scale.

Note! *Turbidity could be of both natural and anthropogenic origin but in both cases turbidity could be medium for the development of microorganisms and bacteria. Human eye can notice turbidity above 3 NTU (Nephelometric Turbidity Unit) level, on that basis the evaluation scale was prepared.*

IX. *Watch the sample for 15 minutes and try to observe behaviour of suspended solids.*

9. Suspended solids-presence: Do you notice suspended solids?

- yes (1)
- no (1)

10. Suspended solids-sedimentation: If yes, does it fall easy (fast)?

- yes (1)
- no (2)

11. Suspended solids-floating particles (a): Are there floating particles?

- yes (1)
- no (1)

12. Suspended solids-floating particles (b): If yes, try to evaluate the type of floating particles.

- organic / natural (e.g. leaf, pollen, stick) (0)
- specific / anthropogenic (e.g. plastic, oil) (2)

13. Suspended solids-character: Mark image similar to your sample after 15 minutes of sedimentation

- if you see two separate phases clearly (1)
  (sediment in the bottom of the vessel
- if you see three phases vaguely (2)
  (most likely there is colloidal fraction, which do not undergoes sedimentation)
- if you do not see a difference after 15 minutes (3)
  (suspended solids are not undergoes sedimentation)

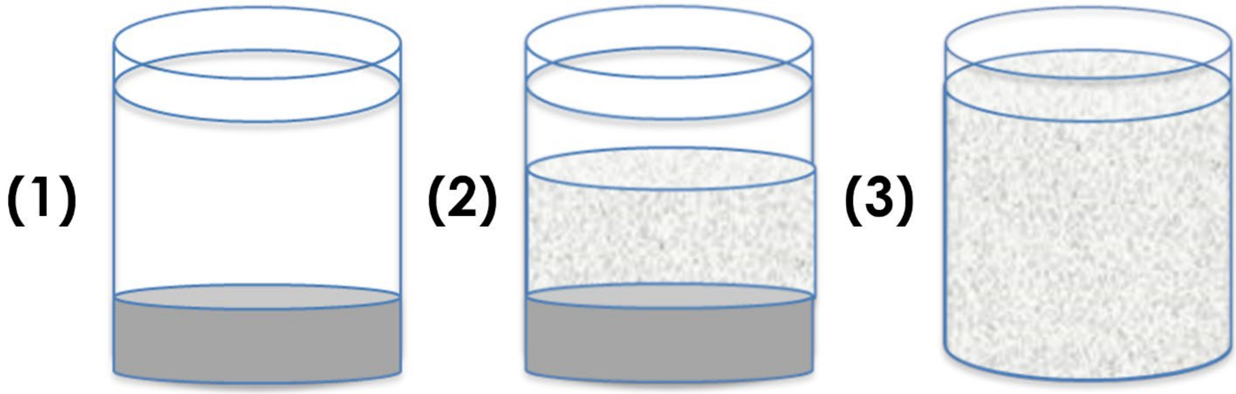


Figure 4.5. Examples of the suspended solids character.

Note! *Too high concentration of the suspended solids may reduce the access of sunlight and interfere with the photosynthesis process. Suspended solids could be both of natural and anthropogenic origin, varied from season (algae bloom) and weather condition (storm events).*

Figure 4.6. Filtration of the sample and color analysis before and after filtration.

X. Prepare a second jar with a funnel inside.
XI. Put the coffee filter in the funnel.
XII. Prepare a stopwatch and start carefully pouring water from the first jar to a second one with the stopwatch on.
XIII. Note the time of filtration and try to define the amount of suspended solids. Tip: filtration time of 1 litre of potable water is approximately 2 minutes.

14. Filtration time

- ~ 2 minutes (1)
- 3 min – 5 min (2)
- over 5 min (3)

XIV. Put the jar on the white paper and compare your sample with images.

15. Color (after filtration)

- no color < 20 mg Pt/L (1)
- 20 – 40 mg Pt/L (2)
- 40 – 60 mg Pt/L (3)
- > 60 mg Pt/L (4)

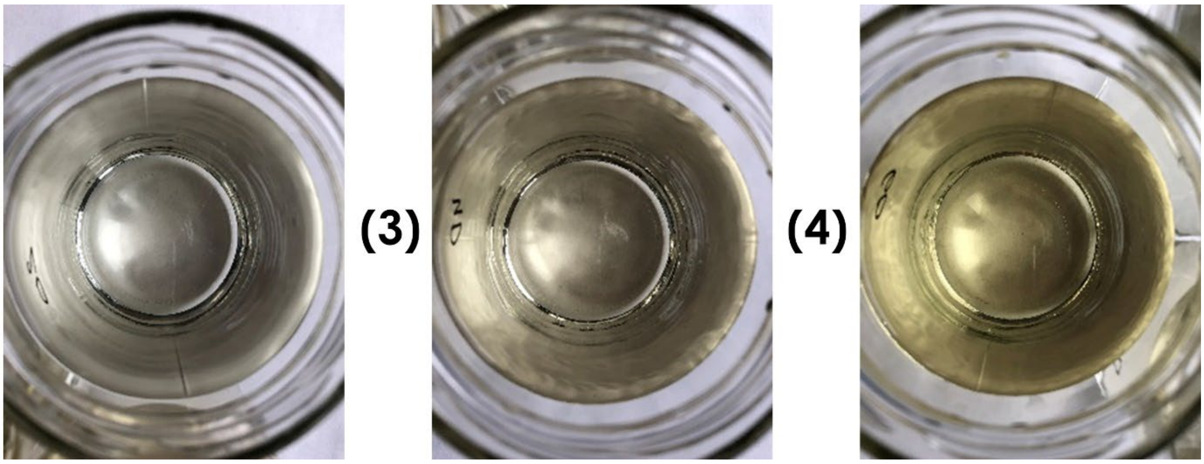


Figure 4.7. Examples of the color scale.

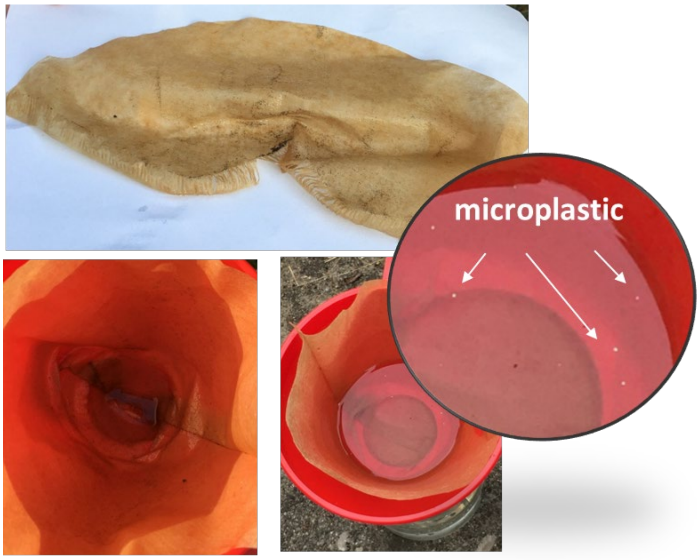


Figure 4.8. Examples of the suspended solids presence – microplastic in the form of glitter.

XV. After pouring all of the water, start observation of the filter leftovers on the white card and try to describe the following parameter:

16. Suspended solids – presence
Are there any suspended solids on the filter?

- no (0)
- yes (1)

17. Suspended solids-structure (after filtration) – assessment and origin

- mineral / sand (1)
- organic / muddy (1)
- specific (plastic, petroleum) (3)

18. Suspended solids – color (after filtration)

- sandy (1)
- brown (1)
- green (3)
- black (4)

Note! *Both color and smell of the water are assessed as acceptable or NOT acceptable. While the turbidity undergoes the quantity assessment because it is strictly linked to microbiological quality of the water body.*

Contact method

Parameters of the sample – pH, temperature, conductivity.

Samples are collected with a glass beaker / jar.

Parameters are measured with a compact precision portable meter.

Temperature could be measured with a thermometer (for non-educated).

pH could be measured with an universal indicator paper (for non-educated).

- **I.** Put the thermometer into the water and wait until the temperature is stable. Note the results.
- **II.** (For students) Prepare a compact precision portable meter with a pH / temperature probe and put it into the water.
- **III.** Wait until the result is stable. Note the results.

19. Water temperature

____

Note! *Water temperature can vary during the season and day. A substantial difference in water and air temperature may indicate anthropogenic pollution (discharge of wastewater or cooling water from industry), if the water temperature is much higher than the air temperature resulting from the season and day.*

- **IV.** Put the universal indicator paper into the water and wait until it is whole wet. Wait about 15 seconds and compare universal indicator paper color with scale color. Note the results.
- **V.** (For students) Prepare a compact precision portable meter with pH probe and put it into the water.
- **VI.** Wait until the result is stable. Note the results.

20. pH

- **a)** 6.5 – 8.0 (1)
- **b)** 8.0 – 9.0 (2)
- **c)** < 6.5 or > 9.0 (3)

Note! *Natural water could have pH in a range of 6.5 – 8.0. Natural water is capable of buffering the pH towards alkalinity.*

Figure 4.9. pH measurement with indicator paper scale.

VII. (For students) Prepare a compact precision portable meter with conductivity probe and put it into the water.

VIII. Wait until the result is stable. Note the results.

21. Conductivity (0.1 – 10 mS/cm)

Figure 4.10. Conductivity measurement with compact precision portable meter.

4.4 Data collection protocol & methodology

Table 4.1. Point evaluation scale.

LP	Name	Method	Reporting Units	Operating Range	Resolution	Minimum Sample Frequency	Raw Data Collection Frequency	Quality rating (range of values)					Data Reporting
								Very low (very bad)	Low	Medium	High	Very high (very good)	
6	**Odour (quantity)**	organoleptic	description			1	1	3		2	1 (7=0)*		
7	**Odour (quality)**	organoleptic	description			1	1	3		2	1		
8	**Turbidity**	organoleptic	description			1	1	3		2	1	1	
9	**Suspended solids-presence**	organoleptic	y/n			1	1	1			1 (10-13=0)**		
10	**Suspended solids-sedimentation**	organoleptic	y/n			1	1	2			1		
11	**Suspended solids-floating particles (a)**	organoleptic	y/n			1	1	1			1		
12	**Suspended solids-floating particles (b)**	organoleptic	description			1	1	2			0		
13	**Suspended solids-character**	organoleptic	description			1	1	3		2			
14	**Filtration time**	time	minutes			1	1	3		2			
15	**Color – after filtration**	organoleptic	description			1	1	4	3	2			
16	**Suspended solids-presence (after filtration)**	organoleptic	y/n			1	1	1			0(17,18=0)***		
17	**Suspended solids-structure**	organoleptic	description			1	1	3		1	1		
18	**Suspended solids-color**	organoleptic	description			1	1	4	3	1	1		
20	**pH**	contact	-			1	1	3		2	1		
22	**Dissolved oxygen concentration**	chemical	description			1	1	5	4	3	2	1	

Explanations

***(7=0)** if there is **no odour** then odour (quality) = 0.

****(10-13=0)** if there are **no suspended solids** then sedimentation, floating particles (a, b), character = 0.

*****(17,18=0)** if there are **no suspended solids after filtration** then structure, color = 0.

Table 4.2. Remarks for the boundary conditions.

LP	Name	Method	Reporting Units	Minimum Sample Frequency	Raw Data Collection Frequency	Quality rating (values)	Remarks
6	**Odour (quantity) – intensivity**	organoleptic	description	1	1		if there is **no odour** (1) the odour (quality) = 0
7	**Odour (quality) – description**	organoleptic	description	1	1		if odour (quality) + odour (quantity) ≥ 5 → **WBP INDEX = VERY LOW**
8	**Turbidity**	organoleptic	description	1	1		
9	**Suspended solids-presence**	organoleptic	y/n	1	1		if there is **no suspended solids** (1) then 10.sedimentation, 11,12.floating particles (a,b), 13.character = 0
10	**Suspended solids-sedimentation**	organoleptic	y/n	1	1		
11	**Suspended solids-floating particles (a)**	organoleptic	y/n	1	1		
12	**Suspended solids-floating particles (b)**	organoleptic	description	1	1		
13	**Suspended solids-character**	organoleptic	description	1	1		
14	**Filtration time**	time	minutes	1	1		
15	**Color – after filtration**	organoleptic	description	1	1		if color = 4 → **WBP INDEX = VERY LOW**
16	**Suspended solids-presence (after filtration)**	organoleptic	y/n	1	1		if there is **no suspended solids after filtration** then 17.structure, 18.color = 0
17	**Suspended solids-structure (after filtration)**	organoleptic	description	1	1		
18	**Suspended solids-color (after filtration)**	organoleptic	description	1	1		if suspended solid-color = 4 → **WBP INDEX = VERY LOW**
19	**Water temperature**	contact	°C	1	1	-	**not included for evaluation**
20	**pH**	contact	-	1	1		
21	**Conductivity**	contact	mS / cm	1	1	-	**not included for evaluation**
22	**Dissolved oxygen concentration**	chemical	description	1	1		if dissolved oxygen concentration = 5 → **WBP INDEX = VERY LOW**
			Water biological pollution INDEX			**0**	

Boundary conditions for **VERY LOW** water biological pollution (WBP) INDEX:

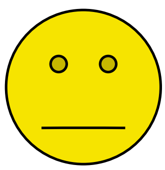
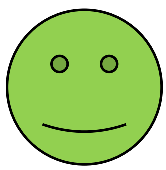
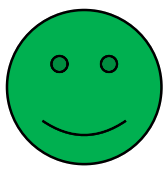
1) if odour (quality) + odour (quantity) ≥ 5
2) if color = 4
3) if suspended solid – color = 4
4) if pH = 3
5) if dissolved oxygen concentration = 5

Final results for Water biological pollution INDEX

Table 4.3. Water biological pollution INDEX evaluation point scale.

	Name	Index equations	Range of values	Quality rating (range of values)				
				Very low (very bad)	**Low**	**Medium**	**High**	**Very high (very good)**
6	Water quality INDEX	total points	40 – 7	40 – 36	35 – 30	29 – 20	19 – 14	13 – 7

Table 4.4. Water biological pollution INDEX evaluation graphical scale.

Very low (very bad) 40 – 36	Low 35 – 30	Medium 29 – 20	High 19 – 14	Very high (very good) 13 – 7
				

Example

Table 4.5. Example results for basic information about sampling condition.

Basic information about sampling conditions		
1.	**Season**	
	a)	spring
	b)	summer
	c)	autumn
	d)	winter
2.	**Time of the day**	
	a)	morning (8.00am – 11.00am)
	b)	noon (11.00am – 2.00pm)
	c)	afternoon (2.00pm – 4.00pm)
	d)	evening (4.00pm – 8.00pm)
3.	**Air temperature**	
	9 °C	
4.	**Precipitation events (past 48 h)**	
	what type? (rain / snow)	
	description	Rain
	intensity? (drizzle / heavy rain)	
	description	Light (<5 mm)

Table 4.6. Example results for basic information about water body.

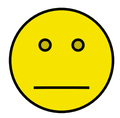
Basic information about water body		
1.	**Type of reservoir**	
	a)	standing water
		type (natural / artificial):
	description	Natural lake
		type (lake, pond, sea / reservoir):
	description	Oxbow lake by the river Labe
	b)	flowing water
		type (natural / artificial):
	description	
		type (stream, river / channel):
	description	
2.	**Type of the catchment**	
	a)	urban (centre of the city, close to main street)
	description	
	b)	semi-urban (outskirts of the city)
	description	
	c)	rural (close to agriculture areas)
	description	Located within riparian forest in countryside
	d)	semi-rural (scattered housing)
	description	
	e)	other
	description	

3.		**Type of reservoir entrenchment**
	a)	none (natural course is maintained)
	description	Natural bed
	b)	partly – what type? (fascine, gabions, concrete)
	description	
	c)	full – what type? (fascine, gabions, concrete)
	description	
	d)	other
	description	
4.		**Potential sources of the pollutants**
	a)	are there any discharges, connection with pipes?
	description	
	b)	are there any connection with other water bodies?
	description	During the flooding there was a possible connection with a big nearby river (Labe).
	c)	**nearness of an industrial plant (what type?)**
	description	**Large chemical factory (toxical chemicals of all types)**
	d)	other
	description	

Table 4.7. Example point results for water biological pollution INDEX.

LP	Name	Method	Reporting Units	Minimum Sample Frequency	Raw Data Collection Frequency	Quality rating (values)	Remarks
6	**Odour (quantity) – intensivity**	organoleptic	description	1	1	2	if there is **no odour** (1) the odour (quality) = 0
7	**Odour (quality) - description**	organoleptic	description	1	1	1	if odour (quality) + odour (quantity) ≥ 5 → **WBP INDEX = VERY LOW**
8	**Turbidity**	organoleptic	description	1	1	3	No visibility
9	**Suspended solids-presence**	organoleptic	y/n	1	1	1	if there is **no suspended solids** (1) then 10.sedimentation, 11,12.floating particles (a,b), 13.character = 0
10	**Suspended solids-sedimentation**	organoleptic	y/n	1	1	2	No visible sedimentation
11	**Suspended solids-floating particles (a)**	organoleptic	y/n	1	1	1	Yes
12	**Suspended solids-floating particles (b)**	organoleptic	description	1	1	0	Natural origin of particles
13	**Suspended solids-character**	organoleptic	description	1	1	3	No difference after 15 minutes
14	**Filtration time**	time	minutes	1	1	1	1.1x of drinking water filtration time
15	**Color – after filtration**	organoleptic	description	1	1	3	if color = 4 → **WBP INDEX = VERY LOW**
16	**Suspended solids-presence (after filtration)**	organoleptic	y/n	1	1	0	if there is **no suspended solids after filtration** then 17.structure, 18.color = 0
17	**Suspended solids-structure (after filtration)**	organoleptic	description	1	1	1	Organic / muddy origin
18	**Suspended solids-color (after filtration)**	organoleptic	description	1	1	3	if suspended solid-color = 4 → **WBP INDEX = VERY LOW**
19	**Water temperature**	contact	°C	1	1	-	**not included for evaluation**
20	**pH**	contact	-	1	1	-	
21	**Conductivity**	contact	mS / cm	1	1	-	**not included for evaluation**
22	**Dissolved oxygen concentration**	chemical	description	1	1		if dissolved oxygen concentration = 5 → **WBP INDEX = VERY LOW**
			Water biological pollution INDEX			**21**	MEDIUM water quality (also regarding the tests not performed)

Medium
29 – 20



4.5 Final results description

For the presentation of the methodology to your students you can use WBaMP presentation.pptx. During measurements, the results will be collected in WBaMP INDEX data sheet.xlsx manually or via app and send the results to the Climate Scan database**.** Students should prepare a full report of data collection and data analysis, including photo documentation of sampling and measurements conduction. Report should include analysis of weather conditions and area and reservoir description (+ photos). The last step should include conclusions and summing up regarding the result of Total water quality INDEX. For the knowledge income verification use the WBaMP pre-post test to print.doc.

4.6 External materials

See: https://impetus.aau.at/outputs/

Folder: Water biological and microplastic pollution

- WBaMP instruction.pdf
- WBaMP INDEX data sheet.xlsx
- WBaMP pre-post test to print.doc
- WBaMP pre-post test key.doc
- WBaMP presentation.pptx

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5 Flooding

5.1 Introduction

Water has always been present in human life. Unfortunately, floods and droughts are now a serious problem, especially in urbanized areas. Climate changes that we observe every day have a significant impact on changes in water management. Flood risk is related to many aspects. The most global is the observed gradual rise in the level of seas and ocean. This may result in gradual flooding of low-lying areas of the coastal. Water will remain there permanently, absorbing the space we are used to living in. It is worth remembering that our decisions influence the quality of life of future generations. Rivers and reservoirs are a more common threat, Figure 5.1 showing the frequency of floods. This shows that they most often occur not in the coastal zone, but in the middle of the continent. Weather anomalies are observed more and more often, including precipitation characteristics transform into local flash floods. Rivers and reservoirs are a more common threat. Probably everyone has seen the rainwater flowing down his/her streets. This is because the catchment area is unable to absorb the enormous amount of water that falls on it in a short time. In the first place, all depressions are flooded, rivers and reservoirs are filled, and rainwater drainage pipes are flooded. When this is not enough, water floods the basements of building, streets, and entire neighbourhoods. Therefore, nowadays water management is becoming one of the most important tasks of engineers.

Water management is an important task not only for the authorities, but also for every citizen. To be able to manage water, it is necessary to monitor the amount of water in rivers, reservoirs, urban and green areas. Measurement networks already exist in many cities to control and manage water resources. However, there are still too few of them. So, it is important that not only the authorities but also city citizens can easily monitor the water level in their cities, settlements or houses. Such actions make it possible to anticipate upcoming threats and, if possible, prevent them. And if this not possible, the allow to limit their negative effects. Then, thanks to such measurements, today each of us can protect our city, housing estate or home against the adverse effects of water.

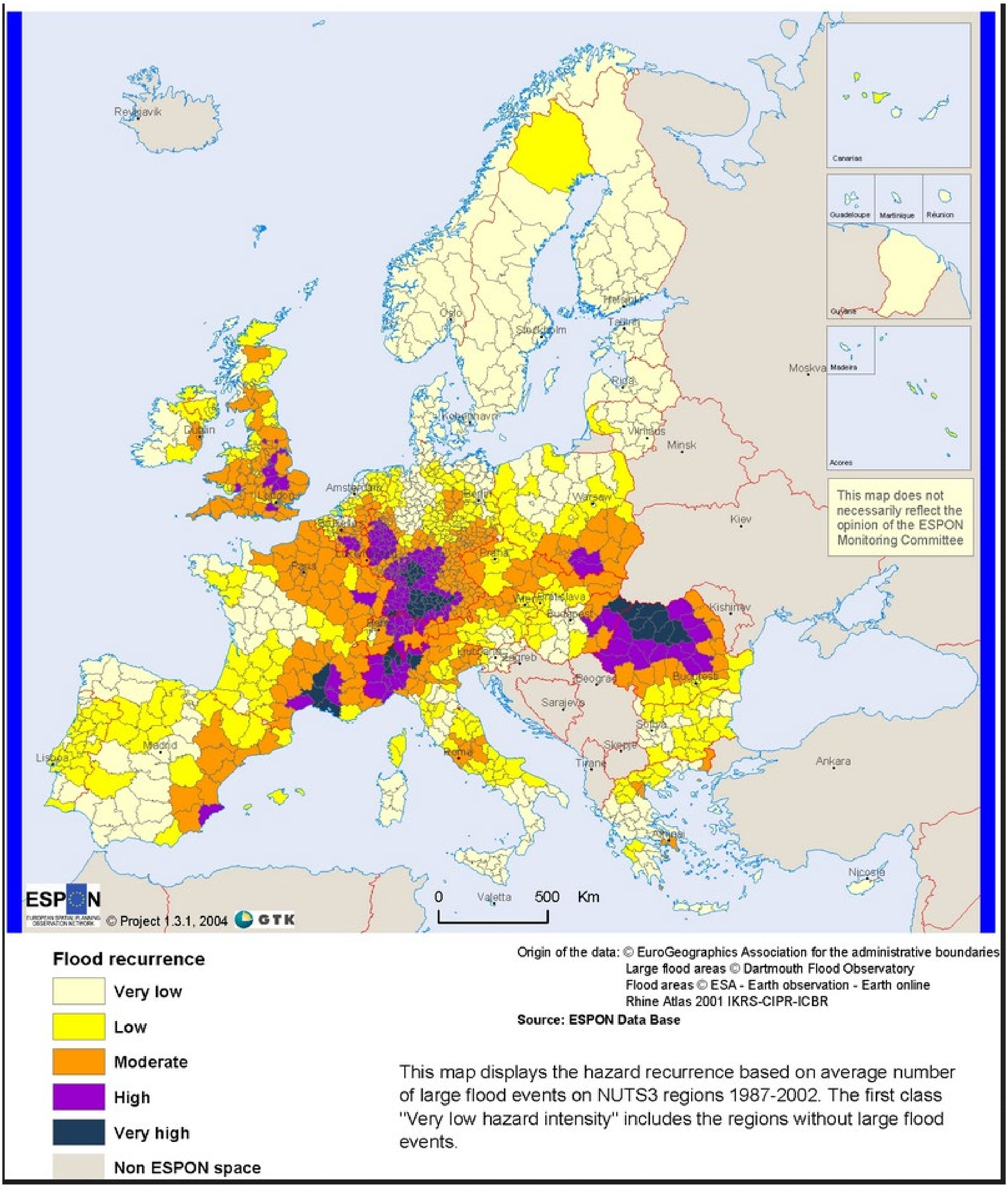


Figure 5.1. Flood frequency map (source: European Spatial Planning Observation Network (ESPON)).

5.2 Flood risk maps

Law basics

In 2006, the European Water Directors decided to establish a European exchange circle on flood mapping (EXCIMAP). European Union has adopted a European Directive on the Assessment and Management of Flood Risks [3], which aims to reduce the adverse consequences on human health, the environment, cultural heritage, and economic activity associated with floods in the Community. This Directive sets out the requirement for the Member States to develop three kinds of products:

- a preliminary flood risk assessment,
- flood mapping, with a distinction between flood hazard maps and flood risk maps,
- flood risk management plans.

According to this, flood hazard maps shall cover the geographical areas which could be flooded using at least three scenarios: low, medium, and high probability of occurrence. For each scenario the flood extent, the water depths or water level, as appropriate, and where appropriate the flow velocity, have to be represented on the maps (look at Figure 5.2 and Figure 5.3).

Rising sea levels

Rising sea level is not the most urgent problem, but it is worth visualizing its consequences. It is worth checking whether our hometown may suffer, it can be done with the „calculators" such as flood map: https://www.floodmap.net/ (Figure 5.2).

Rivers flooding

Flood risk maps can be found in European collections (for example: https://data.jrc.ec.europa.eu/collection/id-0054) as well as in local resources – Figure 5.3 (country, province, or city scale). River related floods are the most often and are caused by:

- intensive rainfall and / or snowmelt,
- ice jam, clogging,
- collapse of dikes or other protective structures.

Figure 5.2. An example of the effects of a sea level rise of 1, 5 and 10 meters (source: https://www.floodmap.net/).

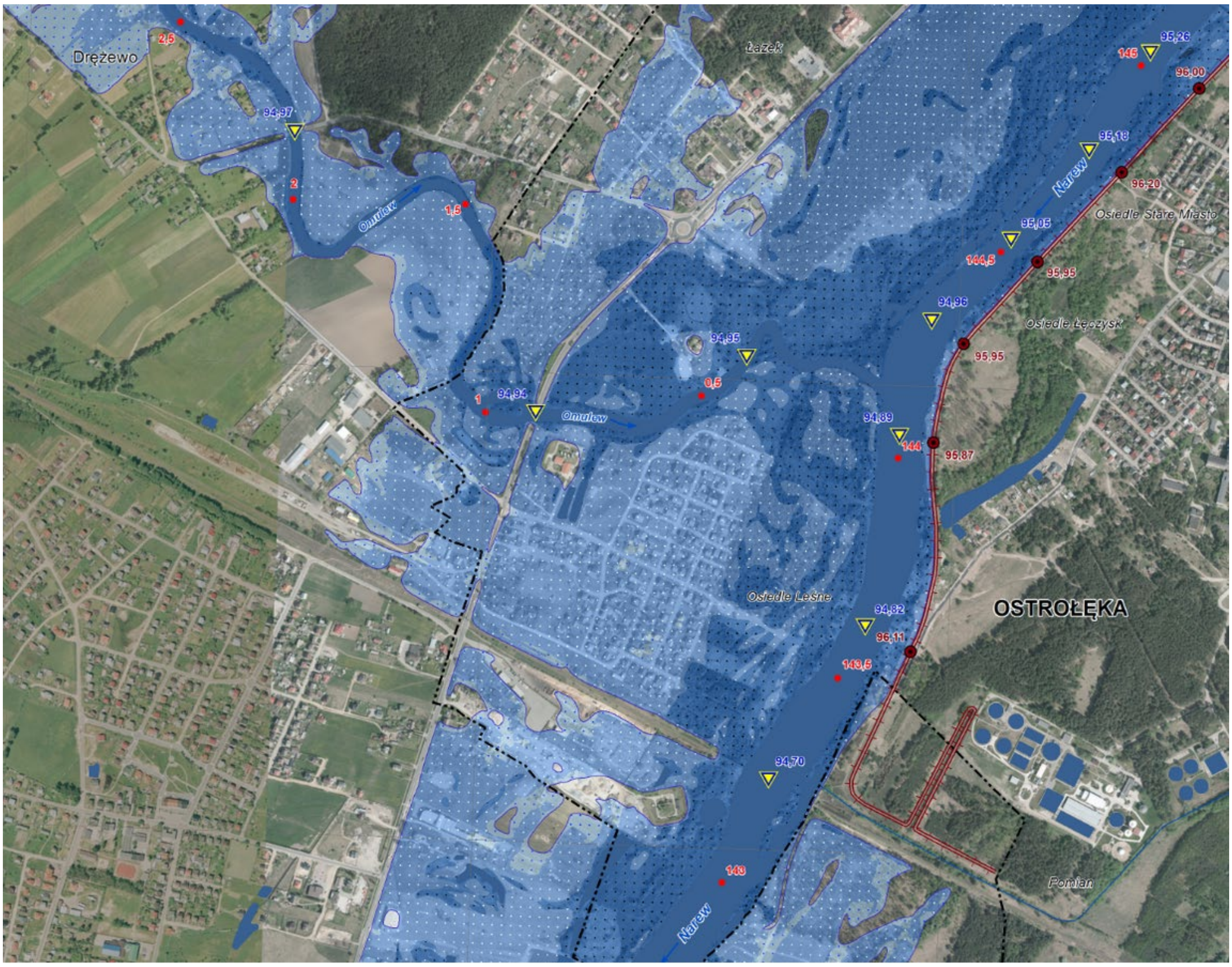


Figure 5.3. Narew river, an example of a flood risk map from Poland - the expected flood range and water depth are marked (source: https://www.kzgw.gov.pl).

If we look at maps and European flood risk analyses, we see that mainly the largest watercourses are analysed (Figure 5.4). Of course, main rivers generate the most terrible threats and cause the biggest material losses on the country scale. However, from the point of view of the rivers in our neighbourhood, the most important thing is what happens behind the fence and has a direct impact on his health and property. Those with a better or worse effect are handled by the local administration.

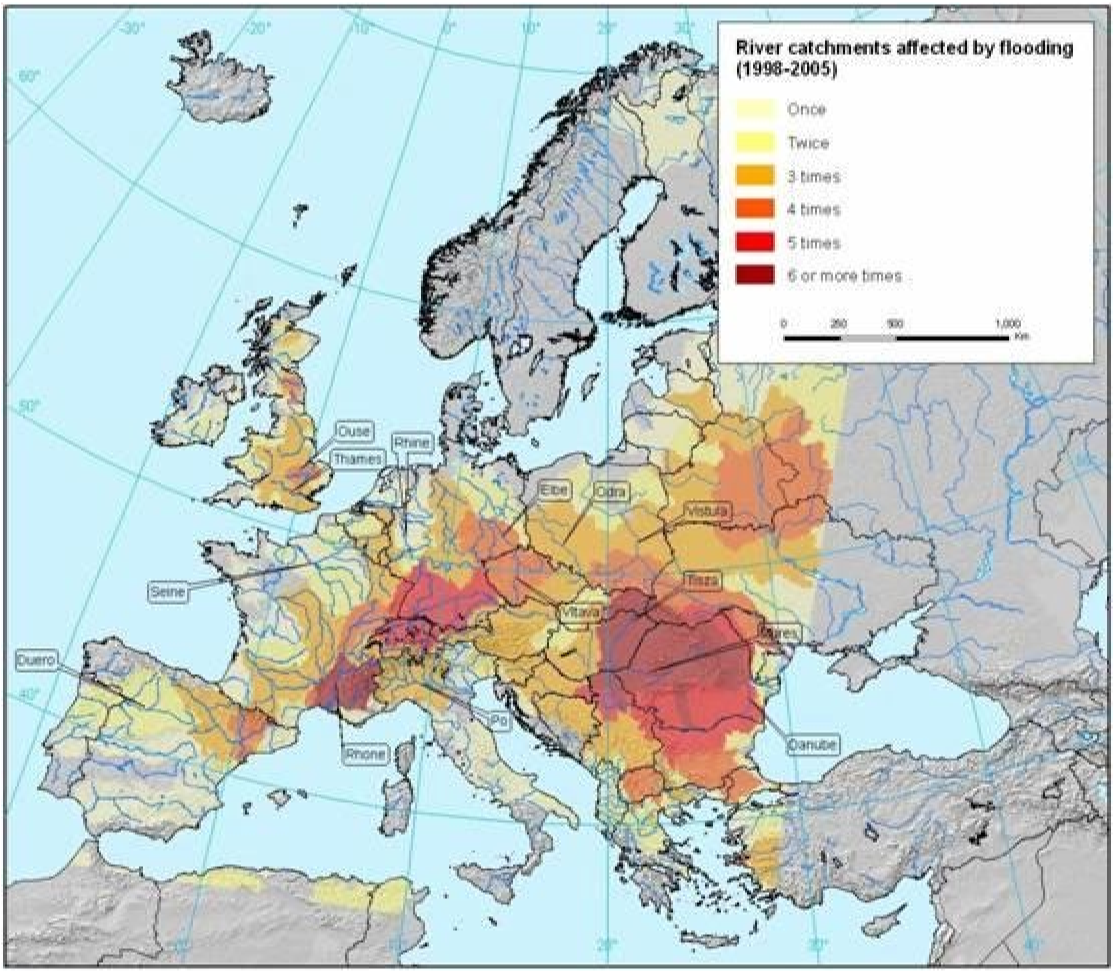


Figure 5.4. Recurrence of flood events in Europe between 1998 and 2005 (source EEA).

Every year, the awareness and commitment of members of local communities are growing. Contrary to appearances, estimating the flood risk in our area does not have to be difficult. We can all help to monitor flood risk index, regardless of our engineering and technical advancement level.

5.3 The channel capacity

When we want to determine the state of flood risk in our place of residence, we need certain parameters describing the water level in places that are characteristic and important from the point of view of flooding. Such parameters include, for example:

- the water level in the river / reservoir,
- type of land cover around the river / reservoir (green areas, forest, city centre, asphalt parking etc.),
- the percent of green areas,
- the amount of water that falls during rainfall (from the closest rain gage),
- amount of water infiltrating into the ground etc.

All these parameters are needed to determine the channel capacity. Because the maximum capacity for these characteristic places gives engineers information about the amount of water that can flow in these places. Such information allows us to determine the degree of flood risk and, if necessary, start actions aimed at limiting the negative effects of floods. To illustrate the most important parameters allowing to determine the amount of water in the city and to determine the capacity, the measurements carried out by students in Gdańsk during their internships are described below. The below-described measurements were made using measuring devices under the supervision of a teacher. However, it is also possible to obtain estimates of river flow and capacity by performing the measurements described in chapter 4.2.4. Such measurements can be performed by anyone without the need for measuring equipment. Performing such measurements is an important element in creating a local measurement network that protects our homes, housing estates and cities.

Manning formula

The Manning formula is an empirical formula, which can be used to calculate cross-sectional average velocity flow in open channels. The Manning equation is a widely used and very versatile formula in water resources. It can be also used to compute the flow in an open channel, compute the friction losses in a channel, derive the capacity of a pipe, check the performance of an area-velocity flow meter, and many more. The Manning formula uses water surface slope, cross-sectional area, and wetted perimeter of a length of uniform channel to determine the flow rate. There are many ways to express the Manning equation. The equation was derived to describe the velocity in a conduit, but for hydraulic computations, it is often desirable to express the equation in the form of a flow. The basic version of the equation will be discussed:

$$V = \frac{1}{n} \cdot R_h^{\frac{2}{3}} \cdot S^{\frac{1}{2}}, \quad (1)$$

where:

V – cross-sectional mean velocity [m/s],

n – Manning coefficient of roughness [s/m$^{(1/3)}$] – in general rougher conduits with higher friction have a higher value, and smoother conduits with lower friction have a lower value, depending on the type of material and the channel condition, select a value from the table (it can be found on the internet).

R_h – hydraulic radius [m] – this is the variable in the equation that accounts for the channel geometry. Hydraulic radius is computed from the area divided by the wetted perimeter of the flow. The wetted perimeter is literally just like it sounds – it is the length of the conduit around the perimeter that is wet. (Figure 5.5).

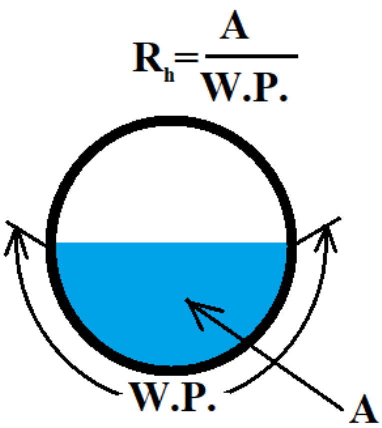


Figure 5.5. Hydraulic radius.

S – slope of the energy gradient [m/m] – often calculated as channel bottom slope (Figure 5.6).

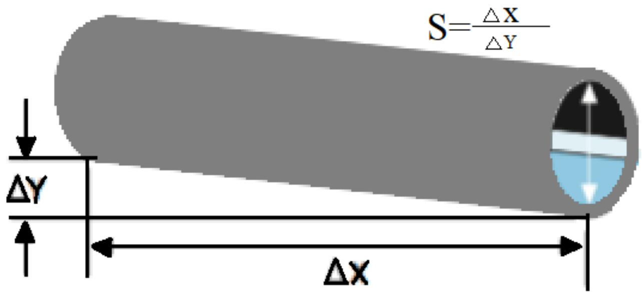


Figure 5.6. Hydraulic radius.

Based on the above formula, it is possible to determine the average flow velocity in the watercourse cross-section. However, to determine the throughput, we use the flow rate. Therefore, to calculate the flow rate, it is necessary to use additionally the continuity equation:

$$Q = V \cdot A = constans, \tag{2}$$

where:

Q – flow rate [m^3/s],

V – cross-sectional mean velocity [m/s],

A – cross-section area [m^2].

Case study Gdańsk

Students performed measurements to determine the capacity of the river in different sections of the analyzed stream. The measurements took place on June 25, 2020 in Gdańsk in the Jelitkowo district at the mouth of the Gdańsk Bay. In the area of measurements were located the "Jelitkowska" reservoir and the "Oliwski" stream (Figure 5.7).

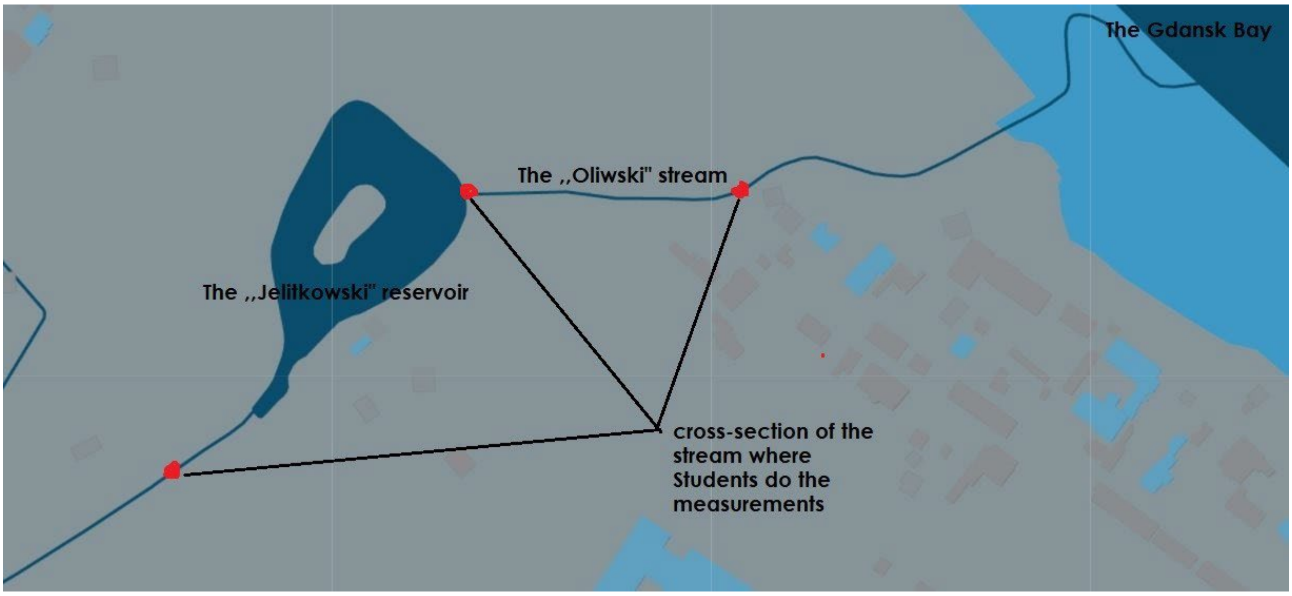


Figure 5.7. The area of the measurements.

The measurements were carried out as part of student internships, where under the supervision of a teacher, the students could take the necessary measurements using the available measuring devices. During the measurement's students performed:

- bottom sounding in two cross-sections of the stream,
- measurement of the flow velocity with the use of hydrometric mills in these cross-sections (Figure 5.8),
- measurement of surface velocity using floats and a stopwatch.

Moreover, in order to determine the longitudinal slope of the water level, height measurements were made with a technical level. In addition, in one of the cross-sections located at the outflow from the reservoir, measurements of the load of the overflow with a sharp edge (weir) were made (Figure 5.9).

Figure 5.8. The cross-section where students did measurements.

Figure 5.9. The cross-section shown on Figure 5.7 where students measured the load of the overflow with a sharp edge (weir).

Thanks to the performed measurements, it was possible to precisely determine the maximum capacity of the channel in places important from the perspective of flood risk. Such measurements allow not only to control the current flow conditions, but also to determine the limits, the exceeding of which means the occurrence of a flood risk. Therefore, it is important to make such measurements cyclically over a long period of time.

As can be seen in the figures above, two river cross-sections with bridge structures and a sharp-edge overflow cross-section were selected for measurements. This choice was not accidental, because during a flood it is possible that in these cross-sections the river will overflow onto nearby areas, such as a tram terminus, a street with a roundabout. It is important, therefore, to determine the maximum capacity of the channel in these places and periodically control the water level in order to limit losses in the event of danger. Students on the basis of measurements performed diagrams illustrating the dimensions of the channel and the bridge as well as the depth of water on the day of measurement (Figure 5.10, Figure 5.11). On the basis of these data, it is possible to determine the maximum capacity of the channel (Table 5.1 and Table 5.2). For this, Manning's formula (1) and continuity equation (2) should be used.

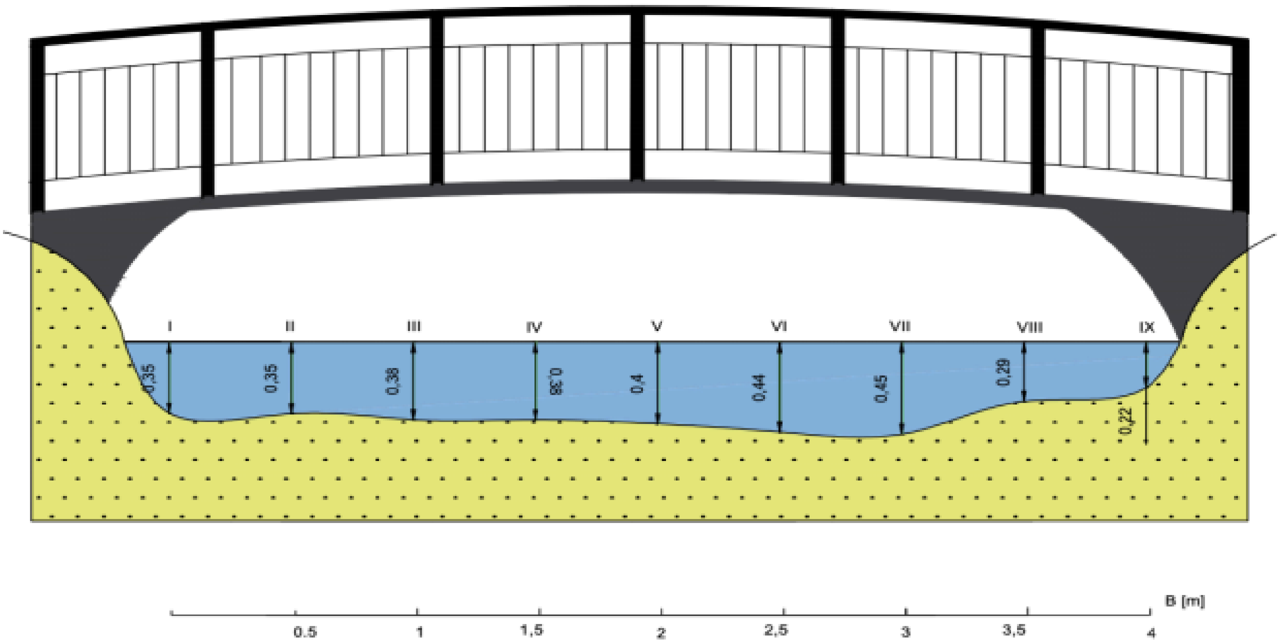


Figure 5.10. The cross-section of the stream at a section before the reservoir, B - cross-section width.

Table 5.1. The parameters needed to determine capacity for cross-section of the stream at a section before the reservoir under different flow conditions.

parameters	during measurements	taking into account the bridge when flowing with a free surface	taking into account the bridge when flowing under pressure
cross-sectional area A [m²]	1.567	4.578	4.578
hydraulic radius R_h [m]	0.332	0.733	0.555
slope of the energy gradient S [‰]	0.895	0.895	0.895
Manning coefficient of roughness n [$m^{-1/3}$ s]	0.028	0.026	0.024
flow rate Q [m³/s]	0.803	4.282	3.854

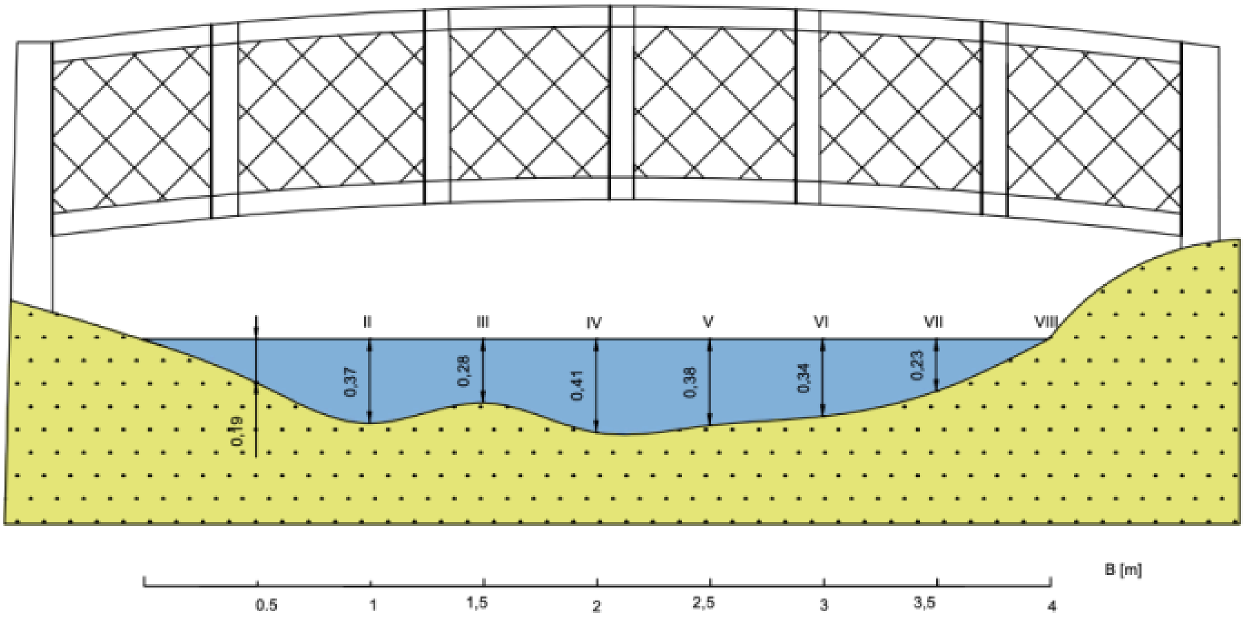


Figure 5.11. The cross-section of the stream at a section behind the reservoir and overflow with sharp edge (weir), B – cross-section width; I, II, ..., VIII – hydrometric verticals.

Table 5.2. The parameters needed to determine capacity for cross-section of the stream at a section behind the reservoir and overflow with sharp edge under different flow conditions.

parameters	during measurements	taking into account the bridge when flowing with a free surface	taking into account the bridge when flowing under pressure
cross-sectional area A [m^2]	1.118	3.890	3.890
hydraulic radius R_h [m]	0.268	0.650	0.487
slope of the energy gradient S [‰]	0.895	0.895	0.895
Manning coefficient of roughness n [m$^{-1/3}$ s]	0.030	0.028	0.026
flow rate Q [m^3/s]	0.463	4.282	3.854

To determine the flow rate and the overflow capacity, it is necessary to determine the values of the parameters described in the figure below – Figure 5.10.

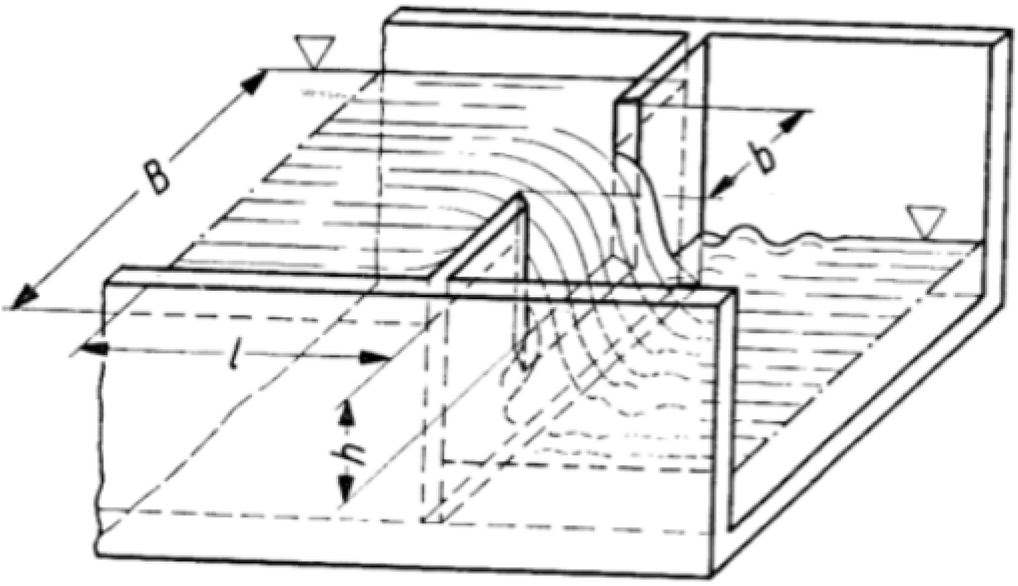


Figure 5.12. Sharp edge overflow with rectangular cut-out (www.prz.rzeszow.pl) where: B – width of the flowing water stream; b – width of the overflow edge; h – damming over the overflow edge (overflow load); l – distance of measured damming.

During the measurements, the students dealt with an overflow that had two spans, the structure as shown in Figure 5.12 and Figure 5.9, based on the measurements, they determined such parameters as:

- the ordinate of the overflow for span I: 2.652 m above sea level,
- the ordinate of the overflow for span II: 2.721 m above sea level,
- the ordinate of the water table behind the overflow: 2.633 m above sea level,
- the ordinate of the road: 4.400 m above sea level,
- overflow width for span I: B_I = 1.59 m,
- overflow width for span II: B_{II} = 1.56 m.

Based on these parameters, it is possible to determine the overflow load:

- for span I: h_I = 0.019 m and $h_{I\,max}$ = 1.748 m,
- for span II: h_{II} = 0.088 m and $h_{II\,max}$ = 1.679 m.

Knowing these parameters, it is possible to determine the flow rate and the wire maximum capacity on the basis of the formula:

$$Q = \frac{2}{3} \cdot \mu \cdot b \cdot \sqrt{2g} \cdot h^{\frac{2}{3}} \left[\frac{m^3}{s}\right], \quad (3)$$

where:

Q – flow rate [m^3/s],

μ - discharge coefficient [-] can be determined experimentally or from literature data,

b – overflow width [m] (Figure 5.12),

g – acceleration of gravity [m/s^2],

h – overflow load [m]

Flow rate for measurements:

$$Q_I = \frac{2}{3} \cdot 0.675 \cdot 1.59 \cdot \sqrt{2 \cdot 9.81} \cdot 0.019^{\frac{2}{3}} = 0.226 \left[\frac{m^3}{s}\right],$$

$$Q_{II} = \frac{2}{3} \cdot 0.675 \cdot 1.56 \cdot \sqrt{2 \cdot 9.81} \cdot 0.088^{\frac{2}{3}} = 0.615 \left[\frac{m^3}{s}\right],$$

$$Q = Q_I + Q_{II} = 0.226 + 0.615 = 0.841 \left[\frac{m^3}{s}\right],$$

The maximum capacity:

$$Q_I = \frac{2}{3} \cdot 0.81 \cdot 1.59 \cdot \sqrt{2 \cdot 9.81} \cdot 1.748^{\frac{2}{3}} = 5.519 \left[\frac{m^3}{s}\right],$$

$$Q_{II} = \frac{2}{3} \cdot 0.81 \cdot 1.56 \cdot \sqrt{2 \cdot 9.81} \cdot 1.679^{\frac{2}{3}} = 5.271 \left[\frac{m^3}{s}\right],$$

$$Q = Q_I + Q_{II} = 5.519 + 5.271 = 10.79 \left[\frac{m^3}{s}\right],$$

Tools

In the calculations presented in chapter 4.2.3.2, the parameters determined during field measurements were used. However, we do not always have the opportunity to go out and measure everything in the field, especially with the use of specialized (usually expensive) measuring equipment. Parameters such as depth and water velocity (and thus the discharge) can be measured in a simplified way (details in chapter 4.2.4), after all, even very estimated information is better than none. Even if we cannot estimate these parameters visually, we can perform calculations for various variants. Assuming a set of values, like water depth or velocity, we are able to determine the parameters determining the threat, as well as the characteristic values of these parameters.

The channel and cross-section geometries are the most difficult parameters to estimate. Fortunately, almost all of us have access to a computer and the Internet (even in public libraries), and as we know, the Internet is a powerful data resource. In this case, a digital elevation model (DEM) can be used. DEM is a 3D computer graphics representation of elevation data to represent terrain. Based on it, we can quite accurately determine, among others, height above sea level, as well as the terrain. profile – e.g. a floodplain. Files with the numerical terrain model can be found in the European database (https://www.eea.europa.eu/data-and-maps/data/copernicus-land-monitoring-service-eu-dem). However, as with flood hazard maps, it is also worth checking local sources, sources of altitude data for individual locations can be found, inter alia, via the website: https://www.opendem.info/opendemsearcher.html or on government portals (Figure 5.13 – an example from Poland).

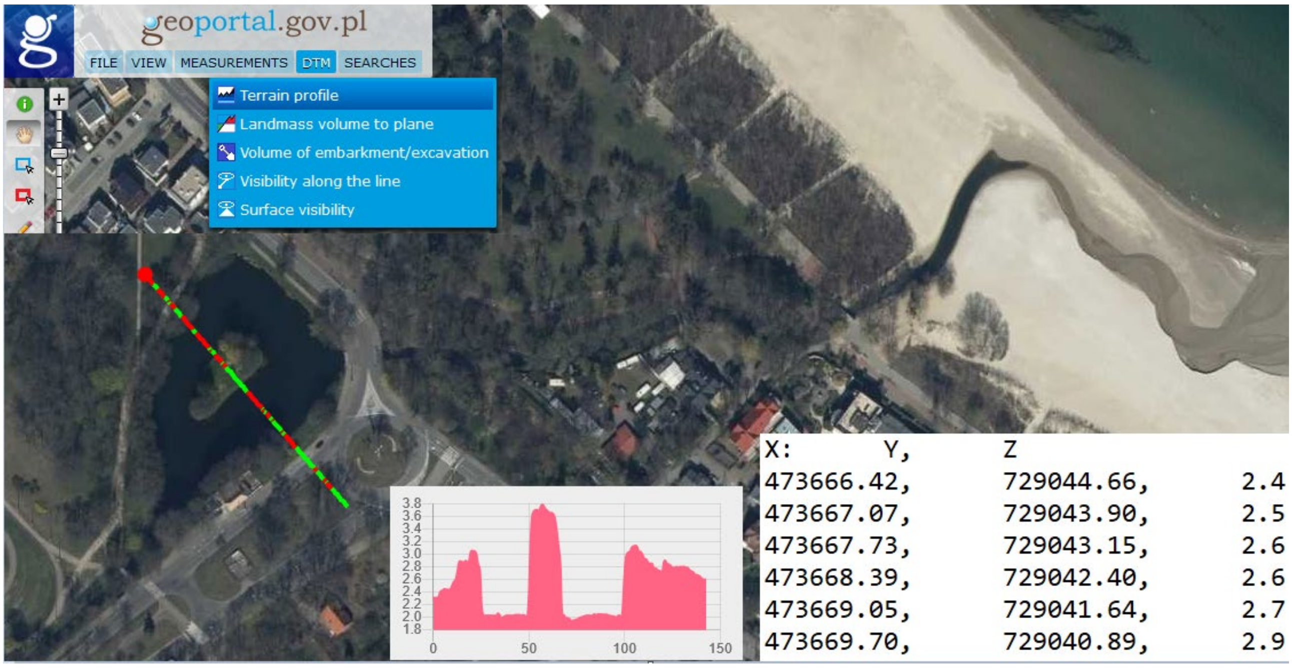


Figure 5.13. The example of cross-section geometry, based on DEM (sources: geoportal.gov.pl).

Linking a measurement point to an existing observation network

It is not always possible to make measurements (or even observations) during heavy rain, in an unmeasured area with flood risk. In such situations, local observation networks can be used. But what if there is a local measurement network in the area, but the point of our choice is not there? If you decide to set up your observation point, it is a good idea to "link" your cross-section to the nearest professional measuring point. This can be done even if we are separated from it by a large distance or if the point is located on a neighboring watercourse (a more difficult task requiring a longer series of observation data). It is enough to find a statistical connection between observed parameters and measurements at the closest, already existing, measuring station. It should be remembered that, as in the case of empirical formulas, a full correspondence will not be obtained in this way, as the results will be estimated but sufficient to determine the risk of flooding.

How to find the relation between measuring points P1 and P2 (Figure 5.14). Hydrology like creativity, there is plenty of options e.g.:

- measure the discharge at P2, with different water levels at point P1, then determine the relation $Q_{P2}(H_{P1})$,
- measure water levels at P1 and P2, and find the relation $H_{P2}(H_{P1})$, then base on Manning formula calculate $Q_{P2}(H_{P2})$ for set of water levels,
- find relation between the QP1 and QP2 base on the hydrological atlas
- mix up methods... etc.

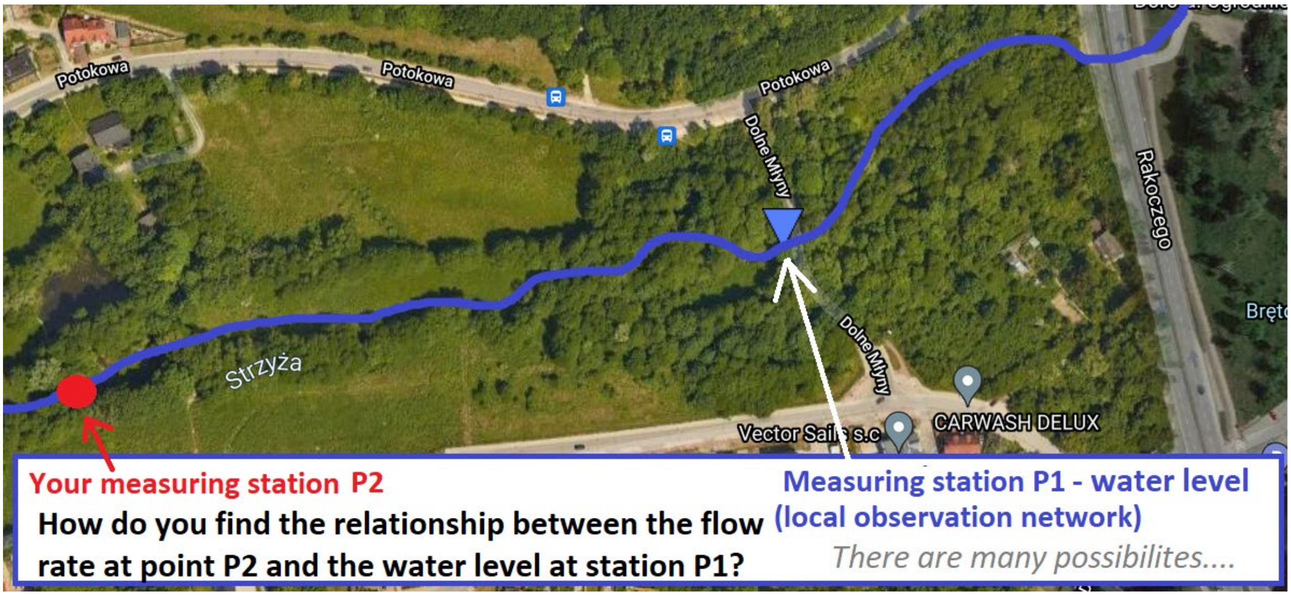


Figure 5.14. Linking a measurement point to an existing observation network.

The most important conclusions

- Due to modern technology, you can define the basic parameters determining the risk of flooding without leaving your home. Everyone has an impact on reducing the effects of flooding (early threat detection), it is worth knowing your area well.
- If our nearby canal is not included in the flood risk maps, you can define safe conditions yourself. It is also worth monitoring other parameters such as retention capacity, weather conditions, and standard relationships between rainfall and surface run-off / flow in watercourses (for basic methods look at 4.2.4).

5.4 Simple methods for measuring parameters affecting the flood index

Water surrounds us everywhere, even if it is not obviously visible. We must remember that water-related risks are not only determined by the rivers, seas, and water reservoirs. Monitoring of parameters related to the water can be and should be performed in any location. All you need to do is select the appropriate module. Measurements can be carried out in places such as: ***river*** (a place where water flows), ***reservoir*** (a place where water collects), ***green area*** (an area where water filters into the ground) and an ***urban area*** (an area where water flows over a built-up area). All measurements can be made independently, without the help of a teacher and without the use of specialized devices. These measurements make it possible to determine the parameters of water and its quantity. When choosing a place to take measurements, it is good to look around in the vicinity for such places. In cities, you can find places where several such areas are next to each other, e.g. a park through which a river flows. In such a place, measurements can be made from the river module, green area module and urban area module. The Table 5.3 presents a list of possible measurements depending on the current location.

Table 5.3. List of possible measurements in different locations.

Name	Location			
	Green area	Urban area	Stagnant water	Flowing water
Questionnaire				
Precipitation	x	x	x	x
Infiltration	x	x	x	x
Surface runoff	x	x	x	x
Basin description	x	x	x	x
Nature-based solution	x	x	x	x
Sewage system		x		
Water level (reservoir)			x	
Water level (river)				x
Measurement				
Precipitation	x	x	x	x
Infiltration	x	x		
Surface runoff	x	x		
Water level (reservoir)			x	
Water level (river)				x
Velocity (river)				x
Discharge (river)				x
Velocity (surface runoff)	x	x		
Retention	x	x		
Temperature	x	x	x	x

Would you like to take care of your surroundings and be more aware of the changes that occur there (from the point of view of water management and flood risk)? You can make regular hydrometric measurements, or collect information by filling out periodic questionnaires that monitor environmental changes related to increasing or decreasing flood risk. By analyzing the results collected over months and years, it is possible to determine probable trends concerning retention capacities, frequency of precipitation (and its volume), water levels in rivers and water reservoirs in the analyzed area, etc. It is clear that if the amount of precipitation is increasing and the catchment is subject to progressive urbanization, with no anticipation of sites that allow for local retention, the flood risk index is increasing and the risk is becoming greater. So try to find as many relationships as possible for your area to predict the flood risk index especially in places where you know that local flooding and flooding already occur or in places that are of particular concern to you. For the field characteristic description use file Flooding Questionnaire.doc and create your set of tables according to Table 5.3.

Green area

Table 5.4. List of possible measurements in green area (check list).

Green area	Precipitation	Infiltration	Surface runoff	Basin description	Nature-based solution	Velocity (surface runoff)	Retention	Temperature
Questionnaire	x	x	x	x	x			
Measurement	x	x	x			x	x	x

Retention – Field easy {output: location – text, area – numbers [m^2], volume – numbers [m^3], description – text, photo}

Is there small retention in your area? These are places where water can accumulate rather than go directly to the rainwater drainage system. Small retention can take the form of depression (water will collect and evaporate there), a green area (rainwater will settle on plants, infiltrate into the ground), rain gardens, green roofs, etc. Try to find several places in your area that will allow you to locally keep the water or restore it to its natural circulation. For each site, take a picture, describe how the water is stored, and also try to estimate how much water can be collected there (volume, area, etc.) – measurement can be made with any device, even with a piece of stick or a shoe (something that you can later dimension).

Infiltration – Field easy {output: location – text, infiltration time – numbers [s], water volume – numbers [ml], base area – numbers [cm^2]}

Measuring device:

- prepare a cylinder-shaped container (bucket, plastic bottle, etc.),
- cut off the bases, and if this is impossible, make a hole as large as possible in both bases,
- measure the volume of the cylinder and the area of the base / hole in the base,
- prepare several portions of water, about 1 liter of water each – water may be more or less depending on the capacity of the prepared device,
- prepare a stopwatch.

Find several different types of land cover in your area (pavement, lawn, bare earth, asphalt), these will be measuring points. At each point, place an empty measuring device. At the same time, pour the prepared portion (0.5-1 liter) of water and start the stopwatch, measure the time needed for the whole poured water to infiltrate. Due to the very low infiltration velocity in impervious areas a safe place should be selected, you cannot block the passage, or expose yourself to unexpected interruption of the measurement.

Precipitation – Field easy {output: container inlet area – number [cm^2], volume – number [ml], time – number [s], daily sum of precipitation – number [dm^3 / day]}

A rain gauge can be any container in which we can collect water: a bowl, a jar, a bottle with cut-off neck (any shape of the inlet). The volume of water that will be collected in the container and the time it took for this water to collect should be measured. The measurement can be performed in two variants measurement of: the daily sum of precipitation, and the instantaneous intensity of the rainfall episode.

Measurement of the precipitation intensity. During the rain, at the same time, set the container to catch rainwater and start the timer. We check how long it took to fill the entire container (if it did) and how long all the rain was. In the case of a long rainfall episode, the measurement can be stopped when you notice a significant reduction in the strength of the precipitation (e.g. transition to a drizzle). Then we measure the volume of the collected water.

Measurement of the daily sum of precipitation. The rain gauge should be put in a safe place that allows it to be left for several days or even months. Every day at the same time the volume of collected water should be measured. The rain gauge should be emptied and put back in the same place after the measurement. If you notice any "rubbish" such as leaves or other debris, remove it immediately (taking care not to take away the collected water).

Temperature – Field easy {output: location – text, air temperature – number [°C], water temperature – number [°C]}

An outdoor thermometer should be used to measure the temperature. Measurements should be performed at the beginning and at the end of field research. In the case of measurements are longer than 2 hours or noticeable temperature changes during the exercise will be noticed, the temperature should be measured several times – the frequency of measurements should be selected to capture the dynamics of temperature changes.

The air temperature is measured in the same way as checking the temperature on a windows thermometer. During the first measurement (after removing the thermometer), wait a few minutes for the exact value to stabilize.

Urban area

Table 5.5. List of possible measurements in urban area (check list).

Urban area	Precipitation	Infiltration	Surface runoff	Basin description	Nature-based solution	Sewage system	Velocity (surface runoff)	Retention	Temperature
Questionnaire	x	x	x	x	x	x			
Measurement	x	x	x				x	x	x

Surface runoff – Field easy {output: water depth – number [cm], stream width – number [m], description – text, photo}

The surface runoff can be measured in two variants – during / just after the rain or in the dry period.

Measurement in the "wet" period *– choose a place in the area that turns into a periodic stream after rain (e.g. on the street or pavement). Take a photo, measure the water depth and the width of the "stream" and then calculate the cross-sectional area.*

Measurement in the "dry" period *is limited to locating and dimensioning the places where surface run-off is potentially to be observed. Take a picture of the streets (or other places) where water flows after heavy rain. Let us assume that these places become periodic streams. Measure them and try to determine the maximum capacity, e.g. in the case of street, check the maximum cross-section that water can flow (street width and height of the curb).*

Velocity (surface runoff) – Field easy {output: cross-section length – number [m], flow time – number [s], description – text and photo}

Measure the velocity of the surface runoff:

- find a straight section of the street – a place where surface runoff is pronounced, mark the beginning and the end, measure the length (L [m]),
- prepare a "float" – something that will float on the water surface, it can be a piece of wood, a paper ship, etc.
- throw in the float at least one meter before the beginning of the marked section, measure the time needed for the float to swim between the marked points (t [s])
- calculate the surface speed v = L / t [m / s]

Take photos and make notes – how the surface runoff looks like (grass, sand, sidewalk, concrete, asphalt etc.). If you have measured both: surface runoff velocity and surface runoff cross-section area then you can calculate the discharge, according to the continuity equation (2).

Precipitation – Field easy {output: container inlet area – number [cm^2], volume – number [ml], time – number [s], daily sum of precipitation – number [dm^3 / day]}

A rain gauge can be any container in which we can collect water: a bowl, a jar, a bottle with cut-off neck (any shape of the inlet). The volume of water that will be collected in the container and the time it took for this water to collect should be measured. The measurement can be performed in two variants measurement of: the daily sum of precipitation, and the instantaneous intensity of the rainfall episode.

Measurement of the precipitation intensity. During the rain, at the same time, set the container to catch rainwater and start the timer. We measure the time remaining until the rainfall ends or until the container (rain gauge) is completely full. In the case of a long rainfall episode, the measurement can be stopped when you notice a significant reduction in the strength of the precipitation (e.g. transition to a drizzle). The we measure the volume of the collected water.

Measurement of the daily sum of precipitation. The rain gauge should be put in a safe place that allows it to be left for several days or even months. Every day at the same time the volume of collected water should be measured. The rain gauge should be emptied and put back in the same place after the measurement. If you notice any "rubbish" such as leaves or other debris, remove it immediately (taking care not to take away the collected water).

Temperature – Field easy {output: location – text, air temperature – number [°C], water temperature – number [°C]}

Water temperature is measured in a similar way to air temperature measurement. Approximately 1 minute must elapse between the insertion of the thermometer in the water and the value reading (liquid inertia in the thermometer). Read the temperature carefully, do not remove the thermometer from the water while taking the measurement.

Stagnant water – reservoir

Table 5.6. List of possible measurements in reservoir (check list).

Stagnant water	Precipitation	Infiltration	Surface runoff	Basin description	Nature-based solution	Water level (reservoir)	Temperature
Questionnaire	x	x	x	x	x	x	
Measurement	x					x	x

Water level (reservoir) – Filed easy {output: location – text, water level – number [m], measurement location sign – text}

The water level in the reservoir is measured with a metal or wooden rod. It can be made from the bridge, on the edge if it is safe to do, or from a platform on the tank if available. Observe all safety rules during the measurement. If the reservoir is monitored, you can read the water level in a water gauge.

Temperature – Field easy {output: location – text, air temperature – number [°C], water temperature – number [°C]}

Water temperature is measured in a similar way to air temperature measurement. Approximately 1 minute must elapse between the insertion of the thermometer in the water and the value reading (liquid inertia in the thermometer). Read the temperature carefully, do not remove the thermometer from the water while taking the measurements.

Flowing water – river

Table 5.7. List of possible measurement in river (check list).

Flowing water	Precipitation	Infiltration	Surface runoff	Basin description	Nature-based solution	Water level (river)	Velocity (river)	Discharge (river)	Temperature
Questionnaire	x	x	x	x	x	x			
Measurement	x					x	x	x	x

Water level (river) – Field easy {output: location – text, measurement location sign – text, measuring point number – number [-], water level – number [m]}

The water level in the river can be measured with a metal or wooden rod. The water level in the river should be measured in several places (cross-section perpendicular to the shore). Measurement should be taken from the bridge or the edge. If it is safe to do so, the measurement can be made by entering the river. Observe all safety rules during the measurement, especially when someone is in the water.

Velocity (river) – Field easy {output: location – text, distance – number [m], time – [s]}

The flow velocity in the river can be measured with a piece of wood. To perform the measurement, you need to find a straight part of the river, then select the starting and ending points and measure the distance between them. The next step is to throw a wooden piece into the river before the starting point – it should be placed in the center of the cross-section. As soon as the piece of wood passes the starting point, start the timer and measure the flow time of the wooden piece to the endpoint. By knowing the time and distance traveled by the piece of wood, you can calculate the velocity. This is the surface velocity of water in the river.

Temperature – Field easy {output: location – text, air temperature – number [°C], water temperature – number [°C]}

Water temperature is measured in a similar way to air temperature measurement. Approximately 1 minute must elapse between the insertion of the thermometer in the water and the value reading (liquid inertia in the thermometer). Read the temperature carefully, do not remove the thermometer from the water while taking the measurement.

Data collection protocol & methodology

The collection of measurement data will be done through a spreadsheet. The measurement results from the selected place should be saved in one file with name of this place and date. In this file each of the tabs with the names of modules will contain the measurement results from this module. If no measurements have been made in the selected place, just skip it. Questionnaire measurements are completed in google forms (look at chapter 1.6).

5.5 Difficult methods for measuring parameters affecting the flood index

Difficult methods require the use of professional measurement equipment such as a flow meter. Therefore, the measurement procedure and the type of results obtained will vary depending on the devices used. Remember! Some measurements, such as those relating to the sewage system, must be performed with special care. Difficult measurements should be made alternately (or additionally) with the selected easy measurements selected for a given location – Table 5.3.

Rivers and reservoirs

Water level (river) – Field difficult

The measurement of the water surface level in the river can be done using a metal or wooden rod. It can be made from a bridge or shore if safe to do so. If the river is small, the measurements of the water surface level can be done by entering the river. The measurement of the water surface level in the river should be made in the selected cross-section in several places by making the so-called probing. This allows to determine the shape of the measurement cross-section and its characteristic parameters, such as the cross-sectional area, wetted circumference, or the width of the river at the water surface level.

Water level (reservoir) – Field difficult

Measurement of the water surface level in the reservoir can be made with the use of a marked metal rod or the ordinate of the water level with the use of staff and a leveller. The measurement can also be taken from the gauge if the reservoir is monitored. Measurement can be taken from the bridge, on the shore if it is safe to do so, or from a platform on the tank if available. Warning! Observe all safety rules during the measurement.

Local velocity (river) – Field difficult

The local velocity in the river is measured using a current meter or other velocity measuring device. To perform the measurement first, it is necessary to probe the cross-section of the river bed. After the probing is completed, the number and position of the measurement verticals are determined (Table 5.8, Table 5.9). In each of them, velocity measurements are made at appropriate depths. Spot velocity measurements can be divided into:

- complete – measurements are made in many points for many verticals,
- surface – in verticals at the water surface, this is to determine the maximum velocity because, based on the velocity curves, can be known that there is a maximum speed under the water surface level,
- shortened – at selected points and verticals:

- single-point – at a depth of 0.4h or 0.6h from the bottom, where h is the water depth in the hydrometric verticals:

$$v_m = v_{0,4h} \text{ or } v_m = v_{0,6h},$$

- two-point – at a depth of 0.2h and 0.8h from the bottom:

$$v_m = 0{,}5 \cdot (v_{0,2h} + v_{0,8h}) \text{ or } v_m = 0{,}25 \cdot (v_{0,2h} + 2 \cdot v_{0,4h} + v_{0,8h})$$

Table 5.8. Rules for the selection of hydrometric verticals.

river width [m]	pilot distribution [m] not less than	number of hydrometric verticals
to 2	0.2	not less than 3
3 – 10	0.5	4 – 5
11 – 30	1.0	7 – 8
31 – 80	2.0	9 – 10
81 – 200	5.0	11 – 12
over 200	10.0	over 15

Table 5.9. Distribution of measurement points in hydrometric verticals.

depth h [m]	free surface flow		ice cover or an overgrown riverbed	
	distribution of measurement points	number of measurement points	distribution of measurement points	number of measurement points
< 0.2	0.4 h	1	0.5 h	1
0.2 – 0.6	0.2 h, 0.4 h and 0.8 h	3	0.15 h, 0.5 h and 0.85 h	3
> 0.2	at the bottom, 0.2 h, 0.4 h, 0.8 h and near the surface	5	at the bottom, 0.2 h, 0.4 h, 0.6 h, 0.8 h and near the surface	5

Discharge (river) – Field difficult

The measurement of the flow rate is indirectly acquired by measuring the flow velocity. The velocity is measured at selected points in the cross-section, called the hydrometric cross-section. Such a cross-section must meet the following conditions: it should be located on a straight section of the river, it should be single, compact, and regular. In such a selected cross-section, first, the depth sounding from the bottom to the water surface level is carried out, and then at selected points located on the hydrometric vertical (at different depths) of this cross-section, the velocity is measured. The velocity measurements can be made using e.g. a current meter. Based on the measurements with a current meter, the flow velocity is calculated using the formula:

$$V = \alpha + \beta \cdot n$$

where:

V – flow velocity [m/s],

α, β – current meter constants,

n – number of current meter revolutions per second [rev./s].

Using velocity measurements for individual hydrometric verticals, velocity curves can be plotted (Figure 5.14). Making use of velocity measurements for individual hydrometric verticals, velocity curves can be plotted. On their basis, the average velocity for the hydrometric verticals is determined. It is calculated by dividing the area under velocity curves by the vertical water depth.

Based on these measurements, the flow rate can be calculated by the following methods:

I. Harlacher's method – computational and graphic,

Calculation according to this method is performed as follows:

1) Sketch of a cross-section with marked hydrometric verticals (Figure 5.15).

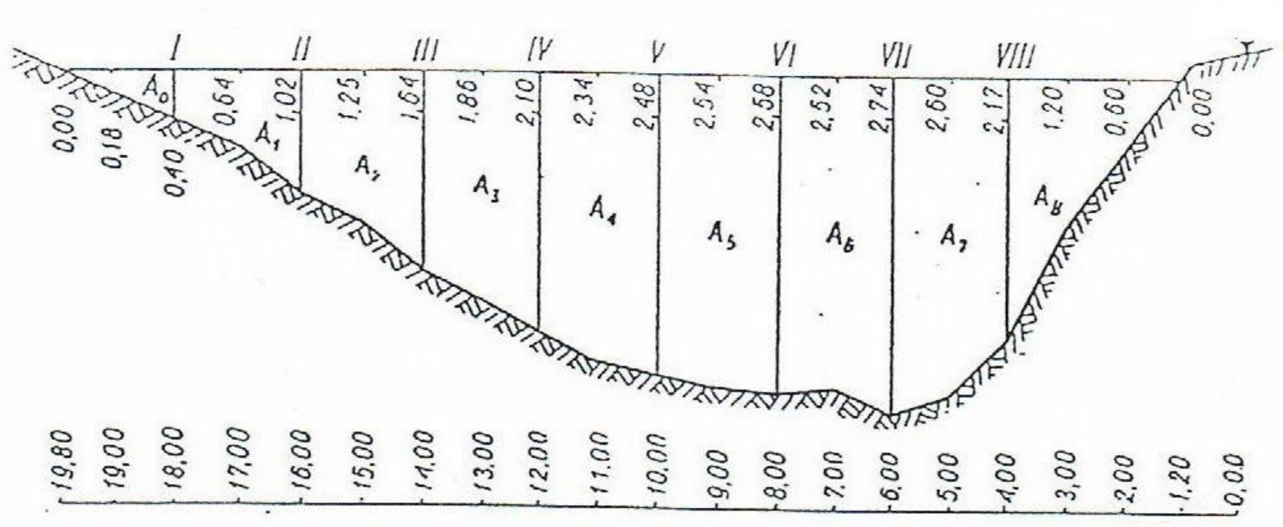


Figure 5.15. Sketch of the cross-section with marked hydrometric verticals.

2) Calculation of the subsections of the cross-sectional areas of trapezoidal or triangular shapes (outermost areas). The average depth for each subsection of the cross-section is determined as the arithmetic mean of the depths of the hydrometric vertical limiting the field. Based on the width of each subsection and the average depth, the area of each subsection is calculated.

3) Determination of the average velocity for each of the hydrometric vertical using the velocity curve (Figure 5.16).

4) Calculation of the middling value of average velocity as the arithmetic average of the average velocity for the perpendiculars of a given subsection or for the extreme (triangular) subsections as 2/3 of the average value for the perimeter perpendicular.

5) Determination of partial flows as the product of the subsection values by the average velocity values. Summing up the calculated partial flows, the value of the flow rate for the analysed cross-section is obtained (Harlacher's computational method) (Table 5.10).

6) Drawing of the average velocity curve by putting vertically upwards the average velocity value in individual hydrometric verticals. This curve makes it possible to determine the value of the average velocity for any vertical in the cross-section (Figure 5.16).

7) The product of the depth in a given hydrometric vertical by the average velocity in this hydrometric vertical $x = h \cdot v$ [m^2/s] are calculated and the lengths x are placed vertically downwards. This creates a flow curve. Warning! The scale of this curve must be selected so that it fully fits in the cross-section (Figure 5.17).

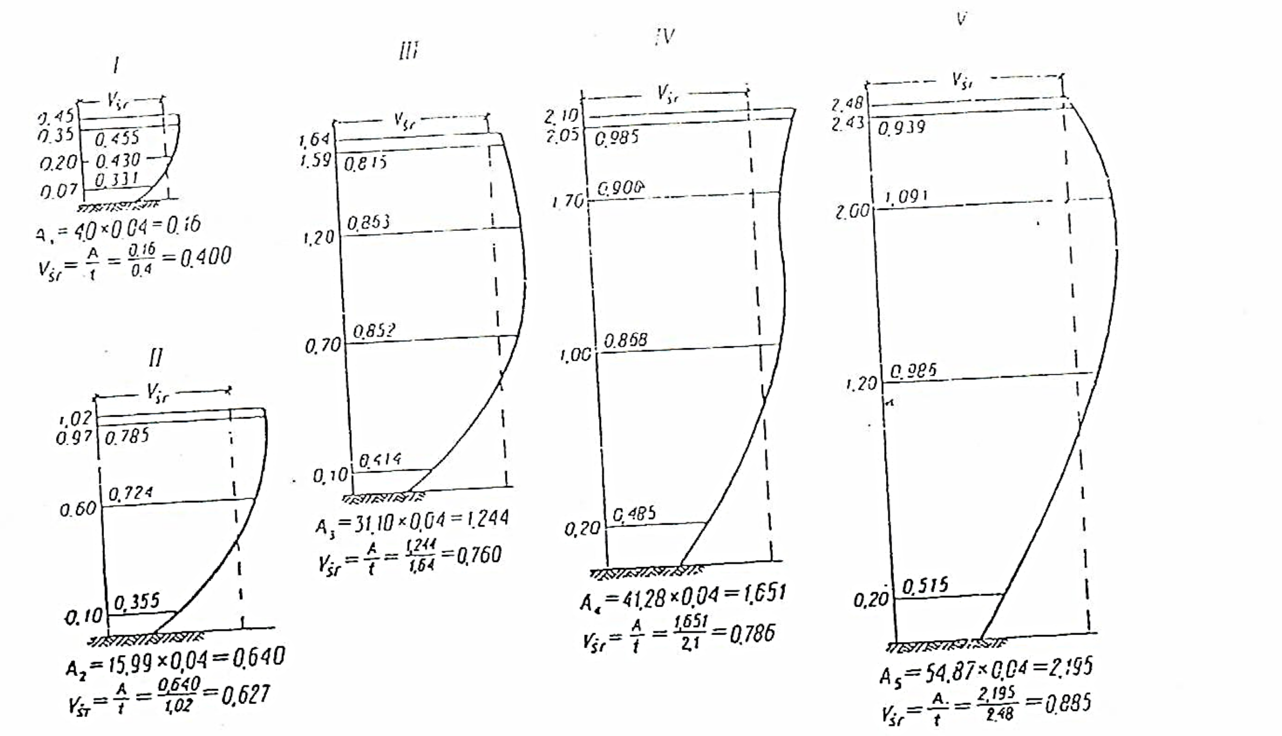


Figure 5.16. Sample sketches of the velocity curve with calculations of the average velocity for the hydrometric vertical.

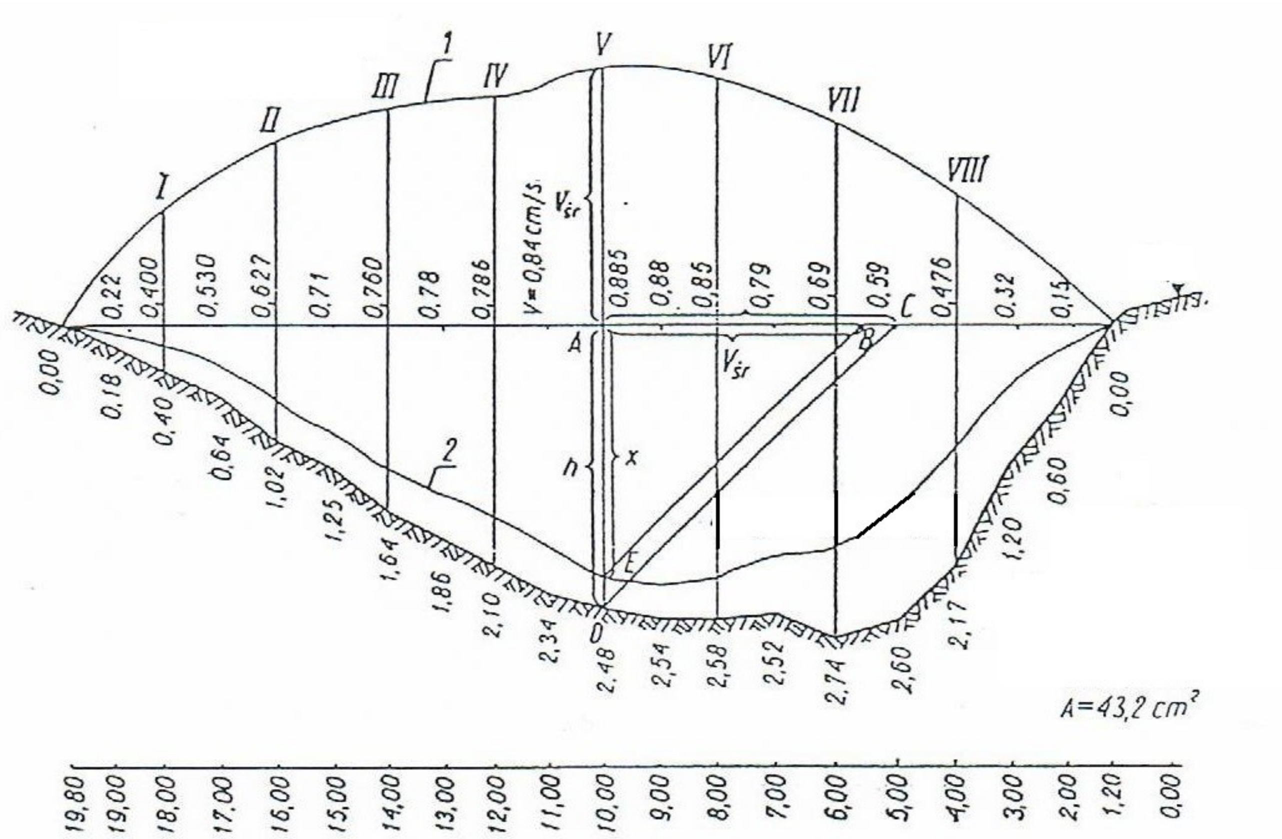


Figure 5.17. Sketch of the cross-section with marked hydrometric verticals with the average velocity curve (1) and the flow curve (2).

Table 5.10. Summary of calculation results of flow rates for Figure 5.17.

Hydrometric vertical number	The depth of the river at the vertical point [m]	Width of the subsections [m]	Areas of subsections of the cross-section between verticals [m²]	Average velocity in verticals [m/s]	Middling value of average velocity for fields [m/s]	Partial flows [m³/s]
I	0.40	1.80	0.36	0.400	0.267	0.096
		2.00	1.42		0.513	0.728
II	1.02	2.00	2.66	0.627	0.693	1.843
III	1.64	2.00	3.74	0.760	0.773	2.891
IV	2.10	2.00	4.58	0.786	0.835	3.824
V	2.48	2.00	5.06	0.885	0.867	4.387
VI	2.58	2.00	5.32	0.850	0.770	4.096
VII	2.74	2.00	4.01	0.690	0.583	2.862
VIII	2.17	2.80	3.04	0.476	0.317	0.964
			Sum: A = 31.09 m²		Q = 21.691 m³/s	

8) On the basis of the resulting flow curve, the total flow rate is calculated by determining the value of the area bounded by the flow curve (graphical Harlacher's method) (Figure 5.15).

II. Culmann's method

This method consists in determining the lines of equal velocities, i.e. isovel, in the cross-section. Isovels are determined on the basis of the measured velocity values in individual hydrometric vertical. To determine the flow rate with this method, perform the following steps:

1) Draw a sketch of the cross-section with the hydrometric verticals and velocity values at individual points of the verticals (Figure 5.18).

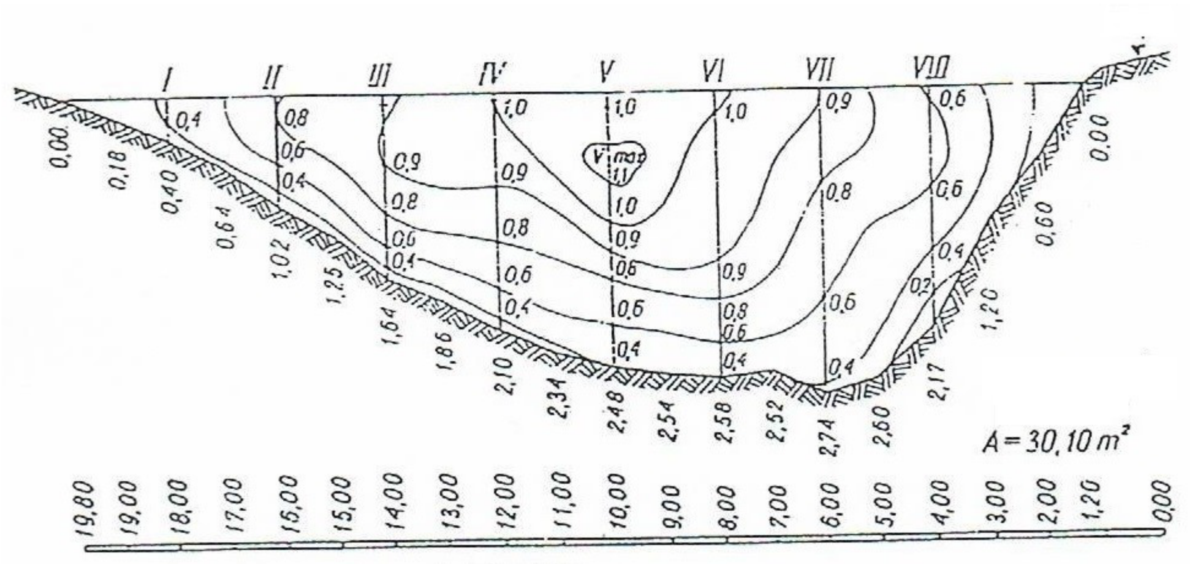


Figure 5.18. Sketch of the cross-section with marked hydrometric verticals with isovels.

2) On the basis of known values of point velocities, determine isovels by interpolation between points.
3) On the basis of the drawing, determine the values of the surface area between the designated isovels.

4) Calculate the average velocity between isovels. In the case of extreme values, the average velocity value is determined as follows:

$$V_A(\min) = 0.5 \cdot V_{min}$$

$$V_A(\max) = V_{max}$$

where:

V_A – average velocity between isovels [m/s],

V_{min} – minimal velocity on isovel [m/s],

V_{max} – maximal velocity in isovel [m/s].

5) Knowing the values of the average velocities between isovels and the surface area between them, it is possible to determine the partial flow rates by multiplying these values for individual component fields. By summing up the values of the partial flow rates, the flow rate for the entire cross-section is obtained (Table 5.11).

Table 5.11. Summary of calculation results of flow rates for Figure 5.18.

Hydrometric vertial number	Subsections of the cross-section between verticals [m/s]	Areas of subsections [m²]	Average velocity of subsections [m/s]	Partial flows of subsections [m³/s]
I	0.2 – 0.0	0.60	0.10	0.060
II	0.4 – 0.2	2.55	0.30	0.765
III	0.6 – 0.4	6.10	0.50	5.050
IV	0.8 – 0.6	6.60	0.70	4.620
V	0.9 – 0.8	5.20	0.85	4.420
VI	1.0 – 0.9	5.80	0.95	5.510
VII	1.1 – 1.0	2.93	1.05	3.080
VIII	1.1	0.32	1.10	0.350
			Sum: A = 30.10 m²	Q = 21.86 m³/s

Geometry (river cross-section) – Field difficult

The geometry is measured for the selected river cross-section. The needed parameters are the shape of this cross-section, and its dimensions, such as the cross-sectional area, the maximum cross-sectional area and the width at the water surface level, as well as for the maximum filling. Measurements are made by probing the bottom of the channel, and measuring the width with a metal ruler. The cross-section measurements should be selected so that it is easily accessible. It can be located near the bridge or in any section of the watercourse.

Geometry (reservoir cross-section) – Field difficult

The geometry of the reservoir is measured by measuring (if possible) its dimensions and water depth. In addition, the geometry of the river that flows in and out of the reservoir should be measured. The dimensions of the riverbed / reservoir are determined by the so-called probing the bottom in several longitudinal and transverse sections and levelling of slopes and dry parts (if any). It is necessary to perform as many measurements to accurately reproduce the river/reservoir geometry. It can be done from bridges, structures going deep into the reservoir, a pontoon, and if it is not possible from the shore, but in several (several dozen) places. The reference point for all measurements (so as to combine the measurement of the bottom with the measurement of slopes) can be the water surface level.

Sewage system

Measurement of the flow rate in the rainwater sewage system must be supervised (teacher, technician, or employee of the municipal company), **never do this measurement alone**. Due to many unpredictable factors, such as e.g. heavy water pollution, strong current, sharp objects in the sewage, be especially careful during the measurement. Measurements in collectors of combined sewage systems should be performed carefully, with gloves, trying to limit contact with water to a minimum.

Water level (sewage system) – Field difficult

The first step of the measurement is the visual inspection and description of the cross-section, the following information should be recorded:

- the type of rainwater collector (a pipe, an open channel, etc.),
- type of medium (rainwater drainage, combined sewage system),
- condition of the collector at the measurement location (observations regarding the fragments before and after the cross-section),
- the state of flowing water (color, amount of suspended solids, type of suspension, sediment, smooth or rushing flow, etc.),
- the shape of the collector and the material it is made of,
- characteristic dimensions (collected dimensions must enable drawing with the collector cross-section in the place where the measurement is performed),
- collector slope – if it is possible.

The water level in the analysed cross-section should be measured. The measurement should be performed in such a way that it will be possible to draw a line representing the water table level on the drawing of the channel cross-section. The method of measuring the water level must be appropriate to the technical possibilities given by the characteristics of the measurement location. The measurement can be made with a level, levelling rod, any rod or pole, tape measure, ruler, piece of wood, etc. All methods are allowed, but remember that the priority is the safety of the performed measurement.

Discharge (sewage system) – Field difficult

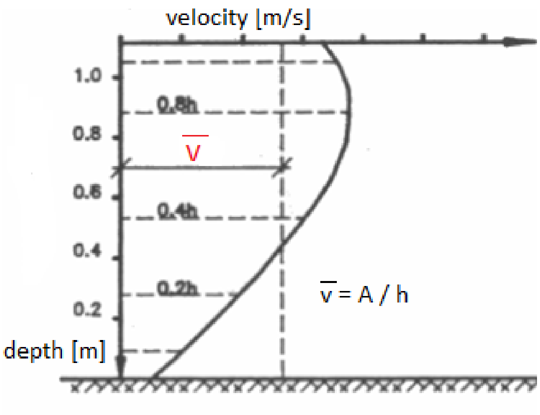
Before measuring the rainwater velocity, make a sketch of the collector and measure the current water level (see previous instructions). The flow meter used for the measurement must be suitable for use in polluted water.

Measurement procedure:

1. Designate the hydrometric vertical points and define the depths of water level and the depths at which the measurements will be made. The number and distribution of measuring points depend on the characteristics of the observed flow (spatial variability) and the dimensions of the collector. Mark the measurement points on the sketch. Before starting the measurement, consult the location of the measurement points with the teacher.
2. At each point, measure the local velocity three times. The measurement is performed following the instructions attached to the flow meter.

Elaboration of the results:

1. For each measurement point, determine velocity value (reject unrealistic values considered as the measurement error, and calculate the average from the remaining values) and estimate the average measurement error.
2. For each hydrometric vertical line, draw depth – velocity curves in each vertical and calculate the average velocity (Figure 5.19).
3. Determine the average velocity over the entire subsection (more information in the „Discharge (river)" instruction).
4. Calculate the discharge, based on the continuity equation or methods described in „Discharge (river)" instruction.
5. Description of the drained area (size, land development, hydrological characteristics, map).



where:

v – the velocity [m/s]

h – the water depth [m]

A – the area under the depth-velocity curves

Figure 5.19. Velocity in hydrometric vertical line.

6. Description of the last rainfall episode observed in the area drained by the analysed collector (if it is possible to find them, e.g. on the websites of municipal companies, environmental monitoring, weather forecasts etc.):
   - location of the rain gauge,
   - when was the last large rainfall,
   - duration and intensity of the last rainfall,
   - weather conditions in the period between the occurrence of the described rainfall episode.
7. Description of measurement procedure (adopted methods and assumptions), conclusion.

5.6 Final results description

For the presentation of the methodology to your students, you can use Flooding presentation.pptx. For the field characteristic description use file Flooding Questionnaire to print.doc to create your set of tables according to Table 5.3 or Flooding Questionnaire set.doc and during measurements, the results are collected via application and send to the database Climate Scan. Students should prepare a full report of data collection and data analysis, including photo documentation of sampling and measurements conduction. Report should include analysis of flooding parameters and terrain conditions as well as weather conditions including photos. The last step should include conclusions and summing. For the knowledge income verification use the Flooding pre-post test to print.doc.

5.7 External materials

See: https://impetus.aau.at/outputs/

Folder: Flooding

- Flooding instruction.pdf
- Flooding Questionnaire to print.doc
- Flooding Questionnaire set.doc
- Flooding pre-post test to print.doc
- Flooding pre-post test key.doc
- Flooding presentation.pptx

5.8 Definitions

Catchment area (*synonym* basin) – the area of land from which water flows into a river, lake, or reservoir.

Reservoir – a natural or artificial lake for storing and supplying water for an area.

Flood risk index – the parameter showing the level of the flood risk, is determined by the summed probability of flood hazards.

Water level – the level of the water surface, in relation to the bottom of this reservoir/river or in relation to the ordinate above sea level.

Channel capacity (*synonym* river capacity, and in general, rain water system capacity) – the maximum amount of water that can pass through a river (including culverts, bridges, changes of channel shape etc.) without causing damage and without flowing over the banks.

River flow (*synonyms* river discharge, flow rate) is the volume of water flowing through a river channel, measured at any given point in cubic meters per second.

5.9 Literature

[1] Mays Larry W., 2010, *Water Resources Engineering,* Arizona State University, USA, Wiley

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6 Weather parameters

6.1 Introduction

What is the weather? What defines the weather? As a basic definition, **weather** is the state of the atmosphere, more precisely, in its lowest layer, the troposphere. But is the weather the level of precipitation, or the temperature of the air?

In fact, weather is made up of multiple parameters, including air temperature, atmospheric (barometric) pressure, humidity, precipitation, solar radiation or wind. Each of these factors can be measured to define typical weather patterns and to determine the quality of local atmospheric conditions. However, the impacts of weather elements do not remain solely in the atmosphere. Weather elements form a chain reaction.

For example, temperature, pressure and humidity (moisture) can interact to form clouds. These clouds, in turn, can reduce solar radiation available for plants; or they can increase precipitation, which can runoff into a body of water and, in case of intense/extreme events, perhaps lead to flooding. Similarly, lack of precipitation affects weather conditions but it also affects soil moisture and water levels, and can lead to the development of drought conditions.

High temperatures, in addition to heating the air, can also increase the heat transfer to local bodies of water and increase evaporation or have an impact on aquatic life/ecology and water pollution. High temperatures can also affect energy balances and consumption, or affect the thermal comfort in cities. Ultimately, it can affect human health or put lives at risk.

Wind speed and direction can be indicative of a front moving into the area, or it can create waves and encourage a stratified water column to mix, in a water body.

Thus, overall, the environmental conditions produced by different weather parameters have an impact on the quality of the surrounding ecosystem.

Monitoring the weather provides an environmental baseline, and it can also provide valuable information that can be used to explain or predict weather events and keep an eye on the quality of human comfort conditions or recreational safety, for example.

6.2 Atmospheric conditions and the weather

The Atmosphere

Regarding the scale of the Earth's atmosphere and the atmospheric processes and conditions, our perception is naturally biassed by the (relatively small) human lifetime scale and a usually surface-based viewpoint. There are in fact two very different scales in the atmosphere, the horizontal and the vertical. Horizontally, the atmosphere is much larger than we can perceive from a point on the Earth's surface, of the order of magnitude of tens of thousands of kilometres. Vertically, by contrast, the scale of the atmosphere is much smaller (smaller than the radius of the Earth), but it very much influences the conditions in which we live. Since much of the material of the atmosphere is squeezed into a shallow layer overlying the surface of the Earth, the distribution of e.g. temperature, humidity and other properties are strongly anisotropic, in the sense that their gross vertical and horizontal distributions are very different; for example, vertical gradients are larger.

Immediately overlying the Earth's surface is a region dominated by turbulent interaction with the surface (the planetary boundary layer); its depth varies greatly with time and location. The layer of the atmosphere that is closer to the Earth's surface, the troposphere, is the most relevant to the (surface) weather.

Meteorology is the study of everything above the Earth's surface, namely the study of the physical nature of the troposphere, focussing on the dynamic aspects of this nature and variability. On the other hand, climatology covers the typical and average aspects. However, most significant physical structures and behaviour of the lower atmosphere have their own meteorological and climatological aspects, which frequently overlap. Thus, there is often some confusion, which is also due to the explosion of interest in climate change and the variable nature of climate.

As the atmospheric activity affects the safety of humanity, occasionally even disastrously (e.g. floods, droughts), forecasting atmospheric behaviour is important, in particular the component affecting the Earth's surface conditions.

The Sun has a direct and important influence on the atmosphere and is ultimately responsible for the weather. Solar energy, much of it in the form of visible sunlight, pours continuously on to the Earth, affecting both the surface and overlying air. The atmosphere is solar-powered, i.e., the Sun can be considered as the prime driver of all atmospheric activity. The diurnal variations of radiative fluxes and their variation with latitude influences, in particular, air temperature.

Sunlight rays are absorbed differently by land and water surfaces (equal amounts of solar radiation heat the ground more quickly than they do water). Differential warming, in turn, causes variations in the temperature and pressure of overlying air masses.

As an air mass increases its temperature, it becomes lighter and rises higher into the atmosphere. As an air mass cools, it becomes heavier and sinks. The cooling of air masses with high water vapour content can trigger precipitation.

Pressure differences between masses of air generate winds, which tend to blow from high-pressure areas to areas of low pressure. Fast-moving, upper atmosphere winds known as *jet streams* help move weather systems around the world.

Weather systems

Large weather systems called *cyclones* rotate counter clockwise in the Northern Hemisphere (clockwise in the Southern Hemisphere); they are also called "lows," because their centres are low-pressure areas. Clouds and precipitation are usually associated with these systems. *Anticyclones*, or "highs," rotate in the opposite direction and are high-pressure areas - usually bringing clearer skies and more stable weather.

The boundary between two air masses is called a *weather front*; here, wind, temperature, and humidity change abruptly, producing atmospheric instability. Such instability leads to the development of storms, bringing rain or snow and sometimes thunder and lightning too.

The weather you experience is influenced by many factors, including your location's latitude, elevation, proximity to water bodies. The degree of urban development, which creates "urban heat islands," and the amount of snow cover, which chills an overlying air mass, also play important roles in some areas.

The next time you watch a weather report on television, think about the many factors that influence our weather, many hundreds of kilometres away, that help make the weather what it is at a given location and time.

6.3 Standard weather parameters

Standard weather parameters include:

- Temperature: Immediate Temperature | Interval Values of Temperature
- Humidity: Instantaneous Relative Humidity | Interval Values of Relative Humidity | Absolute Humidity
- Dew point: Instantaneous Dew Point | Interval Values of Dew Point
- Atmospheric Pressure and Density: Pressure Adjusted to Sea Level | Surface Pressure | Pressure at Higher Altitudes | Air Density
- Wind: Instantaneous Wind Speed | Instantaneous Wind Direction | Horizontal Wind Components | Vertical Wind Component | Interval Wind Speed | Interval Wind Gusts | Interval Wind Direction
- Clouds: Amount of Cloud Cover | Ceiling Height | Cloud Base
- Precipitation: Accumulated Precipitation | Precipitation Type | Precipitation Probability | Hail | Supercooled Liquid Water | Rainfall | Snowfall | Sleet
- Evaporation: Accumulated Evaporation
- Snow and Frost: Frost Depth | Soil Frost | Amount of Snow Melt | Amount of Fresh Snow | Snow Depth | Snow Water Equivalent | Snow Density | Snowfall Probability
- Radiation: Instantaneous fluxes: Clear Sky Radiation | Diffuse Radiation | Direct Radiation | Global Radiation
- Accumulated energy: Accumulated Energy (Direct, Diffuse or Global Radiation) | Clear Sky Radiation
- Other Meteorological Parameters: Geopotential Height | Water Vapor Mixing Ratio | Layer Thickness

Revisiting briefly some concepts:

Solar Radiation

Solar radiation is radiant (electromagnetic) energy from the sun. It provides light and heat for the Earth and energy for photosynthesis. This radiant energy is necessary for the metabolism of the environment and its inhabitants. The three relevant bands, or ranges, along the solar radiation spectrum are ultraviolet, visible, and infrared. Of the light that reaches the Earth's surface, infrared radiation makes up about 50% of it, while visible light provides roughly 42%. Ultraviolet radiation makes up just over 8% of the total solar radiation. Each of these bands has a different impact on the environment.

Sunlight is responsible for warming the Earth, oceans and the atmosphere through infrared radiation. Both water and land reflect back some of that radiation to warm the atmosphere or other objects in contact with the surface. The darker the object or surface, the faster it will absorb light and heat.

Wind Speed and Direction

At a given location, winds are very variable in direction and over time, which is associated with atmospheric turbulence. Horizontal wind direction is indicated by vanes. However, small, light and aerodynamically optimized vanes are needed to register the rapidly varying directions of wind. The meteorological convention is to describe the direction of a horizontal wind by the direction from which it is blowing. Usually, only the horizontal component of wind is appraised because the flattened shape of the atmosphere ensures that the horizontal wind speeds are usually more than 100 times larger than vertical ones, and almost always more than 10 times larger.

In routine observations, ten-minute averages, together with maximum speeds in gusts, are used to define wind speeds near the surface. The strength of wind near the surface, and its effect over land, can be categorized by the Beaufort scale.

Air Temperature

Air temperature is indirectly dependent on solar radiation. While air itself does not absorb infrared radiation, it receives heat from the Earth's surface. This effect occurs through heat transfer by conduction and convection.

Earth absorbs infrared radiation and converts it to thermal energy. As the surface absorbs heat from the Sun, it becomes warmer than the surrounding atmosphere. The heat is then transferred by conduction (contact) from the warmer Earth to the cooler atmosphere. Air itself is a poor conductor of heat, so convection, or the rise and fall of warm and cool air, warms the rest of the atmosphere that is not in contact with the surface. As the warmer air rises, cooler air sinks to the surface, where it continues in the convection process.

Earth's surface also reflects some infrared radiation back into the air. This reflected radiation can be trapped and absorbed by gases in the atmosphere, or re-radiated back to the Earth. This process is called the *greenhouse effect*. Without the greenhouse effect, the Earth's average surface temperature would be about -18°C instead of the current +18°C.

Water Temperature

Infrared light from the Sun is absorbed by bodies of water and converted to heat energy. This low energy radiation excites electrons and warms the top layer of water. Nearly all infrared radiation (about 90%) is absorbed within the first meter of the water column, near the surface. This heat is then transferred to greater depths through movement from wind and convection. While heat is slowly transferred throughout the water column, it often does not reach all the way to the bottom. This is due to water column stratification.

In the ocean and many lakes, water can stratify, or form distinct layers of water. These layers are distinguished by their temperatures, densities and often different concentrations of dissolved substances (such as salt or oxygen). The different water strata are separated by steep temperature gradients known as thermoclines. Even with convection and wind, it is difficult for most of the Sun's heat to cross these barriers. Instead, the lowest strata of water will remain at low temperatures, while the surface water temperature will fluctuate both diurnally (daily) and seasonally.

6.4 Climatic/meteorological observations

How do we observe the atmospheric conditions?

Whereas people can make themselves aware of a wide range of meteorological conditions, their often weak and ambiguous senses reaction severely limits the quality and quantity of our observations. Thus, atmospheric data must be as unambiguous and definite as possible, which can be provided by mechanical aids (i.e. observational instruments). The more common systematic measurements of atmospheric variables include, e.g., temperature, humidity, wind, pressure, precipitation. Of the many other types of observations that could be mentioned, the most relevant concern solar and terrestrial radiation.

Today, advances in science and technology allow us to gather detailed observations using a host of modern measuring instruments, providing a variety of innovative instruments and sensors that are changing conventional instrument-based measurement approaches.

Different observation networks are currently securing a whelm of data of different nature and spatial and temporal resolution are recorded. They include surface, upper air and satellite networks:

The surface network: The conventional monitoring network is composed of ground stations that cover the measurement of standard weather parameters (Figure 6.1).

Figure 6.1. Views of meteorological stations from monitoring networks showing several measuring devices.

Weather stations typically have different instruments, for example: thermometer for measuring air and sea surface temperature; barometer for measuring atmospheric pressure; hygrometer for measuring humidity; anemometer for measuring wind speed; pyranometer for measuring solar radiation; rain gauge for measuring liquid precipitation over a period of time; psychrometer for measuring humidity by taking both a wet-bulb and a dry-bulb temperature reading; wind sock for measuring general wind speed and wind direction; wind vane, also called a weather vane or a weathercock, for showing which way the wind is blowing (Figure 6.2).

Figure 6.2. Examples of instruments deployed at meteorological station. From left to right: anemometer, grass thermometer, rain gauge, and sheltered, thermometer for maxima and minima temperature (in horizontal position) and psychrometer (in vertical position).

The stations of the surface network are scattered across the continents. Each country maintains its own network(s). As far as is possible, the observations are made in sites that are standard in construction and exposure, but are nevertheless representative of the surrounding terrain. However, selected sites vary considerably in altitude, therefore, parameters such as station pressure need to be correct. No attempt is made to correct air temperature for stations' altitude. All instruments used should be designed to conform to international standards, and operated by staff trained to operate them in a consistent and adequate manner. This guarantees that atmospheric data observed across the world are comparable.

In surface networks, conventional analogue instruments are being replaced, to allow for digital (continuously) recording and data transmission (Figure 6.3). Networks of weather radars are as yet very incomplete and limited. At some stations air quality measurements might also be undertaken.

The upper air network: Observations of wind, temperature, relative humidity and pressure are made by radiosondes (free-flying balloons released from the upper-air stations of the synoptic network). While in flight, the data are sent by radio to the ground station, and the sonde's position is monitored by automatically tracking radar. Although these data sampling intervals, in space and time, are much greater in the upper-air network than in the surface network, the fact that the atmospheric structure is much smoother and larger in scale aloft than it is near the surface justifies the interest in this type of data acquisition. The surface heterogeneities generate significantly smaller and more transient structures, especially over land.

Figure 6.3. Examples of automatic weather stations.

The satellite network: the first meteorological satellite was launched in 1960. Since then they have multiplied and developed considerably. Meteorological satellites are platforms for electromagnetic scanning of the atmosphere from above (i.e., *top-side* observations). The scanning can be passive or active. In passive scanning, satellites merely make use of existing radiation emitted or reflected from the atmosphere, without adding to it. The radiometers used are sensitive to one or more wavelength bands, for example, in the visible and infrared ranges. Radiometers that are sensitive in the far infrared are independent of solar radiation and respond instead to the terrestrial radiation emitted continuously by the Earth´s surface and atmosphere. This radiation increases in intensity as the temperature of the emitting materials rise; thus, the resulting imaging has a brightness scale that corresponds to a temperature scale in the original panorama. The brightness scale can be replaced by an arbitrary colour scale for easy of subsequent analysis by eye. Radiosondes are currently under active development, which opens new perspectives in this field. Revisiting times and imagery spatial resolution, as well as the multi-spectral and hyperspectral resolution of the sensors have been increasing much in the last few years. At present, satellites are providing complementary data for characterizing the weather; the data spatial and temporal resolutions depend on the source. For more insight, check images (https://www.ipma.pt/en/espaco/msg/index.jsp) obtained by the SEVIRI sensor on-board the satellite Meteosat Geostationary European Second Generation (MSG).

The World Meteorological Organization (WMO, https://public.wmo.int/en) coordinates the worldwide efforts that are prerequisite for the production of accurate and timely weather forecasts. Currently, there are well over 10 000 manned and automatic surface weather stations, 1000 upper-air stations, 7000 ships, 100 moored and 1000 drifting buoys, hundreds of weather radars and 3000 specially equipped commercial aircrafts that measure key parameters of the atmosphere, land and ocean surface every day. Additionally, there are some 30 meteorological and 200 research satellites in the global network for meteorological, hydrological and other geophysical observations.

Short term monitoring campaigns are also useful to collect data of high temporal and spatial resolution, using eventually a suite of available sensors that are in general different from the sensors used in fixed deployed measuring stations, and which operation does not also follow established standards.

Many **sensors** are currently in use to assess weather parameters, including sensors that are used for measurements that are not carried out within conventional monitoring networks. Technology developments have been directed to this field of environmental monitoring, broadening and improving the range of spatial, temporal and intensity resolutions of instrumentation, in relation to past approaches. This is boosting the need to truly understand how the different sensors work and their response to input signals, as comparison of data from different origins can be easily biased by intrinsic instrumentation and installation features.

Understanding the different origin and resolution of atmospheric data is crucial for correctly interpreting and using data collected by different sensors and types of network.

What do we observe: the weather, the climate?

The relation between weather and climate is that between instantaneous and mean conditions of the atmosphere: "**weather is what you get, climate is what you expect**".

But people often confuse climate and weather - the two really are quite different. For a particular location, weather describes the condition of the atmosphere over a short period of time e.g. from day to day or week to week, while climate describes average (weather) conditions over a longer period of time.

By stepping outside, you might experience many facets of weather. Humidity, air temperature and pressure, wind speed and direction, cloud cover and type, and the amount and form of precipitation are all atmospheric characteristics of the momentary conditions we call weather.

Information about weather parameters can serve different purposes. The intrinsic large temporal and spatial variability in weather processes demands to maintain the continuous operation of dedicated monitoring networks and data collection and analyses.

The data is used to study the climate, its variations and extremes, and its influences on a variety of activities including human health, safety and welfare to support evidence-based decision-making on how to best adapt to a changing climate. Local (ground) data collection and analysis is crucial due to the diversity of environmental conditions found over land, and problems, which requires a case-by-case assessment and decision. Almost all our activities are influenced by weather, climate and water.

Atmospheric data interpretation

In general, the atmospheric data interpretation depends on the scale of climate analysis, which should consider the spatial representativeness of the meteorological stations used.

At a **regional (mesoclimatic) scale**, in which the main climatic differentiation factors are determined by the thermal, hygrometric and dynamic characteristics of the air masses, meteorological stations at a similar altitude and distance from the sea, spaced about 10 km apart, might represent the regional climate satisfactorily; however, this happens despite the spatial contrasts of climatic variables that they inevitably present, but that are mitigated by the parameters of central tendency that characterize the climate.

At the **scale of the local climate (topo/micro climate)**, in which the determining factors of spatial differentiation of climatic variables are linked to the characteristics of the geographic space (e.g., the type of land occupation, altitude and topography), the spatial representativeness of each of the weather stations is heavily restricted. This means that, at this scale of analysis, a given conventional weather station of the surface network is very likely not representative of the climate of a given urban area, or of the urban agglomeration, as a whole.

Thus, one way to deal with this lack of knowledge and that could be important to assess climate issues at the street and neighbourhood scale, for example, is to collect complementary point data in a non-conventional way, often using sensors, many of them operated manually. However, such data, which could be useful to qualitatively assess the impact of different urban features on the urban local climate, is often not obtained by standard instruments and is not operated following standard procedures. Quite commonly, the response times of these sensors are unknown and not respected by the user. This means that, although valuing the contribution that these data might have to raise our awareness of a number of local urban issues, we should not confound the type of information in these data with the information provided by standard meteorological stations. The uncertainty in the data is unquantifiable, and can easily introduce an unquantifiable bias in analysis results. For scientific and technical assessments, or whenever quantitative studies are needed, a sounder and more trustful data collection programme should be established. Nevertheless, the easiness of *ad hoc* data collection allows us for a rapid appraisal, on site, of the main features of the urban environment that seem to dominate the local climate, and this can be quite important to contribute, e.g., to identify problems and/or problem areas within the city (e.g., hotspots, secondary urban heat islands), and find suitable measures to mitigate those problems.

Measurements carried out using non-conventional instruments installed in vehicles (e.g. cars, bikes) are sometimes also considered. This scheme allows one to obtain information on a large number of points (sometimes called dynamic data) and draw detailed maps and profiles that illustrate the spatial variation in the measured weather parameters. This approach could be useful to differentiate between urban areas, suburbs and rural areas and establish types of heat islands for different urban spaces and distinct weather conditions. Disadvantages of this approach include: I) the data obtained by this measuring scheme is not comparable to the data from the conventional network (or other static data), unless the data series undergo non-trivial transformations; II) to guarantee simultaneous measurements, a set of different measuring instruments needs to be used and instrumental errors can easily distort results. To lessen this problems, two-way trajectory measurements could be considered, using the average value of the measurements in graphing profiles; instead of using the real data, it is also possible to use the differences between the temperature observed in each point and the lowest temperature recorded in a given survey trajectory, which diminishes instrumental errors. Nevertheless, the most serious drawback is that this observation system can only be applied to some weather parameters, such as air temperature and humidity; it cannot be applied to precipitation or wind, due to the variability in these processes.

Another path, which also allows for a more comprehensive insight at the urban scale, are remote sensing data obtained by sensors installed in aerial vehicles (AV, drones) and satellites. Whereas sometimes AV flights are heavily restricted over urban areas, or even not allowed, nowadays imagery from satellites are accessible at spatial scales of interest to assess the variability of relevant atmospheric and urban surface conditions. One example regards temperature, which can be appraised from Land Surface Temperature (LST) imaging, for example, from Landsat-8 satellite. The remote sensors capture the radiant temperature of the urban surfaces, which allows a detailed analysis of the temperature spatial distribution and its relation with urban variables. The information on each satellite imagery refers to a specific date that corresponds to the revisit times of the satellite. But the broad spatial coverage of the data is unbeatable, in comparison with other ground-based data types. It can be used, for example, for inspecting differences between the inner city and the surrounding rural area, or for identifying temperature variability across the city.

Thus, depending on the study, one should be able to identify which data are available (from which sources, which spatial and temporal resolutions, which record lengths), their comparability, and how different data sets can be used complementary to better characterise the study area.

About measuring and processing weather data

Weather data collection may vary significantly according to the nature and objective of the study/activity. It concerns, for example: I) the type of variable, the temporal and spatial resolution required, the length of the available record; II) the specific equipment to use, or available, and its ability (or not) for the continuous recording, over time, of a given variable; III) the opportunity to collect static or dynamic data, and analysis tools available. Weather data collection, processing and analysis should be tied to the goal of the particular case study.

Thus, the following should be kept in mind:

- Before collecting data, including *in situ*, make sure that you identify the type of data needed for a specific investigation/study and that you adequately plan the field work.
- Atmospheric fields are extremely variable in time and space, thus, be aware of the representativeness of the data, in particular if acquired during field's measurement campaigns. For the assessment of variations in space of a given variable, make sure that the measurements are conducted within a short period and that the atmospheric conditions (the weather) are not varying significantly during the record period.
- When conducting field measurements, take care about the limitations of the sensors used. Instantaneous single measurements should be avoided. At each point, collect data over a lapse of time and use the average value as a reference value. The duration of the time interval and number of registered values depend on the aim of the study. Do not forget that temperature sensors should be shaded; readings should not be taken when the sensor is exposed directly to incident solar radiation.
- Take note of the exact location (use GPS, if available) and time of the measurements, so that you can interpret the data.
- Make sure, whenever possible, to compare your data with data collected at a nearby weather station from a monitoring network. You could also compare measurements obtained using different sensors, to appreciate similarity and differences in measurement outcomes, in terms of precision, response times, etc.
- Weather stations from measuring networks may offer you the possibility to understand the variation in the data, for example, at the daily, seasonal, annual or larger scales. For example, in relation to heat stress assessments, historic temperature and humidity records will allow you to better appraise the related risk (in statistical terms).
- Long enough data sets will allow you to characterise the climate at the station site. For characterising the urban climate or the regional climate, you need adequate spatial information, which often implies having data for a representative number of points.
- Crude instrumentation and circumstantial observations will not allow one to draw a broad picture of the dominant factors when one refers to atmospheric conditions at the urban scale, ultimately at stake for assessing the urban environment. However, field campaigns might contribute to better understanding the high variability in the measured parameters, and the need to deepen the holistic understanding of the urban environment, as a whole.

6.5 The urban climate

The World Meteorological Organization (WMO) defines **urban climate** as "local climate which differs from that in neighbouring rural areas, as a result of urban development". That means air temperature, precipitation, concentration of air pollutants, noise and wind speed often differ from the surrounding areas. For example, cities usually have a higher air temperature than the surrounding area and hence are in the focus of climatic spatial planning. In times of climate change, the climatic differences between the city and the surrounding regions might result in increasing heat stress on population and infrastructures during the warm(er) seasons.

The climate of a site may be regarded as the integration of a series of controls, differing in scale. In sequence these are: the regional climate, determined by synoptic factors; the modifying effects of the local orography; and the self-induced modifications of the buildings and building groups themselves. In addition, in discussing urban climates, we have nevertheless to distinguish between I) the modification of the climate by the accumulation of buildings (change of topography) and II) the modification of the climate by urban air pollution.

The growing rate of pollutants emitted into the atmosphere by anthropic activities, combined with the influence of topography change, leads to an accumulation of trace substances in the air over cities and, frequently, to the formation of haze. This haze dome, which builds up over densely populated areas, is concentrated or dispersed according to rate of emissions, the effective emission level above the ground, the wind profile, the vertical temperature profile and relief. The characteristics of the haze dome affect the quality of the urban environment.

Thus, all these different factors and effects are important for discussing the urban environment from different perspectives, in particular due to the chain reactions involved.

Some examples of influences of urbanization on urban conditions, namely regarding wind, radiation, visibility, temperature, precipitation and air humidity, are:

Wind

Wind is the basic parameter of urban climate, as a whole. It helps to control pollution concentrations, temperature, fog frequency, evaporation rates and humidity, cloud amount and precipitation. All of these determine the urban environment.

Part of the difficulty in studying wind in urban areas lies in the very complex patterns of airflow in these areas. On the one hand, the whole wind profile and turbulence spectrum changes as air moves across cities; and, on the other hand, there is a rapid increase with height in the time and length of trajectory required for the wind to adjust itself to the change in surface roughness at the urban-rural boundary. Wind speed near the ground (e.g., at 1.5 m above the ground) might differ considerably from the wind speed value measured at 10 m height in meteorological stations.

It is frequently assumed that all winds are reduced in speed in urban areas, although sometimes the opposite is observed. Studies have shown that in urban areas strong winds' speeds are decreased, but light winds' speeds are higher. This might be due to frictional retardation dominating at high speeds, but the relatively enhanced urban turbulence at low speeds may transport greater momentum toward the surface.

Radiation

The pattern of radiation exchanges in urban areas is complex. Short wave radiation is scattered and absorbed by pollution particles of the haze hood, while surface receipts are highly differentiated by the varied geometry, aspect and albedo of city fabrics. Backscatter of the solar beam by pollution aerosols can result in a loss of as much as one fifth in the short wave radiation) received by the earth-atmosphere system. In highly polluted areas, absorption by gases and aerosols can probably result in heating rates in excess of a few couple °C per day, which could not be compensated by stronger infrared cooling. In consequence, there could be a loss, beneath polluted city atmospheres, of visible radiation and ultra-violet radiation. The expectation is that any change in the levels of pollution will lead to changes in the character of radiation exchanges in towns.

Visibility

Ultra-violet radiation plays an important role in photochemical processes involving hydrocarbons and other air pollutants which lead to irritant smog. In general, fogs are both directly and indirectly related to levels of air pollution in cities but the pattern of fog frequencies is not simple; visibility is usually different in city centres and in the suburbs, which could result from warmer but more polluted central areas as compared with the cooler, windier and more humid fringe areas of the city where housing densities are lower and there are more open spaces. For these same reasons, fogs tend to form and disperse earlier in suburban areas than in central areas.

Temperature

The generally higher temperatures inside towns have been noted for a long time. The heat exchange mechanisms leading to the excess heat of towns (the "urban heat island", UHI) in comparison to surrounding (rural) areas are usually influenced by four main contributory factors: I) changes in the thermal characteristics (albedo, heat conductivity and thermal capacity) of the surface following the substitution of farms and fields by buildings and roads; II) changes in the airflow patterns with a reduced diffusion of heat from streets and courtyards; III) changes in evaporation rates and heat losses; and iv) the heat added by humans and human activities. These factors seem to be of differing importance in different cities so that the character of temporal variations (in particular with respect to UHI) also varies, for example, between warmer and colder seasons. The heat island effect is also the main cause for the formation of an *urban circulation system*. The urban structure and construction features can also lead to the development of secondary heat islands (i.e., hotspots) within the city.

Precipitation

Regarding precipitation in towns, the main difficulty is to separate the purely urban controls from the much stronger influences of synoptic climatology and topography within the built-up area.

Three main factors may be the cause of urban-induced changes in precipitation. These are: I) additional condensation nuclei of a particular type; II) increased turbulence because of increased surface roughness; and III) thermal convection resulting from higher temperatures. Presumably because of these influences, a number of cities have been noted to have more rain days, more thunderstorms and more total precipitation than the country areas around them. Only towns above a certain size may affect rainfall amounts. Moreover, it is not necessarily to be expected a coincidence between the area of any change and the limits of the built-up area.

Air humidity

The effects of urbanisation upon atmospheric humidity are hard to assess, and often small in magnitude. But this is not a universal pattern. Proximity to water bodies and green areas can impact importantly on this weather parameter, at the local scale. Urbanization can also induce phenomena such as the *urban dryness island* referring to conditions where lower humidity values are observed in cities relative to more rural locations.

6.6 Understanding and interpreting weather data

The assessment of different urban environmental issues requires insight on local conditions. Often, these are related to weather parameters. For this purpose, exploratory measurements could be carried out. For example, for the better understanding of the risk of heat stress at the street or neighbourhood level based on the Heat Index, air temperature and humidity needs to be assessed at different locations using portable weather stations. Local measurements are key to gain insight into the potential usefulness of different heat adaptive measures, namely green-blue solutions.

While conducting the field survey, you can try to do sketchy maps of the air temperature and/or the Heat Index (or other relevant indicator). This would allow you to confirm (or not) that your planned measurement grid would be suitable for your particular study; while still on location, you could easily collect more data, if needed. You can use the IMPETUS Data Collection App, if applicable to your survey, and/or upload your project in the ClimateScan platform.

However, bear in mind that the weather data that are collected on a given day might not represent well the "typical" (i.e. normal, in statistical terms) local conditions. Remember the difference between the weather and the climate! Thus, you might bias conclusions of your survey regarding the need of adaptive measures implementation if you rely only on circumstantial (single) observations.

In addition to occasional weather variables' measurements conducted across a given study area, whereby you intend to appraise, for example, the spatial variation found for those variables along a given street or neighbourhood, you might like to assess the weather data obtained at a nearby (ground) weather station (e.g., air temperature, relative humidity, wind speed, and global radiation) from a monitoring network for a broader insight and characterization of the weather conditions. Identify the existence of such weather station(s), at a short distance from the study area; annotate the coordinates (including the altitude) and name of the weather station(s).

The sample graphs in Figure 6.4 illustrate the type of data that you could access via the web interface with automatic stations; the data are usually access free. These types of records and graphs will illustrate, e.g., the type of daily variation that you could expect for temperature and air humidity, and for other atmospheric data. Similarly, you can assess seasonal variations in pertinent weather parameters. This could be important for better understanding, for example, the risk of heat stress potentially affecting the area. For climatological studies – that focus on the long-term evolution of atmospheric conditions (years to centuries) - the existence of long data series is required.

You are recommended to make similar graphs for visual interface with the data relevant to your study area. If needed, explore the website of the World Meteorological Organization (WMO) for getting acquainted with the graphical representation of weather and climate data.

There are different web platforms around the world that generically allow users to access weather data or see the evolution of climatological scenarios resulting from numerical modelling of processes applied to the climate parameters for a selected area and/or time interval. Often some platforms provide data through a map service, allow users to perform data download operations and map geoclimatic units.

Figure 6.4. Example of an interface with weather data measured at an automatic weather station. The data were measured on August 5, 2018, at the weather station ICOIMBRA14, Portugal, coordinates 40° 11' 6''N, 8° 24' 46,8''W (https://www.wunderground.com/dashboard/pws/ICOIMBRA14/graph/2018-08-5/2018-08-5/daily).

The material in this module pursued different objectives with respect to contributing to increasing your awareness, curiosity and knowledge on different atmospheric related processes and phenomena, and on the interaction between weather parameters and the urban environment. Namely, you should:

- Be aware of the difference between the weather and the climate.
- Get acquainted with atmospheric parameters.
- Learn about atmospheric observation standards, instruments and networks.
- Appreciate the differences between data collected using standard methods and equipment, and non-professional sensors' data, i.e., between crude instrumentation and circumstantial observations.
- Understand the graphical representation of weather and climate data, at different temporal and spatial scales.
- Comprehend that liveability of cities results from a complex realm of nonlinear processes, including atmospheric processes, which full understanding is still in progress.

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7 Heat Stress

7.1 Introduction

The weather is not the only factor that contributes to many cities feeling uncomfortably hot. The built environment itself exacerbates high seasonal temperatures in urban environments. This is caused by the increasing urbanisation, characterized by increased construction density and paving of ground surfaces, among other factors. This effect is furthermore amplified by climate change and the results in increasing temperatures. At many locations in the world, climate change threatens city development and human safety.

There is thus the need to increase awareness about different urban environmental issues and climate change related vulnerabilities and challenges at local level, and to deal with local adaptation planning.

However, there is often limited availability of up-to-date data about local conditions and the impact of climate change on wellbeing and urban environment, in particular at the local street and neighbourhood level. In addition, there is lack of interdisciplinary approaches and public actions to solve local problems and inability to select the best solutions from a set of alternatives.

The material in this document is aimed at giving support to the exploratory assessments of urban heat stress vulnerabilities and risk.

7.2 Urban heat island effect

In fact, different factors contribute towards a typical climate phenomenon called the **urban heat island (UHI)** effect, which results in an increased air temperature in cities when compared to their rural surroundings. For example:

- **I.** vehicles stuck in traffic emit heat,
- **II.** air conditioners pump waste heat into the air,
- **III.** concrete and asphalt surfaces absorb and radiate the sun's rays
- **IV.** urban canyons formed between tall buildings, trap heat at the street level.

Regarding urban building materials, such as concrete and bituminous materials (asphalt), they can absorb heat during the day and radiate it back at night, much more than areas covered with vegetation do. The effect can add as much as 6–7°C to night-time temperatures in large cities and densely urbanized areas in relation to the surrounding countryside temperatures. There could also be different temperature conditions within the urban area.

Thus, within cities, air temperature strongly depends on building geometry, the thermal properties of the building's construction materials, radiative properties of the urban surfaces (e.g., building, roads and pavements) and anthropogenic thermal release, e.g., domestic heating, traffic and industry (Figure 7.1).

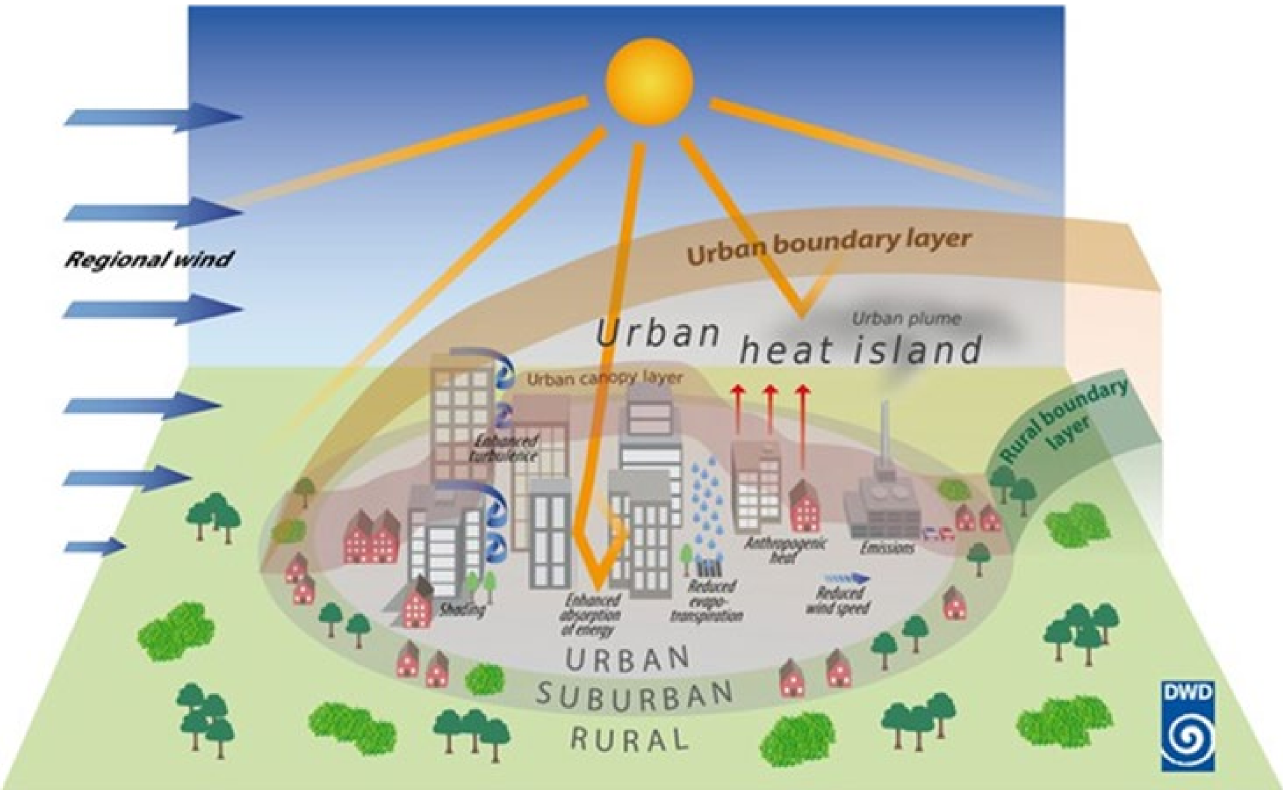


Figure 7.1. The urban climate and its influencing factors (DWD, 2021).

Several studies show also the dependency of UHI on a city's layout, i.e., the spatial organisation/pattern of a city's streets and buildings, including their orientation, plays a crucial role in the local UHI effect. The differences in the heating effect seem to result, for example, from the way buildings re-radiate heat that can then be reabsorbed by other buildings that face them directly.

However, each city is made up of a mosaic of individual buildings and other land-use units; their form and disposition are highly complex and, in detail, unique. Also, each urban unit, wall, roof, pavement, courtyard, street or park creates above it a climatological sheath with which it interacts. The way in which groups of buildings and whole cities affect the overlying air vary between different cities.

Among other main factors contributing to UHIs are the attributes of the surrounding area, the topography upon which the city is built, time of the year (i.e., season) and the regional climate, determined by synoptic factors. The UHI effect intensity might also differ, or not, between seasons (i.e. warmer or colder season), depending on geographical location and attributes of the urban area. Furthermore, this effect does not necessarily apply to cities in desert climates. In the desert, the evapotranspiration of the irrigated vegetation of the city may actually keep the city cooler than the surrounding barren region.

Especially during heatwaves, the higher temperatures in cities lead to a greater use of cooling and air conditioning systems and, thus, to a greater consumption of energy and higher costs. They also contribute to increased emissions of greenhouse gases (e.g., CO2) and air pollutants (e.g., if fossil fuels are used), and to deteriorate water quality. The increased temperatures can lead to smog formation, which is unhealthy and damaging to materials. This is boosted by a warming climate and rapid population growth.

The temperature of surfaces, e.g. pavements and facades, is related with air temperature. Overall, the urban air temperature is influenced, for example, by the percentage of sealed soils, or by the presence of water and vegetation in a neighbourhood. The heating of the air in urban areas is mainly determined by the geometry of the built environment (e.g., sky view factor) and the albedo (Figure 7.2) and emissivity of the surface materials.

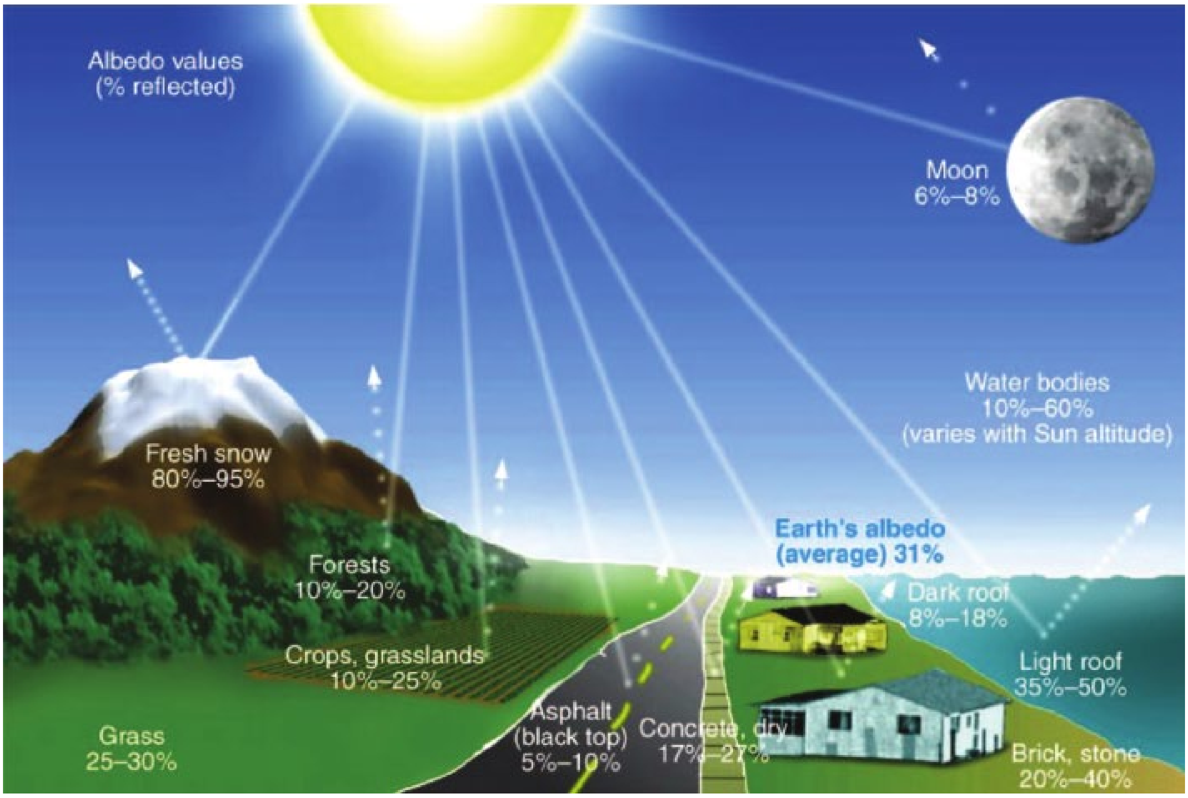


Figure 7.2. Albedo values for various surface materials.

Thus, overall, **why is it important to analyse urban heat islands?** The urban heat island effect and the evolution of the urban thermal environment has a close relationship with human society and important health, environmental and economic consequences.

With the frequency and intensity of heat waves increasing (whether the change has already been experienced or predicted by climate scenarios) it is urgent to tackle the excess heat faced both inside the buildings, and in the cities' outside spaces. There are many ways in which the UHI effect can be mitigated, while also creating more attractive places to live, work and play.

For example, to reduce UHI effects, many cities are planting more vegetation (including intensive tree-planting, creation of new parks, vertical planting and green roofs), recognising its value for urban cooling and the psychological wellbeing of residents; greenery provides shade and it stimulates evapotranspiration, the process by which water evaporating from plants' leaves reduces the adjacent air temperature. Besides cooling, abundant vegetation contributes also to other benefits: absorbing pollutants from the air, producing oxygen, increasing biodiversity and creating a calming, natural setting within the dense city and built environment.

Attaining cooler cities also demands changing the materials they are built from. As urban areas are dominated by dark and hard materials – concrete, asphalt, paving – most of which absorb, rather than reflect, solar radiation, cities are nowadays also using more reflective surfaces. For this purpose, bright roofing materials and cool coatings (typically, lighter pigments in asphalt or white-coloured coatings applied to roads, roofs and facades), which reflect more solar energy away from the city, back to space, are being used.

Water has also been used as a tool to cool cities, for centuries: house courtyards with pools and fountains, stimulate the evaporation of water and cool hot air. However, with respect to water, contemporary heat-proof cities accommodate ponds, pools, fountains, sprinklers and misting systems to cool outdoor spaces. Combining water with other urban cooling strategies can yield significant temperature reductions.

In fact, there is a suite of green-blue infrastructures that use nature-based solutions, which can increase the quality of urban ecosystem services.

There are also solutions that involve adaptable buildings and infrastructure that can morph to respond to different seasons and weather events, and thus keep the inside of buildings cool and comfortable in a warming climate.

The UHI phenomenon has several impacts on the living environment and on the population, namely the increase in **heat stress** risk. High temperatures can have, among others, significant health impacts.

Reducing the effect of UHI is thus vital to ensure that urban growth does not increase heat stress risks that urban citizens will face in the future, which are already being worsened by global warming and climate change.

7.3 Assessing heat stress

Heat stress occurs when our body is unable to cool itself enough to maintain a healthy temperature. Normally, the body cools itself by sweating, but sometimes sweating is not enough and the body temperature keeps rising. In the summer months, urban dwellers face increased risk of heat stress, with negative impacts on human health and comfort. The consequences of heat stress are usually more severe on older people, or people with previous illnesses, e.g., of the cardiovascular system, and small children who are often unable to adapt to higher temperatures.

To appraise the risk of heat stress in a given area, measurements at small scales are needed to provide information on surface and air temperature distribution and to better characterize thermal comfort/stress, at the local/micro urban scale. Ground observations and surveys are crucial to better understand the local conditions and the type of measures that could actually be more adequate to respond to and reduce high heat stress risk. Google Street view can be used as a complementary exploratory tool to conduct virtual appraisals of a city without the need to physically visit the area.

In addition to air temperature, other data such as fine-scale topographic maps, air humidity and urban attributes also provide important information that help to further assess the spatial variability of risk of heat stress.

Several approaches, of varying degree of complexity, have been developed for assessing the risk of heat stress. One example of a comprehensive approach is the Physiological Equivalent Temperature (PET) index (Höppe, 1999), that calculation is based on a diversity of specific variables and models, including physiological ones; however, the use of this indicator is often hampered by data unavailability.

A much simpler indicator of the thermal conditions is offered by the **Heat Index** (HI), which is based on only two atmospheric parameters: air temperature and relative humidity. This index describes how humidity affects the perception of high/warm temperatures in shaded areas, giving a measure of apparent temperature. Since the human body cools itself by evaporating sweat from the skin, higher humidity attenuates the effect of this mechanism. According to the HI, for temperatures below 27°C the HI equals air temperature. This index can be used in expedite assessments of the danger of heat exhaustion and strokes when performing outdoor activities. The HI is the result of extensive biometeorological studies over a period of decades by various researchers, most notably Steadman (1979).

To find the HI temperature, check the Heat Index Calculator or use the Heat Index Chart (Figure 7.3). This chart associates HI classes with different levels of alert in relation to the risk of heat stress: caution, extreme caution, danger and extreme danger (in Figure 7.3, the area without numbers indicates extreme danger). Usually, special alert is issued when the HI is expected to exceed ≈41°C for at least 2 consecutive days, but this limit might depend on the local climate.

A Heat Index Chart for areas with high heat but low relative humidity has also been developed by the U.S. National Weather Service (NOAA). Since HI values were devised for shady, light wind conditions, exposure to full sunshine can increase HI values by several degrees. Also, strong winds, particularly with very hot, dry air, can be extremely hazardous in terms of heat stress.

HEAT INDEX (HI), °C													
Temp. (°C)	Relative Humidity (%)												
	40	45	50	55	60	65	70	75	80	85	90	95	100
47	58												
43	54	58											
41	51	54	58										
40	48	51	55	58									
39	46	48	51	54	58								
38	43	46	48	51	54	58							
37	41	43	45	47	51	53	57						
36	38	40	42	44	47	49	52	56					
34	36	38	39	41	43	46	48	51	54	57			
33	34	36	37	38	41	42	44	47	49	52	55		
32	33	34	35	36	38	39	41	43	45	47	50	53	56
31	31	32	33	34	35	37	38	40	41	43	45	47	49
30	29	31	31	32	33	34	35	36	38	39	41	42	44
29	28	29	29	30	31	32	32	33	34	36	37	38	39
28	27	28	28	29	29	29	30	31	32	32	33	34	35
27	27	27	27	27	28	28	28	29	29	29	30	30	31

Category	Heat index	Possible heat disorders for people in high risk groups
Extreme Danger	≥ 52°C	Heat stroke or sunstroke likely.
Danger	40–51°C	Sunstroke, muscle cramps, and/or heat exhaustion likely. Heatstroke possible with prolonged exposure and/or physical activity.
Extreme Caution	33–39°C	Sunstroke, muscle cramps, and/or heat exhaustion possible with prolonged exposure and/or physical activity.
Caution	27–32°C	Fatigue possible with prolonged exposure and/or physical activity.

Figure 7.3. Heat Index chart and classes, associated with different levels of risk of heat stress (adapted from NWS, NOAA, U.S.).

7.4 Location and characterization of the study area

When investigating the risk of heat stress in a given urban area and actions to prevent or minimize it, it is important to understand the area's geographical context, including its relief and altitude, characteristics of the surrounding area (e.g., forest, agricultural areas), distance to the sea, climate, and demography. For characterizing the local climate, parameters such as air temperature, humidity, precipitation, wind and solar radiation are important.

For example, annual mean air temperature as well as the temperature in the warmest season, its range (what is the maximum and the minimum temperature), and the number of days a year that register air temperature above given thresholds (e.g., maximum temperature above 25°C or 30°C), which is case/location dependent, should be identified. These data are usually available from historic records of weather stations from national monitoring networks, but only representative weather stations will allow you to understand the local climate, and the vulnerability of the area to face critical warm weather conditions (e.g. intensity of the heat, frequency of very warm days, air humidity during hot weather). This type of data will allow you to picture potential heat stress vulnerabilities in a given city or urban area, and the pertinence of studying and fighting heat stress at the local scale, towards a better city liveability.

However, quite often, despite the fact that in many countries the number of urban automatic weather stations has been increasing, data will be available for stations/locations that might not represent well the conditions in the urban area of interest. So, field monitoring at the local scale is important.

Information on precipitation, including mean annual precipitation, identification of wet and dry seasons, and if they superimpose with the warmest season should also be gathered. The conditions regarding air humidity should also be assessed because it relates closely with thermal comfort/discomfort.

It is also important to understand how a given street is embedded in a more or less dense urban grid, and the main features of the urban environment and of the neighbouring/surrounding areas. Google Maps can be used to obtain a quick overview of the study area, and insight on the surroundings, such as the presence of green areas, rivers, lakes, etc. Figure 7.4 shows an example of such an image.

Figure 7.4. Example of an overview of urban residential areas (on the right hand side) and its surroundings, obtained from Google Map. The type of urban layout(s), the proximity between the residential areas and the river (at the bottom of the image) and the extension of the surrounding green areas can be easily appraised.

For an overall insight into the spatial distribution of temperature in the area of interest, different remote sensing technology-based monitoring tools are now able to provide detailed/high spatial resolution information on temperature. The applications promise well for urban climatology where the problems of physical size, and spatial integration of countless individual elements are most difficult.

Remote sensing data, obtained by sensors (e.g. infrared radiometers) deployed in satellites has been shown capable of identifying UHI, due to the extent of the data spatial coverage; these data allow one to appraise (and compare) the temperature in the cities and in their surrounding areas. The satellite-based data are also providing valuable tools to improve our insight into the air temperature distribution across cities and, therefore, assist in identifying problem areas, due to their current high spatial resolution.

Satellite (e.g., Landsat, the NOAA-AVHHR system) systems can provide, for example, Land Surface Temperature (LST) data. LST is the radiative skin temperature of the Earth's surface derived from infrared radiation; it refers to the effective radiating temperature of the soil plus canopy surface. Thus, LST measures the emission of thermal radiance from the land surface where the incoming solar energy interacts with and heats the ground, or the surface of the canopy in vegetated areas. Various methodologies have been developed to retrieve LST from space-based, remotely sensed thermal-infrared data that provides spatially continuous LST measurements with global coverage to examine the thermal heterogeneity of the Earth's surface, and the impact on surface temperatures resulting from natural and human-induced changes.

Figure 7.5 shows an example of such a LST map, which is based on data downloaded from Landsat-8 satellite (https://www.usgs.gov/landsat-missions/landsat-8); the LST map was obtained using QGIS software. This map shows that the surface temperature varies across the urban area and that the city registers higher temperatures than the surrounding area.

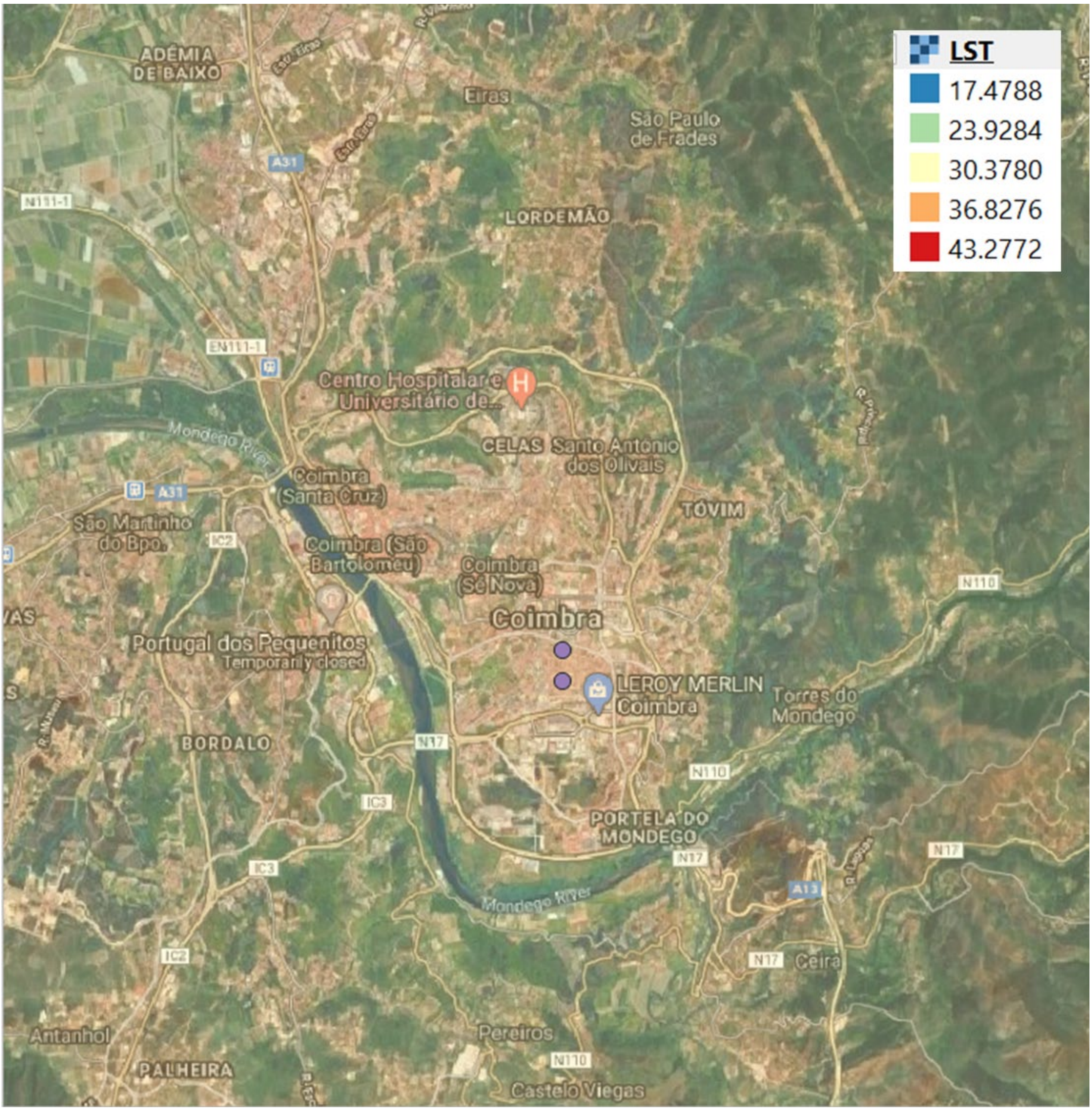


Figure 7.5. Example of a Land Surface Temperature (LST) map view. The image is for the city of Coimbra (Portugal), from August 5, 2018 (reference local time is 11:13am).

There is a strong relationship between LST and near surface air temperature, although the two temperatures have different physical meaning and responses to atmospheric conditions. In complex terrain, these differences are amplified. Because LST influences the partition of energy between ground and vegetation, it determines the surface air temperature. In general, air temperatures above a surface reflect the same trends as ground surface temperatures, but ground temperatures are likely to be more extreme.

Nevertheless, LST is an easy to access indicator and is one of the most important parameters to quantify urban microclimate; microclimate refers to the climate of a very small or restricted area, which assessment is especially important when it differs from the climate of the surrounding area.

7.5 Exploratory field survey description

An exploratory field survey focusing on an urban area, or street(s), could provide important knowledge on the local urban environment and increased understanding of the role played by different urban attributes. Overall, usual aims of such a survey are:

- to appraise ambient conditions, namely with respect to air temperature and relative humidity;
- to assess the risk of heat stress through, e.g., the calculation of the Heat Stress Index;
- to try to identify relations between air temperature, relative humidity and surface temperatures, and features of the urban area and streets, with special emphasis on the urban layout (e.g., street width, type of buildings, buildings' height, density of construction, orientation), surface materials (e.g., stone facades, green facades, lawns, streets and tracks' pavements, vegetation type), shades, water bodies, among others.

It is useful and recommended to follow a checklist to assist you in exploring the study site and collecting information on urban features that might have an impact on the urban thermal comfort/stress, and that might also determine the type of adaptive measures to adopt locally. An example of such a list is given in section 1.6. The list of features identified in that example is not exhaustive, so you can always identify other attributes that would likely have a potential important impact on the overall assessment of the local conditions and heat stress vulnerabilities, at the street and neighbourhood level.

For each one particular street of interest, the investigation should focus on the conditions along the street and the area in which the street is embedded. For each street, for reference, consider a start point coordinate (0,0,0) for the experiment. Consider the coordinates x, y and z (x,y,z), with x being the distance to the origin (along the street that is being studied, see Figure 7.6), y the distance in the perpendicular direction, and z representing the elevation. The start point can be used to identify the position of the different elements that are identified as being pertinent for the case study. Use a GPS to identify the spatial coordinates of the relevant points.

Google maps and tools can be used, namely, to roughly estimate elevation, lengths (e.g., street length, street width, distance to a water body or green space), building's heights and areas (e.g., green areas, parking lots, yards).

In order to assess the vulnerability of the urban areas to heat stress, you should explore **weather data** (air temperature and relative humidity) obtained, for example, using simple portable weather stations, which are easily accessible, at low cost. These observational data on a warm day will allow you to roughly estimate the Heat Index for the local conditions, and better understand how this and other indicators can be used to classify the thermal comfort/stress at different locations and conditions. Annotate, always, the time of the records. Be aware that if the performance of the sensors is not known, there could be some unquantifiable bias in the measurements, which should only be accepted for exploratory studies.

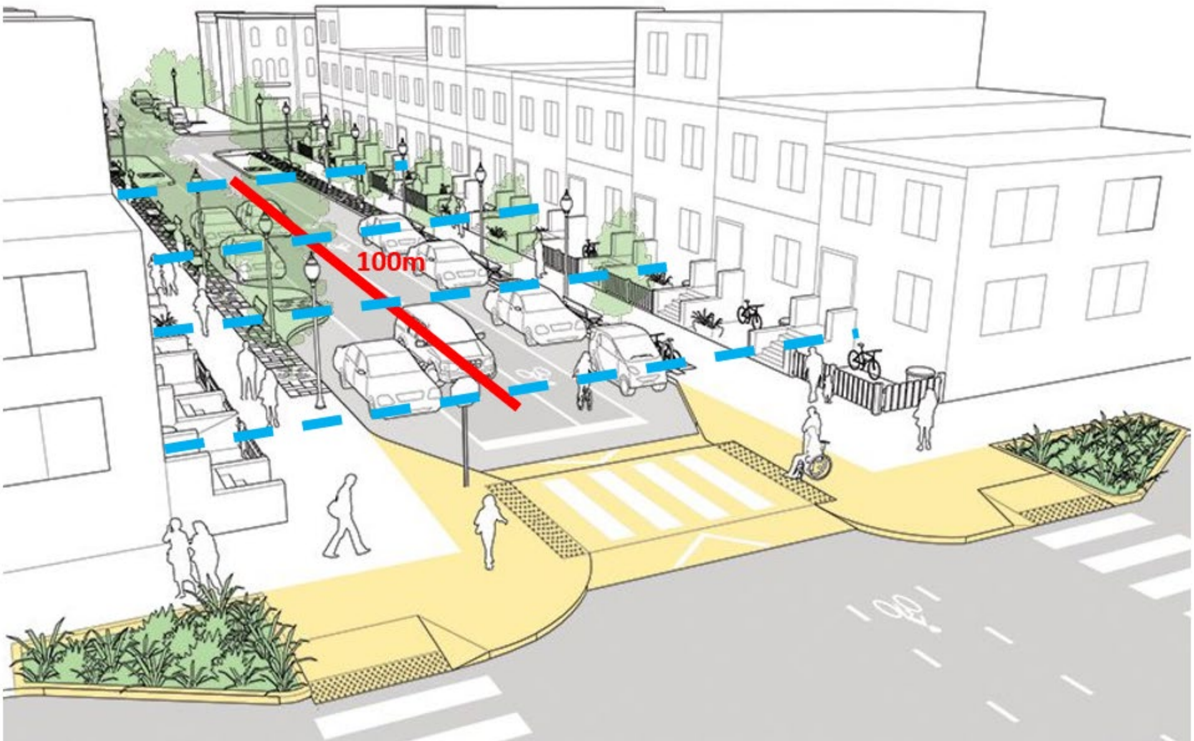


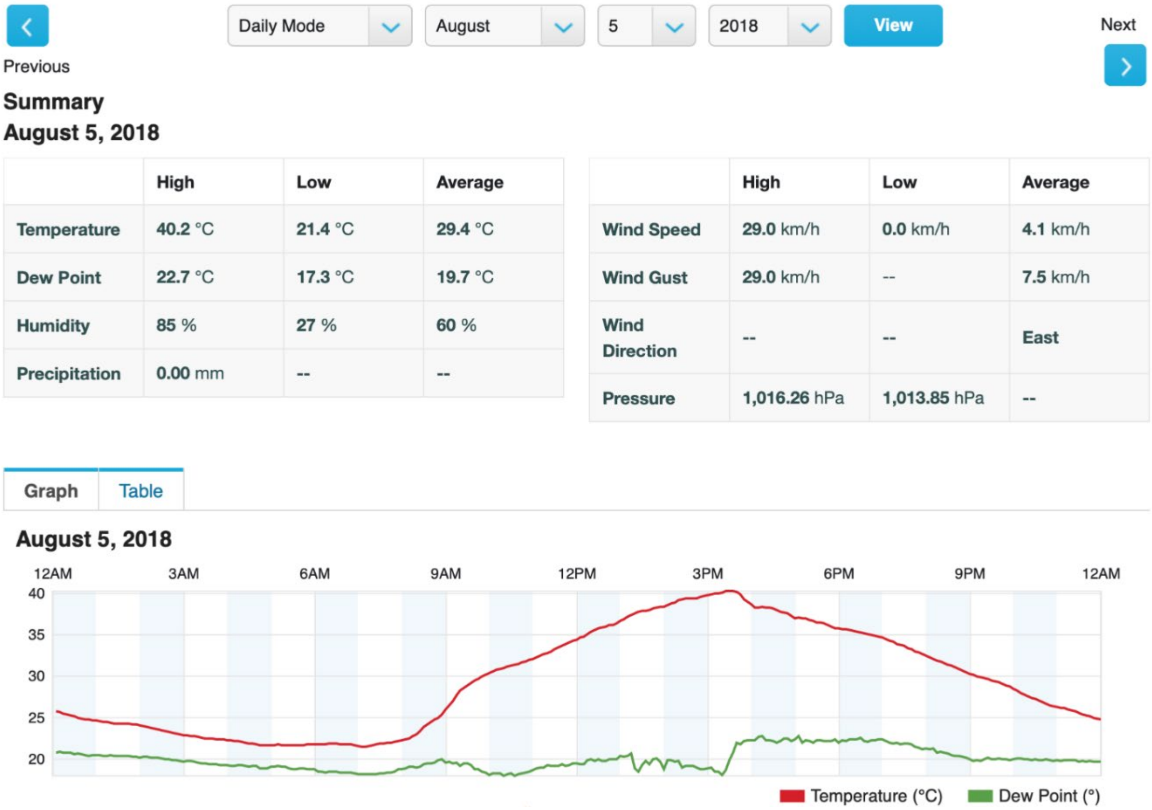
Figure 7.6. Sketch of an example of a survey, at the street level, illustrating the longitudinal direction and cross sections (sketch not to scale).

During the survey, an infrared thermometer can also be used to measure the **temperature of different urban surfaces** such as pavements and walls. Pay attention to the **urban environment and construction details** that surround you, even if you are unable to register the temperature of those surfaces.

Bear in mind that the weather data that are collected on a given day might not represent well the typical conditions of a local "warm day", which might bias conclusions if you rely only on circumstantial observations.

For example, you might like to additionally assess the weather data obtained at a nearby (ground) weather station (air temperature, relative humidity, wind speed, and global radiation) for a broader insight and characterization of critical weather conditions, regarding the risk of heat stress. Identify the existence of such a weather station(s), at a short distance from the study area; annotate the coordinates (including the altitude) and name of the weather station(s). The sample graphs in Figure 7.7 illustrate the type of data that you could access via the web interface with many automatic stations; the data are usually access free. These types of records will illustrate what type of daily variation you could expect for temperature and air humidity, and for other atmospheric data.

Bear in mind that the proposed exploratory appraisal of the study area is expected to assist you in identifying problem areas in the urban environment with respect to heat stress, and the effect of urban features on air temperature and humidity, which are determinant parameters of the risk of heat stress. This is key to gain insight into the potential usefulness of different heat adaptive measures, namely green-blue solutions.



	High	Low	Average
Temperature	40.2 °C	21.4 °C	29.4 °C
Dew Point	22.7 °C	17.3 °C	19.7 °C
Humidity	85 %	27 %	60 %
Precipitation	0.00 mm	--	--

	High	Low	Average
Wind Speed	29.0 km/h	0.0 km/h	4.1 km/h
Wind Gust	29.0 km/h	--	7.5 km/h
Wind Direction	--	--	East
Pressure	1,016.26 hPa	1,013.85 hPa	--

Figure 7.7. Example of an interface with weather data measured at a weather station. The data were measured on August 5, 2018, at the weather station ICOIMBRA14, Portugal, coordinates 40o 11' 6''N, 8o 24' 46,8''W. (https://www.wunderground.com/dashboard/pws/ICOIMBRA14/graph/2018-08-5/2018-08-5/daily).

So, **summing-up,** the proposed survey approach to gathering field data on the urban environment includes the following actions:

- Inspect longitudinal (and cross sectional…) temperature (and air relative humidity) variations for each street of interest based on data mapping, if available (e.g., LST maps), for an exploratory appraisal;
- According to the different local conditions found at the street/neighbourhood level, take on site measurements of air temperature and air relative humidity with a portable weather station/sensor. Be aware that you will need to wait a few minutes before taking the reading given by the sensor(s), which depends on the response time of the sensor(s). If the data are collected manually, take also note of each point measurement coordinates. If possible, check the temperature of different surfaces (e.g., wall, pavements) using an infrared thermometer, or the air temperature in the proximity of those surfaces.
- During the visit to the sites, take note of observed attributes of the urban environment that could potentially explain the assessed temperature and humidity variations in the urban area;
- Take pictures of important features of the urban environment, including the built environment, to better understand the result of your survey, and conditioning factors of the observed air temperature and humidity fields.
- Use the portable weather station data on air temperature and relative humidity to estimate the Heat Index range [min, max], for the relevant locations in the studied area/street (add the date and time during the day, for this result), and its variation across the area, and classify the corresponding local thermal perception conditions based on this index;
- Using available data from local weather stations (the data is only relevant if the station is in the proximity of the study area): *i)* assess the difference between the portable sensor records

and the station's records, for simultaneous records; ii) appraise the diurnal variation in weather parameters and, thus, how heat stress risk may typically vary during the day.

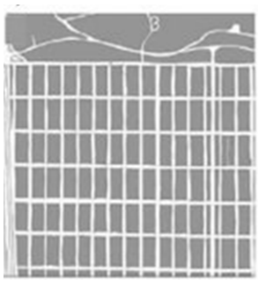
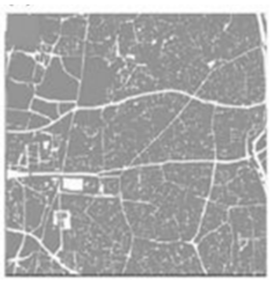
- Summarize the results obtained in your survey and observations, in particular, regarding the association between observed local features of the urban areas of interest and the temperature records. Give location for the corresponding key measurement points, and describe briefly the surrounding area, highlighting the features that are likely contributing to less favourable thermal conditions or heat stress. This could be the basis for discussing suitable measures to deal with the conditions found, which could contribute potentially to lessen heat stress risk.
- Remember that web platforms such as the existing database ClimateScan (https://www.climatescan.nl/) can be used to map heat stress vulnerabilities of a defined urban area, as well as solutions implemented (namely blue-green approaches). ClimateScan provides an interactive web-based map application for international knowledge exchange that works as an open educational resource and community awareness tool.

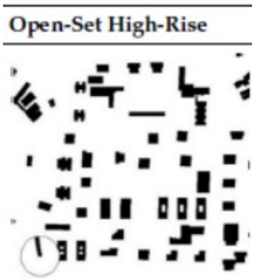
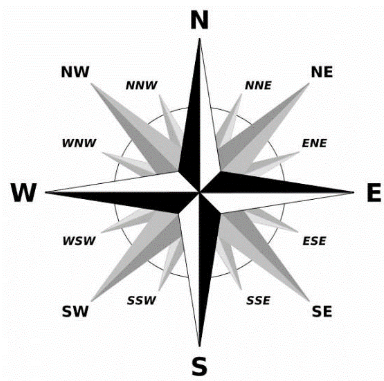
7.6 Example of a checklist for field data collection and analysis

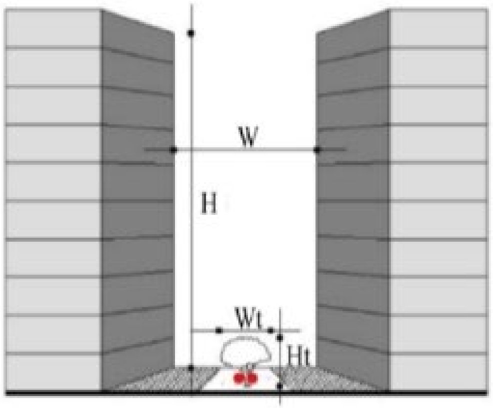
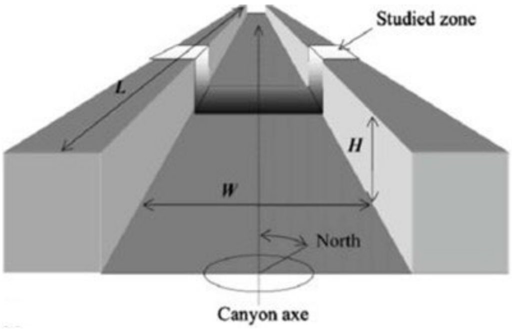
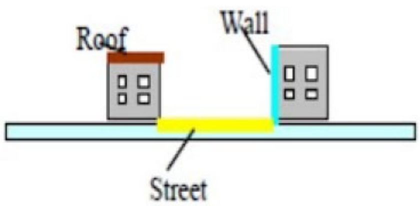
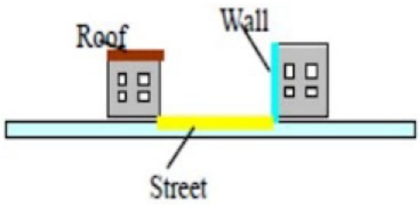
For gathering field data, it is important to be systematic. The use of a registration form, or similar dedicated product, can be helpful in this task.

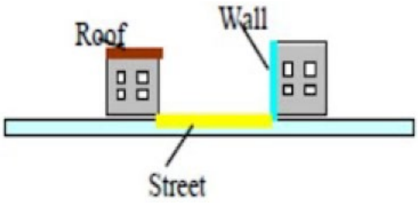
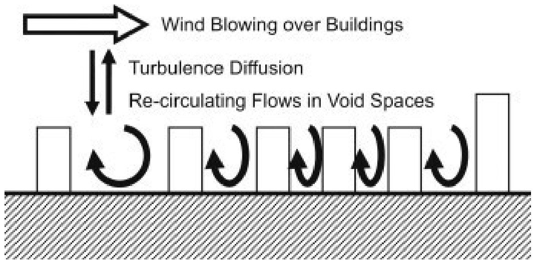
Using the same measurement procedures in different surveys is important, since it allows to unify the measures and make datasets comparable.

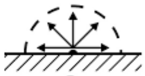
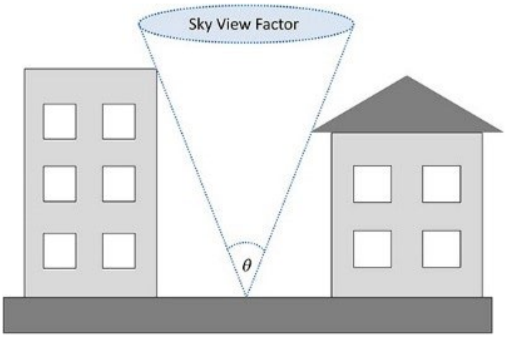
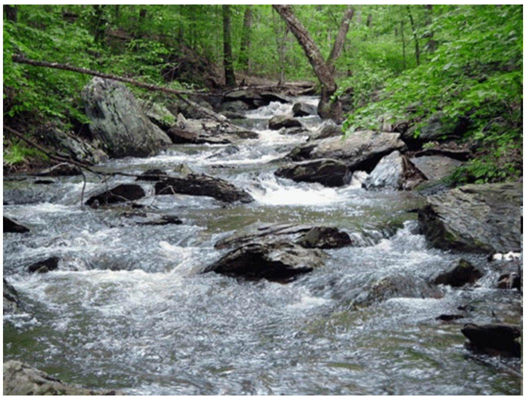
See the example that follows:

FIELD SURVEY FOR HEAT STRESS ASSESSMENT IN URBAN AREAS				
#	**Feature description**	**illustration**	**Answer/observation**	**X**
Identification of the observer				
1	Name of the observer(s)			
Identification of the urban area and observations				
2	City name			
3	Name of selected street or neighbourhood			
4	Date of observation (DD/MM/YY)			
Based on your observations, register representative attributes of the selected street and neighbouring area				
5	Type of urban area grid	 	regular grid	
			irregular grid	

6	Type of construction composition	  	compact low-rise	
			open low-rise	
			compact mid-rise	
			open mid-rise	
			compact high-rise	
			open high-rise	
7	Type of occupation		residential	
			commerce	
			business Centre	
			services	
			parking	
			green area (leisure)	
			schools	
			sport fields	
			other	
8	Length of the studied street (m)			
9	Maximum elevation difference (m)			
10	Orientation of the main street and buildings		N-S	
			E-W	
			NE-SW	
			NW-SE	
			NNE-SSW	
			NNW-SSE	
			WNW-SES	
			WSW-ENE	

11	Mean buildings' height (H, in m)			
12	Mean street's width (W, in m)			
13	Street canyon aspect ratio (=H/W)			
14	Consider the distance between two major intersections along the street, defined as the length (L, in m) of the street canyon. The street canyon is a		short canyon (L/H ≈ 3)	
			short canyon (L/H ≈ 3)	
			long canyon (L/H ≥ 7)	
15	Symmetry of the street canyon, with respect to the height of the buildings that make the canyon (i.e., on both sides of the canyon)		symmetric canyon	
			asymmetric canyon	
16	Building's roof material		terracotta	
			metal	
			concrete	
			green roof	
			other	
17	Building's roof colour:		light	
			medium	
			dark	
18	Buildings' facade/wall material:		glass	
			concrete	
			plastering	
			bricks	
			stone	
			metal	
			wood	
			green wall	
			other	
19	Buildings' facade colour:		light	
			medium	
			dark	

20	Type of street paving material:		bituminous (asphalt)	
			cement	
			stone	
			bricks	
			other	
21	Type of street paving colour		light	
			medium	
			dark	
22	Type of side-walk paving material		bituminous (asphalt)	
			cement	
			stone	
			tiles	
			bricks	
			other material	
			no side-walk	
23	Type of side-walk paving colour		light	
			medium	
			dark	
			no side-walk	
24	Squares/void spaces along the street (approx. % of total street length)			
25	Front yard of houses along the street (approx. % of total street area)			
26	Public greenery areas along the street (approx. % of total street area)			

<table>
<tr><td rowspan="5">27</td><td rowspan="5">Type of vegetation in green areas</td><td rowspan="5"></td><td>lawns</td><td></td></tr>
<tr><td>shrubs/bushes</td><td></td></tr>
<tr><td>small canopy tress</td><td></td></tr>
<tr><td>big canopy trees</td><td></td></tr>
<tr><td>there are no green areas</td><td></td></tr>
<tr><td rowspan="4">28</td><td rowspan="4">Shade on the street</td><td rowspan="4"></td><td>shade from canopy of trees, sparsely distributed</td><td></td></tr>
<tr><td>shade from canopy of trees, close together</td><td></td></tr>
<tr><td>there is shade, but from other sources</td><td></td></tr>
<tr><td>there is no shading</td><td></td></tr>
<tr><td rowspan="3">29</td><td rowspan="3">Visibility of the sky (Sky View Factor - SVF, ranges from 0 to 1); when a location has buildings and trees, SVF decreases.

</td><td rowspan="3">
</td><td>unrestricted</td><td></td></tr>
<tr><td>reduced</td><td></td></tr>
<tr><td>very limited</td><td></td></tr>
<tr><td rowspan="5">30</td><td rowspan="5">Type of nearby water body</td><td rowspan="5"></td><td>River</td><td></td></tr>
<tr><td>Canal</td><td></td></tr>
<tr><td>pond</td><td></td></tr>
<tr><td>Lake</td><td></td></tr>
<tr><td>None</td><td></td></tr>
<tr><td>31</td><td colspan="2">Proximity to water body (minimum distance, in m)</td><td colspan="2"></td></tr>
<tr><td>32</td><td colspan="2">Air temperature range [min, max] along the street, in degree Celsius (on the observation date)</td><td colspan="2"></td></tr>
<tr><td>33</td><td colspan="2">Air relative humidity (%) range [min, max] (on the observation date)</td><td colspan="2"></td></tr>
<tr><td>34</td><td colspan="2">Give your estimate of the Heat Index range [min, max], for the observation date, in the studied area/street. Add the time of the observations, for this result.</td><td colspan="2"></td></tr>
</table>

35	Based on the Heat index, comment on the overall local thermal perception condition. Give location for the corresponding measuring points, and identify striking features in the proximal area.	
36	Based on the observation of the urban area, identify the local attributes that likely have stronger impact on heat stress in the area.	
37	In your view, what could be the nature of measures that could be implemented to benefit the area with respect to heat stress risk?	
38	Collect material (e.g. photo, map) that illustrates your assessment. Upload pertinent material in a dedicated platform.	

7.7 Final results description

To analyse heat stress in urban areas, use the Heat Stress Field Survey Report to print.doc or the app and put the results at the ClimateScan database. Having surveys from different urban areas done on the same day or several surveys from the same urban area but from different days you select the material ready to be discussed with your students. If possible, find for your analysed location the heat stress maps and compare the results. For the students' knowledge income verification use the Heat stress pre-post test to print.doc and Heat Stress pre-post test key.doc.

7.8 External materials

See: https://impetus.aau.at/outputs/

Folder: Heat Stress

- Heat Stress instruction.pdf
- Heat Stress Field Survey Report to print.doc
- Heat Stress pre-post test to print.doc
- Heat Stress pre-post test key.doc

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8 Riverine plastic waste measurements

8.1 Introduction

Plastic pollution in the world's oceans and seas is under growing attention and the environmental impact of plastics in the environment has only recently been studied. It is however known that much of this plastic pollution comes from urban areas, where disposed plastics are discharged through rivers and streams to finally end up in the oceans (Jambeck, et al., 2015; Lebreton, et al., 2017; Meijer et al., 2021).

To be able to tackle the influx of plastics into the marine environment data on plastic discharge by rivers is needed so appropriate measures can be taken. The discharge can be measured by surface measurements (visual camera registration of floating items), river body monitoring (actual sampling in the water column using nets and filtration systems) and riverbank monitoring (monitoring of plastic litter deposited on river banks) (Gonzáles & Hanke, 2017; Gonzáles, et al., 2017; UNEP, 2020; Vriend & van Emmerik, 2020). The latter seems the most practical method to get quick indicative results on types and numbers of litter transported by rivers, since it does not involve technical tools and logistics such as nets, boats and cameras.

Since there is a strong variation in river morphology and amount of plastic discharged as well between rivers as within a river basin, a standardized method is needed to be able to validate recorded data on plastic riverine litter. For marine litter the OSPAR beach monitoring method is long standing (Ospar Commission, 2010). Since 2017 this method has been adapted to suit river bank monitoring in the Netherlands within the Schone Rivieren (clean river) project (Schone Rivieren, sd; van Emmerik, et al., 2020). However this method focuses on natural riverbanks instead of urban systems where plastics can accumulate on hotspots on riverbank structures.

Therefore an adapted methodology for rivers in urban environments has been developed to be able to obtain comparable data on plastic waste in these systems. The method involves randomized subsampling in order to make quick assessments in different conditions possible.

8.2 Field measurement description *Randomized OSPAR riverbank monitoring*

In this method you will determine the amount and composition of riverine plastic litter on a riverbank using a random subsample. For a riverbank length of 100 m 10 subsamples of 1 m2 will be collected. The measurements consist of marking down the observed river litter on the adapted OSPAR form, per square. On each square a detailed photo is taken (with clear boundaries of quadrant).

Tools needed:

- **Riverine Plastic Waste Measurements Riverbank form.xls**,
- Measure tape,
- Camera (smartphone),
- Quadrat 1x1m or string/cord of 4m, with each m marked,
- Bin Bags,
- Gloves,
- Ruler (optional).

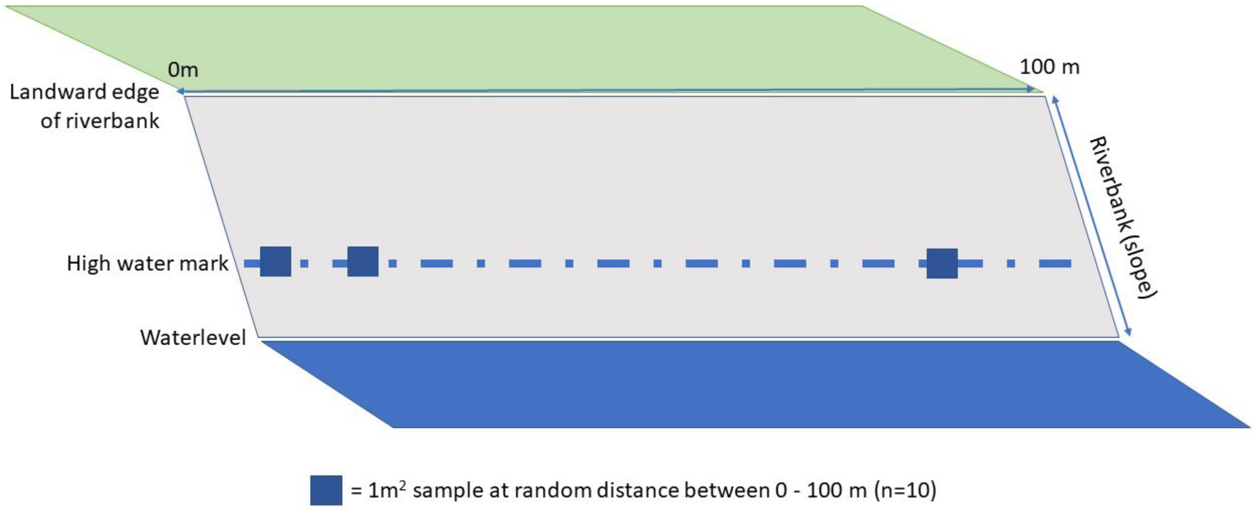

Figure 8.1. Schematic display of the sampling grid for OSPAR monitoring along urban riverbank.

Data collection protocol & methodology

The following steps are taken for data collection:

1. Select a stretch of riverbank of 100m length, that is safely accessible. Mark the beginning and end of the stretch.
2. Describe the type of waterway, for example river / canal / stream and indicative characteristics such as width, flow velocity etc. (Please note that this method focusses on natural river systems. The selected river should preferably have a relatively natural flow regime (e.g. periodical fluctuation of discharge. Canals or highly controlled discharges are less suitable for riverbank monitoring). Take pictures for future reference!
3. Generate 10 random numbers between 0-100, for example by using www.randomizer.org. These numbers relate to the distance at which a m^2 sample will be collected.
4. For your stretch of riverbank. See if you can recognize an average highwater mark. Usually visible by a higher level of debris (branches, sticks and other organic material) and litter (plastic waste etc.) or by color difference on soil or rocks.
5. Roughly following this high water mark. Place the square meter quadrant at the selected 10 different distances.
6. A photograph is taken of each square prior to the measurement, using the quadrant (see example in Figure 8.2).
7. All items are counted and registered according to the different categories and types given in the OSPAR monitoring form.
8. Did you count and record all items? All forms complete? Great! Now, while you're here: let's do a riverbank Clean Up by collecting all trash in binbags and dispose of them in the right way!
9. **OSPAR forms should be filled in per square clearly stating the square ID (Location and distance recorded), and handed in per form in excel**.
10. Photographs should be saved as .jpg, with square ID in name (LocationXdistanceX.jpg)

Figure 8.2. Example photograph of square m² measured.

Data analysis

The following steps in data analysis should be executed:

1. Make sure a separate form for each measured m² **sample is recorded in excel**. Thus resulting in 10 completed forms.
2. Determine the total amount of litter found on 100m riverbank by extrapolating the number of items found in the 10 samples (sum of sample 1-10 x 10).
3. Determine the composition of the litter found, for example by visualizing in a circle diagram (see example in Figure 8.3).

Can you determine the mean density of litter found on the river bank (mean number of items / m²) by measuring the total riverbank surface (total area m² of riverbank: length x width of riverbank slope)?

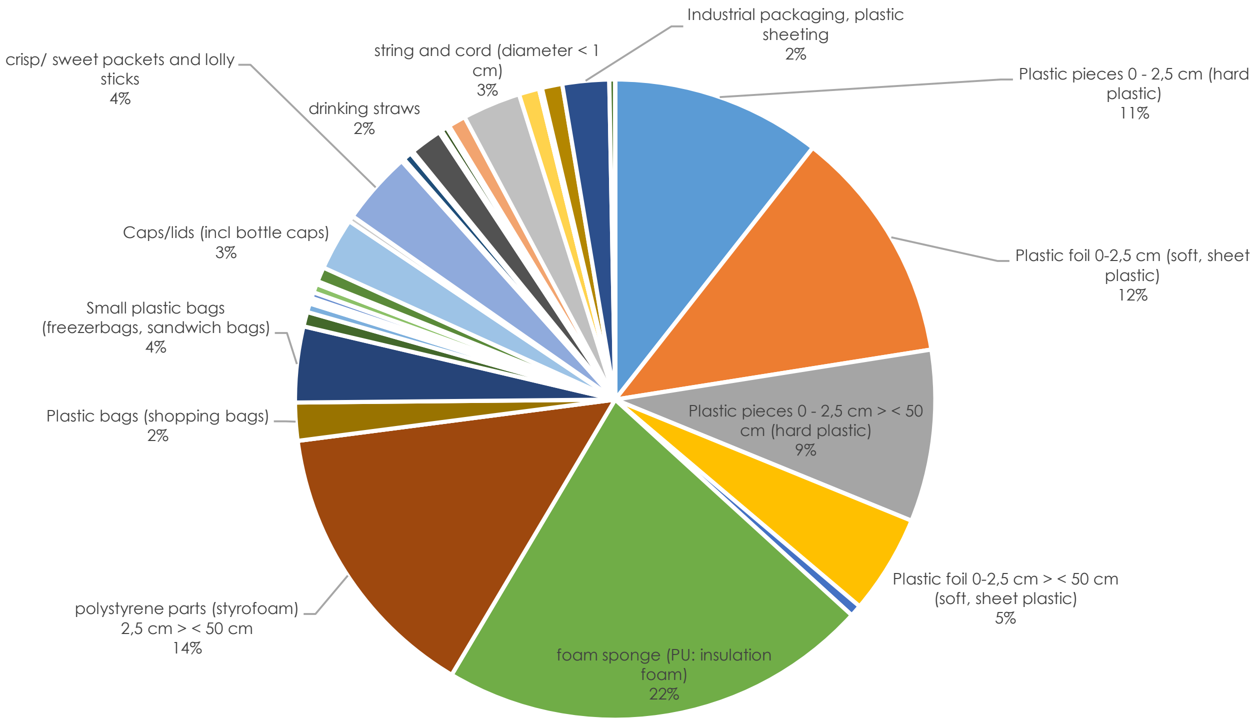

Figure 8.3. Example of riverine litter composition along the river Meuse (The Netherlands).

8.3 Field measurement description *Randomized OSPAR floating plastic waste*

Since several water systems consist of very slow velocity waters with stable water levels it is not always possible to measure riverbanks to get an insight on plastic waste in the water system.

Therefore an additional method has been developed to measure floating plastic waste.

During these measurements you will focus on potential litter hotspots. These hotspots are presumably in canal corners (corners in harbors, dead ends, sluice etc.). The measurements will be taken by observation from the quay, because of this it will be difficult to exactly measure the normally used 1 m^2.

Tools needed:

- **Riverine Plastic Waste Measurements Floating Form.xls**,
- Camera (smartphone),
- Optional: measure tape or ruler.

Data collection protocol and methodology

The following steps are taken for data collection:

1. Select a litter hotspot. Make an assumption of 1 m^2.
2. Describe the type of waterway, for example river / canal / stream and indicative characteristics such as width, flow velocity etc. (Please note that this method focusses on natural river systems). Take pictures for future reference!
3. A photograph is taken of each square prior to the measurement, make an estimation of 1 m^2.

4. All items are counted and registered according to the different categories and types given in the OSPAR monitoring form.
5. After filling in the form you will categorize the location of measurement according to the table below (Table 8.1).
6. OSPAR forms should be filled in per square clearly stating the square ID (Location and distance recorded), **and handed in per form in excel**.
7. Photographs to illustrate the amount of pollution can be included in the file.

Data analysis

The following steps in data analysis should be executed:

1. Make sure a separate form for each measured m^2 sample is **recorded in excel**.
2. Determine the composition of the litter found, for example by visualizing in a circle diagram (see example in Figure 8.3)

Extra:

3. Can you determine the mean density of litter found in the river / canal (mean number of items / m^2) by measuring the total water surface (total area m^2 of river: length x width of river)?

8.4 Conclusion on plastic waste

On the basis of the data analysis of riverbank and floating plastics conclusions can be drawn on the extent of plastic pollution using the following index.

Table 8.1. Riverine Plastic Waste pollution index.

Riverine Plastic Waste						
Category	**A**	**B**	**C**	**D**	**E**	**F**
Pieces per 1m² floating	0 - 1	2-5	6 - 25	26-50	51-100	100>
Pieces per 100 m riverbank	<10	10 - 50	51 - 250	251-500	501-1000	1000>
	(Almost) clean	Slightly polluted	Polluted	Severely Polluted	Heavily polluted	Extremely polluted

8.5 Online inventory on local plastic waste pollution

Several resources are available to execute an online plastic pollution scan. By analysis of several datasets, scientific resources and open source data an overview of plastic pollution in a local river system can be generated.

The following sources should be assessed:

1. **Online scientific data:** To get an overview of the amount of mismanaged waste and the potential input into river systems the interactive maps created by The Ocean Clean Up can be used:

   - River Plastic Pollution Sources | The Ocean Cleanup
   - Mismanaged Plastic Waste | Mapbox

   Questions you could answer are:

   - How much waste is mismanaged in my research area (kg / km^2 /yr)?
   - Are hotspots of mismanaged waste located around my river system?
   - What is the local discharge of the river? Is this fed primarily by rainfall? How could this affect the amount of waste being transported by the river?
   - What are the estimated outputs of the river into the sea/ocean?
   - How much of this waste could be generated in your reasearch area?

   Answering these questions should give an impression of the local plastic waste input in the local river system. The outcome should be a risk assessment: is plastic waste an environmental threat in our research area?

2. **Open source data:** Of course this data only gives a very rough overview and estimate of the amount of plastic waste in your area. Citizen science data collection tools however can give insight in local conditions. The following data collection apps are very useful: to gather data yourself or to make a quick inventory of local pollution hotspots:

   - 🌎💛Litterati - The Global Team Cleaning The Earth | Litterati
   - CrowdWater App Manual EN – CrowdWater

   Questions you could answer are:

   - Where is data available in your research area?
   - What does the data say in terms of the amount and composition of plastics waste?
   - What do you think are the sources for the plastic waste collected in the apps? (consumer, industrial, shipping, fisheries etc.)
   - Is the data in the vicinity of a local river or stream?

3. **Scientific articles and reports:** there is an ever growing library of scientific articles on plastic riverine pollution. These articles can give either an generic overview of plastic problems that can be transferred to your research area. It can also give very detailed insights in a specific river system, maybe yours. Use search engines such as:
   - Google Scholar
   - Home Feed | ResearchGate

   You can use keywords such as: plastic, river litter, macro litter, riverine plastic waste etc.

8.6 Final results description

During measurements, the results will be collected manually using Riverine Plastic Waste Measurements Riverbank form.xlsx or Riverine Plastic Waste Measurements Floating Form.xlsx depending on the type of measurements and send the results to the Climate Scan database. Students should prepare a full report of data collection and data analysis, including photo documentation of sampling and measurements conduction. Report should include analysis of are and reservoir description and the results of the survey. For the knowledge income verification use the RPWM pre-post test to print.doc.

8.7 External materials

See: https://impetus.aau.at/outputs/

Folder: Riverine plastic waste measurements

- RPWM instruction.pdf
- Riverine Plastic Waste Measurements Riverbank form.xlsx
- Riverine Plastic Waste Measurements Floating Form.xlsx
- RPWM pre-post test to print.doc
- RPWM pre-post test key.doc

8.8 Additional materials

- A scientific poster has been made and presented at the Water Summit in Delft, The Netherlands, illustrating the applicability of the method and showing results on plastic pollution in Rotterdam – Poster Water Summit Randomized OSPAR Sampling.pdf.
- Data has been collected in Rotterdam, Groningen and Gdansk during IMPETUS City Scan weeks. They are presented in the file Measurement results from Gdańsk, Rotterdam, Groningen.xls and can be used for the various analysis.
- The instructional video was developed to help understand the idea of collecting data on plastic pollution - https://youtu.be/YoMJYXej0wI.

8.9 Literature

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9 Street Scorecards

9.1 Introduction

Human-induced climate change is causing dangerous and widespread disruption in nature and is affecting the lives of billions of people around the world, despite efforts to reduce the risks. The people and ecosystems least able to cope are being hardest hit, according to scientists in the latest Intergovernmental Panel on Climate Change report [1]. For cities, some aspects of climate change may be amplified, including heat, flooding from heavy precipitation events, and sea level rise in coastal cities [2]. The world has recorded the hottest decade on record (2010–2020) with 2019 being the second warmest year on record [3]. Implementing nature-based solutions on a larger scale would increase climate resilience and contribute to multiple Green Deal objectives. Blue green (as opposed to grey) infrastructures are "no regret" solutions and provide environmental, social, and economic benefits and help build climate resilience [4]. According to the European Environment Agency, cities have the potential to become a major driving force for a green and just recovery after the COVID-19 pandemic [5]. The challenge is now how to integrate these measures in our cities and to assume directive roles in their implementation [6].

In 2018, an estimated 55.3% of the world's population lived in urban settlements. By 2030, urban areas are projected to house 60% of people globally [7]. All these people will be directly affected by the impacts of climate change. One of the solutions that has been suggested to make cities more resilient is the urban green infrastructure (UGI) [8]. Urban green and blue spaces and green infrastructure are very effective to combat the effects of climate change and to tackle water and heat risks. A common method to evaluate such contributions is to measure the ecosystem services (ES) provided by the vegetation or water bodies present in urban green and blue spaces (UGBS) that constitute the UGI [9]. Examples of urban ecosystem services are air purification, carbon storage, noise reduction, run-off retention, cooling, and recreation [10].

Urban communities are the most affected by changes in the microclimate as a result of climate change. There are examples resilience scorecards that help communities to become resilient [11], or scorecards that aim to assess disaster resilience on the city scale, such as the he United Nations Office for Disaster Risk Reduction (UNDRR) Scorecard [12], or scorecards with sets of indicators that assist communities to perform a self-evaluation, such as the Resilience Performance Scorecard [13]. Labdaoui et al. developed the Street Walkability and Thermal Comfort index (SWTCI) [14], which includes shade.

Most cities do know, on a city scale, which neighbourhoods have less trees, are densely populated, have less parks, and are less green, or in which neighbourhoods lush front yards and an abundance of urban green spots are present. At the level of the street, cities in general do not have much insight regarding which climate adaptation measures are present. In a changing climate that more often causes heat waves, for example, it would be crucial to know in which streets the climate adaptation measures are present and are more or less ready for the impacts of climate change, and which streets are not. In the streets that do not have climate adaptive measures, local governments should invest in the implementation of climate adaptation measures.

An instrument such as a scorecard that assesses the climate adaptive measures at the street level and attaches climate adaptation labels to street segments and streets, is accurate and is easy to use by residents and communities to self-assess streets and neighbourhoods, would be very valuable to identify the least adaptive streets and raise awareness about climate adaptation among the members of the community. In the literature, no such scorecard or instrument was found that systematically assess the presence of climate adaptation measures at street segments or entire streets. This paper therefore proposes a new method to assess climate adaptation measures at the street level, which has been proven to be very successful in scoring measures and labelling streets after testing in two districts in two different Dutch cities. With this method, we hope to equip communities and local government units with a new method to assess climate adaptation measures in their locality.

9.2 Street climate scorecard

To be able to compare streets in different districts, street segments were chosen as units of comparison. Streets are composed of one or more street segments and street segments are used in the virtual street audit of front yards [15] or in streetscapes studies [8,16], or in studies related to crime behaviour [17] or walking speed [18]. A street segment is typically defined as the portion of a public or private street, between its intersections with two other public or private streets [19] (see Figure 9.1).

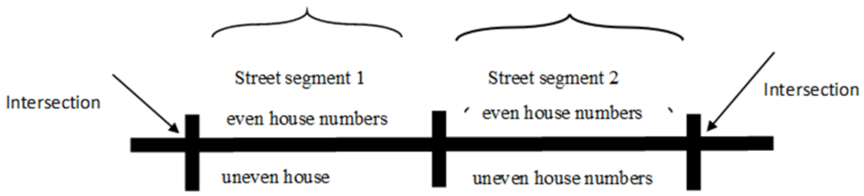


Figure 9.1. Street segment.

For this study, two different urban districts in the cities of Groningen and Rotterdam were selected by the civil servants of the two cities that were involved in the project "Citizen participation in climate adaptation". The two districts were selected based on the fact that the districts are considered as particularly vulnerable to climate change [19]. In order to make the assessment comparable, observations of specific street features and measures both in the street and the housing units at both sides of the street were included in the assessment, and observations were converted into a 100 m street length value. Google street view was used in the field to measure the length of the street segment, then a conversion factor was determined for each street, e.g., divided by 1.2 for a street length of 120 m, and the values were converted into a score for a length of 100 m of street length. In order to be able to score the microclimate adaptation facilities or measures at street level, a literature review was undertaken and a selection of scoreable adaptation facilities or measures was identified. These were divided into three main categories—the green, blue, and grey categories. Each category is a combination of a number of scorable measures at street level. Field visits were undertaken to the two cities for ocular inspection and assessment of the selected streets. In order to make the results of the assessments and the ocular inspection unambiguous, a reference card was made for easy reference. The QR code on the reference card can be opened with a mobile phone and opens an excel file, where the observations can be directly tabulated in excel.

9.3 Scoring and labelling scorecard 1.0

The scorable adaptation measures at the street level were calculated per street segment. In total, a street segment could be awarded a score of 100 points (Figure 9.2). The scores of 1–100 for each street segment were divided into 10 climate adaptation labels with different colors. The presence of many adaptation measures translated into a high score and corresponded with a dark green color. Street segments with few or no adaptation measures translated into a low score and the corresponding color was dark red. A deduction of score points was applied in the grey category. The scoring was composed of three categories, and each category contained one or more measures. For each category, weight was given. The highest weight was given to measures that were most common with the highest chance to be present in a street, and at the same time provided a combination of ecosystem services. Large urban trees and (green) front yards were the most common and provide shade, coolness, and increased infiltration capacity, among other ecosystem services. After testing different measures with different weights totalling 100 points, it was decided to do a full test in two districts with the measures and weights presented in Table 9.1, divided over three categories.

Label	Points
A+	91-100
A	81-90
A-	71-80
B	61-70
C	51-60
D	41-50
E	31-40
F	21-30
G	10-20
H	0-10

Figure 9.2. Climate adaptation labels.

Table 9.1. Climate adaptation measures and weight.

Category	Measure	Maximum Score
Green category	Urban trees	+40
Green category	Green walls	+4
Green category	Façade gardens/front yards	+16
Green category	Green strips	+13
Green category	Climate adaptive roofs	+2
Green category	Green parking spaces	+2
Blue category	Rain barrels	+1
Blue category	Permeable pavement	+3
Blue category	Bioswale	+6
Blue category	Surface water	+6
Grey category	Shaded areas, natural or artificial	+2
Grey category	Additional grey parking spaces	−2 to +2
Grey category	Unpaved surfaces	+2
Grey category	Soil sealed driving lanes	+ 1 or −1 per lane

As awareness among community members was an important objective of the scorecard, reference cards were designed that showed examples of the measure, complementary to the excel file, and supported the researcher in the field while doing the assessment in the field. The front and the back of the reference card are presented in Figure 9.3 and Figure 9.4.

Figure 9.3. Reference card ver. 1.0, front.

Figure 9.4. Reference card ver. 1.0, back.

Green Category Climate Adaptation Facilities and Measures

The green measures are the combined value of the following adaptation facilities or measures, namely trees, green walls, façade gardens, green strips, climate-adaptive roofs, and green parking spaces.

Urban Trees

Urban trees represent a large portion of the urban tree canopy and provide a significant amount of ecosystem services for mitigation of the negative environmental impact [20]. The World Health Organization has described in detail the beneficial aspects of urban green spaces [21], such as reduced exposure to air pollution and a reduction of the heat island effect. Trees planted along streets and roads may dampen noise and air pollution levels in residential houses and mitigate the adverse health effects of proximity to busy roads. Wang showed that [22] in the urban green infrastructure, the outdoor human thermal comfort and indoor environment improves [23].

The trees category is divided into three subcategories, namely 0–10 m, 10–15 m, and above 15 m, so as to make the indicator trees scorable. The average floor height in the Netherlands is between 2.4–2.6 according to article 4.28 of the National Building Code [24]. Including the floor material itself, the average floor is about 3 m high. A tree with a height that is just slightly higher than the height of a typical Dutch single-family dwelling, up to 10 m in height, will be tagged as a category 1 tree, with a value of 2. A tree between 10–15 m in height will be tagged as a category 2 tree, with a value of 3, and very tall and older trees that are above 15 m in height will be tagged as a category 3 tree, with a value of 4. The categorization of trees into different categories of 0–10 m, 10–15 m, and above 15 m was chosen so that the three categories could easily be assessed through ocular observation. This categorization was not presented in other studies, but proved to be very efficient for easy analysis. The number of trees on both sides of the street segment was counted, categorized, and tabulated. The maximum score for the urban trees measure was set at 40.

Green Walls

Wall shrubs and climbing plants provide significant thermoregulation around brick walls and appear to be a feasible green wall system for retrofitting existing housing stock in temperate climates [25]. Green wall installation can simultaneously provide multiple benefits such as noise reduction, contribute to urban ecosystems, pollutant removal, and cooling. The green wall had potential to mitigate daytime air temperature in the cooler seasons in all of the investigated climate zones, except in Csb, where a slight increase was found. Such a decrease could be as high as ~5 °C and it might be decisive for mitigating UHI in some cities [26]. Because of the thermal resistance effect of green walls, the temperature reduction at the pedestrian level of the canyon center was 1.16 °C in the flat street canyon, such as residential areas, in a situation where streets are composed of mainly green walls [27]. Streets that do not have green walls represent a value of 0. Streets that are composed of 1–25% green roofs represent a value of 2, 25–50% a value of 2, 51–75% a value of 3, and 76–100% a value of 4.

Façade Gardens / Front Yards

Paving over of front yards (soil sealing) reduces the environmental and social benefits of front yards and trees. Front yards in private residences play an important role in the soil sealing problem of cities worldwide [15]. The impervious cover of front yards contributes to the problems of the urban heat island effect and urban floods, and makes urban neighbourhoods less pleasant. Private gardens play an important role as urban green space and can improve microclimate and address the impacts of climate change – specifically the urban heat island (UHI) effect. Paving over front yards, thus soil sealing, reduces the environmental benefit of front yards. Residential (front) yards comprise a considerable portion of land and green space in the suburbs of cities. A recent study in Rotterdam shows that in an older district, most front yards are soil sealed [18]. The European commission formulated a green infrastructure (GI) strategy to enhance Europe's natural capital [28]. Ecosystem-based approaches are strategies and measures that harness the adaptive forces of nature [29]. Cities are encouraging private citizens more and more to involve citizens, municipalities, and other stakeholders in replacing pavements with vegetation [30]. Cities even provide grants and subsidies to citizens for unhardening private gardens, such as in the city of Rotterdam, which has a subsidy of €10 per m2 for realised green space, to €500 per m3 water storage up to €1500 [31]. Unsealed urban gardens provide patches of natural surfaces that help reduce run-off, reducing the likelihood of urban flooding and replenishing groundwater by allowing rainwater to infiltrate. Small changes households make to their gardens over an extended period of time can add up to major environmental impacts. Adding more paved areas to gardens increases the risk of urban flooding: rainfall cannot seep into the ground and, instead, water runs off the paved surfaces into storm water and sewage systems [32]. It contributes to the development of "sponge cities", where cities are designed as sponges and are designed to absorb and capture rainwater for reducing flooding worldwide [33]. Cities should also invest in nature-based solutions to tackle water and heat risks [34]. In addition to this, urban gardens as a form of urban greenspace are an important resource for the psychosocial restoration of urban dwellers [35], and private gardens are important in terms of the ecological value of cities in complementing public green areas [36]. Not all houses are constructed with (space for) front yards. In order to reduce the temperature and heat stress during a heat wave, residents in Rotterdam are encouraged by the local government to create façade gardens and green facades, which have proven to be effective tools [26]. An example of this is the thousand façade gardens initiative in Rotterdam [37]. Street segments that do not have any façade gardens or front yards are given no points. Streets that have façade gardens in 1–50% of the houses in the street segment represent 5 points, streets with façade gardens in 50–100% of the houses represent 6 points. Houses that have front yards in 1–25% of the housing units represent a value of 10 points, 25–50% represent 12 points, 50–75% represent 14 points, and 75–100% represent 16 points.

Green Strips

Green strips constitute similar benefits as front yards. Green strips could be larger in size than front yards. Green strips are often provided as a beautification project or as a place for dogs in densely populated urban areas. In order to provide water storage or to increase the infiltration capacity, green strips should be placed lower than street level. Street segments that have green strips of max 25 sqm represent a value of 9 points, 25–100 m represent a value of 11 points, and more than 100 sqm represent a value of 13 points.

Climate-Adaptive Roofs

The presence of climate-adaptive roofs can be established by using Google Maps (satellite view). Examples of climate-adaptive roofs are green roofs, roofs with a high albedo (highly reflective roofs, which absorb less heat [38], and blue roofs. Green roofs can easily be recognized on Google Maps, because from above plants/grass and other greenery can be spotted. A high albedo roof is easy to spot because it is often bright white. Houses in the street segment that do have climate-adaptive roofs in 1–50% of the houses represent 1 point, and if more than 50% of the houses in the have climate-adaptive roofs, they represent a value of 2.

Green Parking Spaces

Green parking spaces differ from regular parking spaces because they allow the water to infiltrate, and they contribute significantly to reducing runoff [39]. If the parking lots are made of porous paving materials, between the tiles of parking spots, there are often patches of grass [40]. Houses in the street segment that do have green parking spaces in 1–50% of the houses represent 1 point, and if more than 50% of the houses have green parking spaces, they represent a value of 2.

Blue Category Climate-Adaptation Facilities and Measures

Rain Barrels

Rain barrels or rainwater tanks store water and relieve some stress on the sewage system during heavy precipitation. Rain barrels delay the time that it takes for water to flow into the system. Water from a roof connected to a rain barrel does not flow immediately into the sewage system, and rainwater harvesting can be used as a remedial measure and can help in flood reduction [41]. If one or more rain barrels are present in the street segment, the segment represents a value of 1.

Permeable Pavement

Water-permeable pavements are porous or are laid to allow voids, have an open structure, or are made of partially pervious materials. They allow water to pass through or around them into the soil. This has various advantages: rainwater can infiltrate into the ground, groundwater is replenished, and sewerage systems are relieved [40]. If there is permeable pavement in the street, on the sidewalk, or both, they represent a value of 1, 2, or 3, respectively.

Bioswale

A bioswale is an adaptive measure that has the ability to store water during heavy rain and it redirects surface water to groundwater. It also aids in infiltration and often looks aesthetically pleasing [40,42]. If a bioswale is located within 50 m of the street segment, it represents a value of 6.

Surface Water

Surface water nearby functions as natural water storage. If the surface water is located nearby and is lower than the street level, water can be channelled into the surface water with natural gravity. If the surface water is located within 50 m of the street segment, it represents a value of 6.

Grey Category Climate-Adaptation Facilities and Measures

Shaded Areas (Canopy)

Bonus points can be earned for shaded areas. Shade is beneficial for heat stress relief [43]. Shade may be provided through canopy, natural shadows from trees, or by artificial shadow facilities. If natural canopy is present or there is artificial shade provision, it represents a value of 1 or 2 respectively.

Unpaved Surfaces

If unpaved areas are present, they provide an additional storage capacity for precipitation and may provide cooling facilities through natural vegetation. If unpaved surfaces are located lower than the street level, they represent a value of 2.

Grey Parking Spaces

Paved surfaces, especially parking lots, occupy a significant proportion of the horizontal surface area in cities. The low albedo of many of these parking lots contributes to the urban heat island (UHI) and affects the local microclimate around them. Parking spaces heat up during the day and contribute to a higher temperature. At night, these warm surfaces contribute to the urban heat island effect [44]. If the cars are parked on the driving lane, without additional parking places, the street segments represent a value of 2. If additional designated parking places are present, the segments represent a deduction of 2 points.

Driving Lane

Impermeable "grey" driving lanes with a low permeability similar to the grey parking spaces occupy a significant proportion of the horizontal surface area in cities. The low albedo of many of these driving lanes contributes to the urban heat island (UHI) and affects the local microclimate around them. Driving lanes heat up during the day and contribute to a higher temperature. At night, these warm surfaces contribute to the urban heat island effect [44]. For sustainable urban development, permeable pavement promotes urban water management [40]. If the street segment is a car free street, without soil sealed driving lanes, it represents a value of 2. For each soil sealed driving lane, one point will be deducted.

9.4 Case study – Scores Hillesluis district Rotterdam using scorecard 1.0

Rotterdam, Hillesluis District

The Hillesluis district is located on the southern part of the city of Rotterdam and has a population of around 12,050 residents with a population density of 14,433 [45] residents per square kilometer in 2020. The district is characterized by small streets and a high population density. The narrow streets are alternated by green spaces. The district was constructed between 1920 and 1930 for workers in the port of Rotterdam. Renovation projects have replaced some of the older apartment blocks with newer housing units, but around 70 % of the housing stock date back before 1945.

The district consists mostly of multifamily dwellings and are predominantly social housing (47%) or rental units (27%), with 25% owner-occupied. The population is relatively younger and lower educated compared with other parts of the city with a lower average household income. Around 73% of the population has a non-Western background. About half of the households (47%) are single-person households [46].

In the Hillesluis district, 21 streets were assessed with a total of 42 street segments. The scores per street segment were categorized and a corresponding label (Figure 9.2) was given to each street segment and is visualized in Figure 9.5. The span of the distribution ranges between the lowest score of 3, which corresponds with the lowest climate-adaptiveness label H, and the highest score of 63, which corresponds with climate-adaptiveness label B. The average segment score in Paddepoel was 42, which corresponds to label climate-adaptiveness label D in Table 9.2.

Table 9.2. Scores per segment in the Hillesluis district.

Name of the street	Segment 1	Segment 2	Segment 3	Segment 4	Total Score
Imobilialaan	51				51
Imobiliastraat	24				24
Zeeuwsestraat	3				3
Vlasakkerstraat	10	37	42	14	103
Drentsestraat	48	7			55
Riederstraat	35				35
Overijsselsestraat	27	50	7	20	104
Utrechtsestraat	20				20
Hollandsestraat	6	4	37	28	75
Donkerslootstraat	24	52			76
Riederlaan	63	37			100
Zaadakkerstraat	5				5
Westerbeekstraat	28	45	43		116
Friesestraat	24				24
Brabantsestraat	32				32
Breeweg	50				50
Beijerlandsestraat	45	41			86
West-Varkenoordseweg	36	29	33		98
Beukelaarsstraat	12	39			51
Blokweg	28	17			45
Beverstraat	13	38	24		75
Total number of segments:	42				
Total score:	1228				
Average segment score:	29				

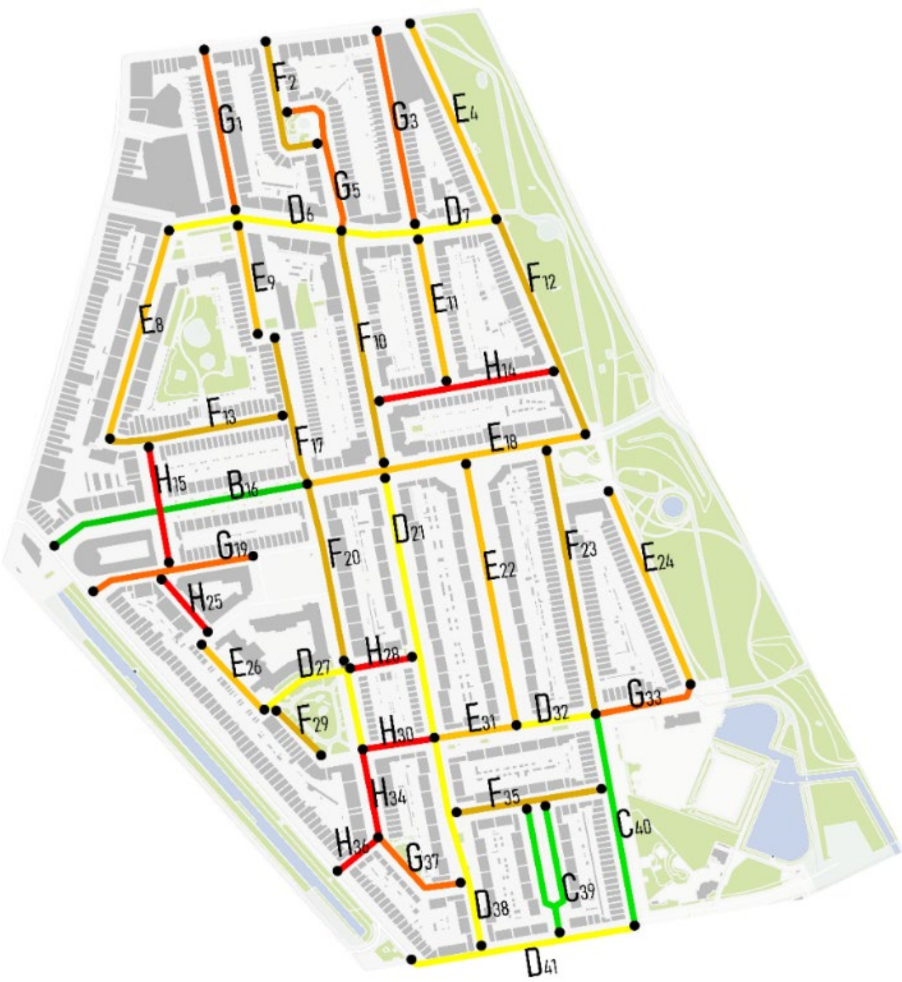


Figure 9.5. Visualization of labels for the Hillesluis district.

Hillesluis District Green Category Climate Adaptation Facilities and Measures

In total, 21 streets in the Hillesluis district were assessed with a total of 42 street segments. The scores of the green category of each street segment are presented in Table 9.3.

The assessment of the streets shows that all streets in the Hillesluis district had trees, except for three street segments. Just four street segments in the Hillesluis district scored the highest score for trees. The average score for trees was 20, which is half of the maximum score of 40. When we look at the green walls score, just five street segments fall in the lowest 1–25% green walls category.

In the façade garden/front yard category, nine street segments did not have any façade garden and/or front yard. Out of the remaining 43 street segments, 20 segments fell into the category of 1–50% façade garden and two street segments fell into the category of 50–100% façade garden. In 10 street segments, front yards were present, although six fell in the lowest category of 1–25% front yard and only four street segments fell in the category 50–75% green front yards.

Hillesluis District Blue Category

The scores of the blue category of each street segment are presented in Table 4. No rain barrels were observed in the Hillesluis district at all, and no permeable pavement in the street or sidewalk was observed. No bioswales were present either. Just three street segments had surface water within 50 m distance away from the street segment. Only three street segments scored 6 points out of a total of a maximum of 16 points.

Hillesluis District Grey Category

The scores of the grey category of each street segment are presented in Table 5. Most of the street segments had shaded areas from trees (one point), but none of the streets had artificial shaded areas (two points). Only 9 segments out of 42 segments did not have any shade at all.

In none of the streets were open unpaved (green) areas observed that were located lower than the level of the paved areas so as to provide infiltration capacity. Neither were unpaved areas observed that were located higher than street level.

In all 42 street segments, designated parking spaces were present (deduction of two points), contributing to urban heat stress.

In 26 street segments, one driving lane was present while in 16 street segments, two way driving lanes were present (deduction of one point per driving lane).

None of the streets scored the maximum 7 points. In total, 18 street segments scored two deduction points, 20 streets scored three deduction points, and 4 street segments scored four deduction points.

Total Score Hillesluis District

When we look closer at the total score of the individual street segments in the Hillesluis district, it can be seen that the maximum score is 58 in Westerbeekstraat, segment 2, and the lowest score in Zaadakkerstraat, segment 1 (see Table 9.3). For more detailed information about the scores per street, please see the Case Study Hillesluis.docx.

Table 9.3. Total score street segments in the Hillesluis district.

	Points	Beverstraat segment 1	Beverstraat segment 2	Beverstraat segment 3	Blokweg segment 1	Blokweg segment 2	Beukelaarsstraat segment 1	Beukelaarsstraat segment 2	West-Varkenoordseweg segment	West-Varkenoordseweg segment	West-Varkenoordseweg segment	Beijerlandsestraat segment 1	Beijerlandsestraat segment 2	Breeweg segment 1	Brabantse straat segment 1	Friesestraat segment 1	Westerbeek segment 1	Westerbeek segment 2	Westerbeek segment 3	Zaadakkerstraat segment 1	Riederlaan segment 1	Riederlaan segment 2
Total score	100	13	38	24	28	17	12	39	36	39	33	45	41	50	32	24	28	58	34	5	51	37

	Donkerslootstraat segment 1	Donkerslootstraat segment 2	Hollandsestraat segment 1	Hollandsestraat segment 2	Hollandsestraat segment 3	Hollandsestraat segment 4	Utrechtsestraat segment 1	Overijsselsestraat segment 1	Overijsselsestraat segment 2	Overijsselsestraat segment 3	Overijsselsestraat segment 4	Riederstraat segment 1	Drentsestraat segment 1	Drentsestraat segment 2	Vlasakkerstraat segment 1	Vlasakkerstraat segment 2	Vlasakkerstraat segment 3	Vlasakkerstraat segment 4	Zeeuwsestraat segment 1	Imobiliastraat segment 1	Imobilialaan segment 1	Average
Total score	24	39	19	4	37	28	20	27	50	7	17	31	48	7	10	37	42	14	3	24	51	29

9.5 Hillesluis district results

The highest score in the Hillesluis district was observed in Westerbeekstraat, segment 2 (Figure 9.6 and Figure 9.7). Westerbeekstraat segment 2, scored 58 points for trees, which is just below the maximum of 40 points, as well as zero points for green walls, fourteen points for green front yards (75–100%), zero points for green strips, zero points for climate adaptive roofs, and zero points for green parking lots. In the blue category, Westerbeekstraat, segment 2, does not score any points for the presence of rain barrels, permeable streets or pavements, or nearby surface water. In the grey category, Westebeekstraat, segment 2, scored one point for shadows from canopy, zero points for green areas, and a deduction of two points for the presence of (soil-sealed) parking spaces and a deduction of 1 point for a (soil-sealed) driving lane.

Figure 9.6. Westerbeekstraat [47].

Figure 9.7. Westerbeekstraat [47].

The lowest score in the Hillesluis district, of three points, was Zeeuwsestraat, but as this street was very short, about 35 m, with only four housing units, the next street with the lowest score will be discussed here. The street with the second lowest score, of five points, was observed in Zaadakkerstraat (Figure 9.8 and Figure 9.9).

Zaadakkerstraat scored just three points for trees. Zero points for green walls, five points for façade gardens (1–50%), zero points for green strips, zero points for climate adaptive roofs, and zero points for green parking lots.

In the blue category, Zaadakkerstraat did not score any points for the presence of rain barrels, permeable streets or pavements, or nearby surface water.

In the grey category, Zaadakkerstraat scored zero points for shadows from canopy, zero points for green areas, and a deduction of two points for the presence of (soil-sealed) parking spaces and a deduction of one point for one (soil-sealed) driving lane.

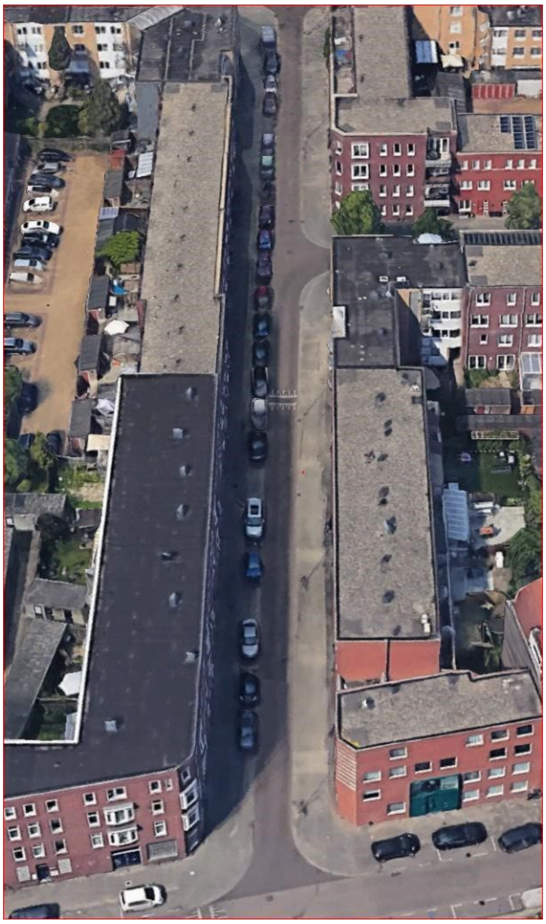


Figure 9.8. Zaadakkerstraat [48].

Figure 9.9. Zaadakkerstraat [48].

9.6 Discussion

The aim of the study was to create a tool, a score card, that was relatively easy to use by community members and stakeholders that could assess the presence of climate adaptive measures in streets and give insight into the level of climate adaptation for a street segment or an entire street. At the neighbourhood level, studies have already shown that there is a mismatch between demand and supply of ecosystem services in neighbourhoods and values for different ecosystem services for cooling and run-off retention and air purification [9]. These studies do not assess and score climate adaptation measures for an entire street. The objective was therefore to come up with a scorecard that can label a street segment or an entire street with a score of 1–100 and a label from A+++ to G, similar to the new EU energy labels for selected appliances, which were effective as of 1 March 2021 [53].

The method that was used in this research enabled the assessment of the presence of climate adaptive measures in different street segments. The results show that the scorecard method generated a clear numerical distinction between streets and street segments that contain climate adaptive measures and streets that do not have such climate adaptive measures.

As streets vary in length and longer streets tend to differ in terms of the date of construction for the housing units and building style, it is more effective to work with street segments as the unit of analysis. Other research in other fields of study also use street segments as units of analysis, such as virtual street audits of front yards [18] or streetscapes studies [8,16], or studies related to crime behaviour [17] or walking speed [18]. To make the analysis of different streets segments comparable, a conversation factor was used to recalculate the values for a 100 m street length. This recalculation of values for 100 m of street length was not discussed in other literature, but it was effective to compare the street segments.

A literature review was undertaken and the most important climate adaptation measures were selected. The selected measures are not complete as many other climate adaptation measures were found in the literature and on websites about green and blue measures 6. The selection of climate adaptation measures was based on the most common measures that are present in Dutch streets and cities. The contribution of urban green infrastructure (UGI) to human well-being has been demonstrated in several studies.

The first selected climate adaptation measure was urban trees, as they represent a large portion of urban tree canopy and provide a significant amount of ecosystem services for mitigation of the negative environmental impact [20], and they improve the outdoor human thermal comfort and indoor environment [23]. Front yards in private residence play an important role in the soil sealing problem of cities worldwide [27]. The impervious cover of front yards contributes to the problems of the urban heat island effect and urban floods, and makes urban neighbourhoods less pleasant. Private gardens play an important role as urban green spaces, and can improve the microclimate and address the impacts of climate change—specifically the urban heat island (UHI) effect. Green strips constitute similar benefits as front yards.

Climate adaptive roofs are green roofs, roofs with a high albedo (highly reflective roofs, which absorb less heat [38]), and blue roofs. Green roofs were chosen as an upcoming adaptive measure that can easily be recognized on Google maps, because, from above, plants/grass and other greenery can be spotted. Green parking spaces are an upcoming climate adaptive measure and they differ from regular parking spaces because they allow the water to infiltrate and contribute significantly to reducing runoff [39]. If parking lots are made of porous paving materials, between the tiles of parking spots there are often patches of grass [44]. Rain barrels or rain water tanks store water and relieve some stress on the sewage system during heavy precipitation. Rain barrels delay the time that it takes for water to flow into the system. Water from a roof connected to a rain barrel does not flow immediately into the sewage system, and rain water harvesting can be used as a remedial measure and can help in flood reduction [41]. Water-permeable pavements are porous or laid so as to allow voids, have an open structure, or are made of partially pervious materials. They allow water to pass through or around them into the soil; rainwater can infiltrate into the ground, groundwater is replenished, and sewerage systems are relieved [44]. A bioswale is an adaptive measure that has the ability to store water during heavy rain and redirects surface water to groundwater [42]. The surface water nearby functions as natural water storage. If the surface water is located nearby and is lower than the street level, water can be channelled into the surface water with natural gravity, and is an important adaptive measure in times of heavy precipitation. If unpaved areas are present, they provide an additional storage capacity for precipitation and may provide cooling facilities through natural vegetation. Paved surfaces, however, especially parking lots, occupy a significant proportion of the horizontal surface area in cities. The low albedo of many of these parking lots contribute to the urban heat island (UHI) and affect the local microclimate around them. Parking spaces heat up during the day and contribute to a higher temperature. At night, these warm surfaces contribute to the urban heat island effect. Similarly, impermeable "grey" driving lanes with a low permeability similar to the grey parking spaces occupy a significant proportion of the horizontal surface area in cities. At night, these warm surfaces contribute to the urban heat island effect [44].

The weight that was given to the different climate adaptive measures is based on their perceived impact to address the impacts of climate change and address heat stress and water management problems. After testing the scorecard with different weights, the maximum score for the urban trees measure was set at 40. Three different categories were given a different number of points. The maximum score for urban trees was 40 points, or 40% of the maximum score. Green walls is a less common adaptive measure and this was given a maximum of 4 points or 4% weight. Façade gardens/front yards were given a maximum of 16 points or 16% weight. Green strips were given 13 points, or 13% weight. Climate adaptive roofs were given 2 points, or 2% weight. Green parking places were given 2 points or 2% weight. Rain barrels were given one point or 1% weight. Permeable pavements were given 3 points, or 3% weight. Bioswale was given 6 points or 6% weight. Surface water was given 6 points or 6% weight. Shaded areas/artificial shade were given 2 points 2%. There was a deduction of 2 points for the presence of designated parking areas, or 2% weight, and a deduction of 1 point per soil sealed driving lane or 2% of the weight.

The weight that was given to the climate adaptation measures was mainly given after testing several times with different weights for each factor. An important criterion for the future successful application of the scorecard is easy assessment and the scorecard should be able to distinguish adaptive from non adaptive streets. (Large) Trees are an important factor for reducing heat stress and water storage in roots and leaves. After testing, the maximum score and weight for trees was set at 40%. Façade gardens and front yards are also an important factor in climate adaptation and provide a lot of ecosystem services. The weight was set at 16% after testing. Similarly, the weight for green strips was set at 13%. The other climate adaptive measures were set at lower weights.

The feedback from the community members that participated in the climate adaptation training in Rotterdam was that the scorecard method gave them insights into the lack of adaptation measures in their street and neighbourhood, as well as the lack of ecosystem services in their outdoor living environment. The community members mentioned that the scorecard method enabled them to better understand climate change and the local effects, as well as the actions they could take themselves to address the effects of climate change in their locality with simple measures, such as green yards, more facade gardens, planting trees, and increasing the infiltration capacity. They could also see which streets are greener and are better prepared for the effects of climate change, which, according to the community members, puts them in a better position and leaves them better prepared to discuss these issues with the local government.

A weakness of this method is that after the comparative study between the two districts in Groningen and Rotterdam, it became clear that some measures were not present at all in the two districts. In the green category, these were climate adaptive roofs and green parking lots. In the blue category, these were rain barrels, permeable streets and sidewalks, bioswales, and surface water. For the scorecard 2.0, these adaptive measures could be left out of the scorecard. Bio swales and other climate adaptation measures can be linked to climatescan [54] during future climate cafes [55] and city scan activities [56]. The three categories, namely green, blue, and grey measures, could be omitted in scorecard 2.0 as the distinction between the categories was not relevant for the scorecard. Another weakness is that the weights of the different measures were not based on the geospatial data analysis, but through ocular inspection. Although, for the purpose of this scorecard, namely creating awareness and being easy to use by stakeholders in the community, this suffices.

The scores—numerical values—are non-dimensional and the scores are interpreted by the user. A reference card with reference pictures has been provided in order to reduce the chance of different interpretations. Different users of the method may interpret climate adaptive measures, for example the height of the trees, differently, which could lead to inaccurate scoring. However, as the scores were non-dimensional, and the scores were mainly used for comparing the different streets with each other in order to identify adaptation gaps, this might not impose a serious problem.

9.7 Conclusions

The objective of this study was to test a method that assesses the presence of climate adaptive measures in street segments and streets, and to provide a score between 1 and 100 that indicates to what degree the street is climate adaptive. Based on the score, a label can be given between A+++ and G, so that residents and decision makers are aware which streets are adaptive and which streets have an adaptation potential. In the Paddepoel North district in the city of Groningen, 17 streets were assessed, composed of 45 street segments with an average climate adaptiveness score of 47. In the Hillesluis district in the city of Rotterdam, 21 streets were assessed, composed of 21 streets with an average score of 29 points. The climate adaptive measures that were observed in the street segments were tabulated and each climate adaptive measure was given a weight based on the perceived ecosystem service of the measure. Based on the adaptive measures multiplied by the weight, a score for a street segment could be given. Each score corresponds with a climate adaptation label.

The results show that the method is useful to score street segments and to attach labels to streets segments and entire streets, so that residents that live in these communities are aware of the level of adaptation of their street. Similarly, local governments and other stakeholders know which streets score low and which streets have a larger adaptation "potential".

The study developed and tested a new method to label the level of adaptation of street segments and entire streets, so that streets can be compared with each other. The method was proven to be relatively simple and useful for street assessments, as the assessment was done after a short training with several community groups in the Hillesluis district in Rotterdam. The method can easily be duplicated and used by local governments and community groups in order to have better insight into the level of climate adaptation of their street. Labels for entire streets can be used to encourage residents to take action and expand the number of climate adaptation measures in their own street.

9.8 Climate Scorecard 2.0

Two approaches of field measures were developed: The Scorecard 1.0 described above and Scorecard 2.0 with similar indicators, but presented in a different form to make it more easy and ready to use by non-professionals. In the Scorecard 2.0, the indicators and instructions to follow are presented on an A3 laminated card. It is convenient to be used when you walk through a street or street segment and do the visual assessment (see Figure 9.10 and Figure 9.11 below).

The steps to the field survey are as following:

Step 1	Street segment
Step 2	Measuring street segment
Step 3	Trees
Step 4	Green front yard
Step 5	Green façade garden
Step 6	Green wall
Step 7	Green roof
Step 8	Green parking space
Step 9	Field of grass
Step 10	Bioswale
Step 11	The total

Following the steps, you put the values on the card and get the total amount of points. Comparing the sum with the Street Score Sheet ver.2.0, you can assess the level of the street adaptiveness to the climate changes.

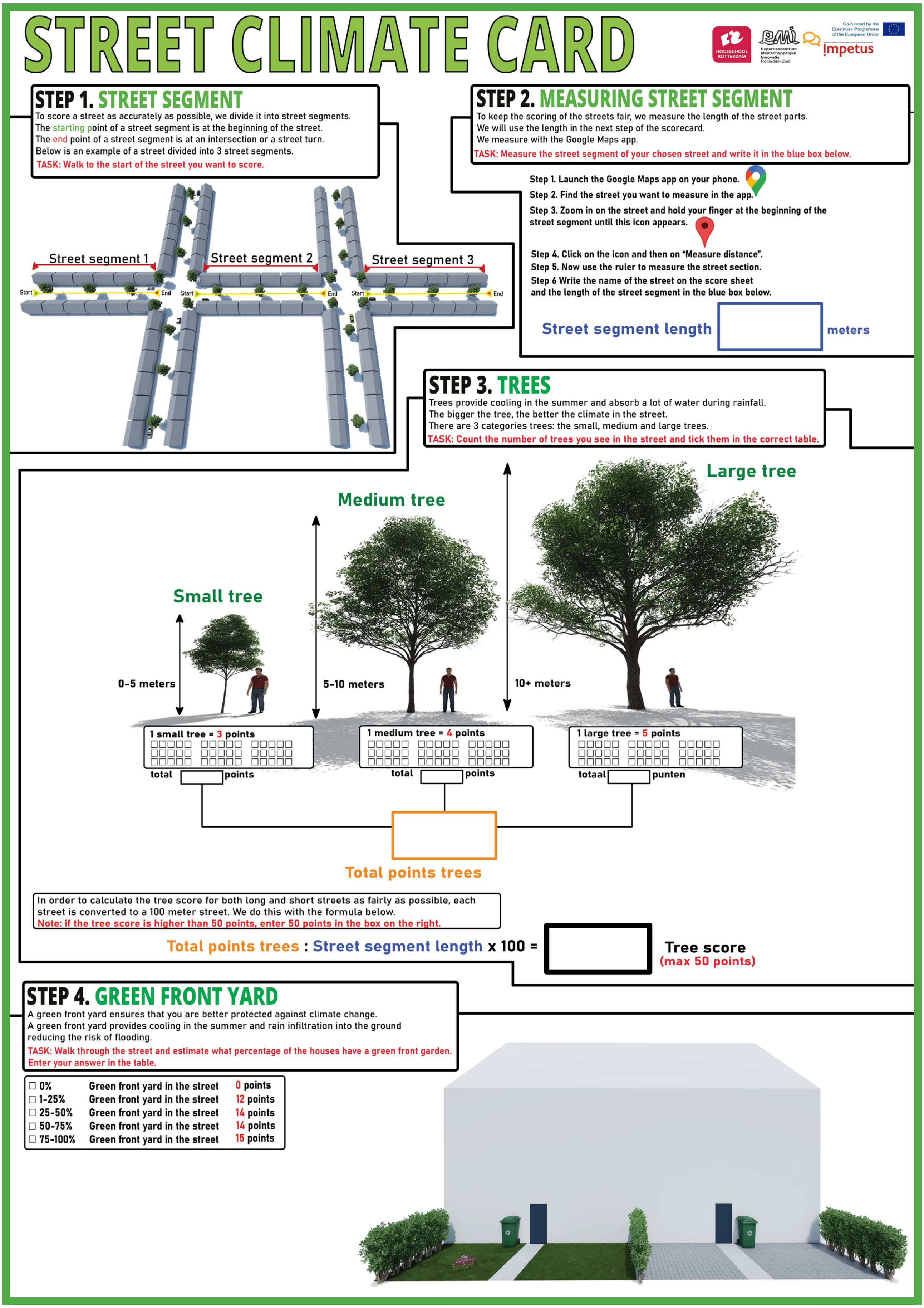


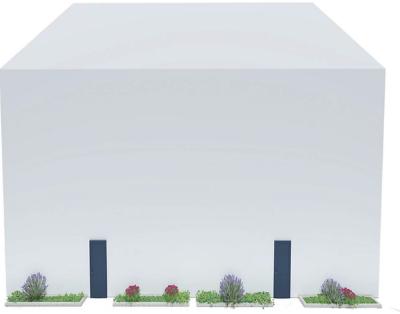
Figure 9.10. Street Climate Card 2.0 front side.

STEP 5. GREEN FACADE GARDEN

Just like a green front yard, a green facade garden makes sure you are better protected against climate change on a smaller scale.

TASK: Walk through the street and estimate what percentage of the street consists of a facade garden.

☐ 0%	Green facade garden in the street	0 points
☐ 1-25%	Green facade garden in the street	3 points
☐ 25-50%	Green facade garden in the street	4 points
☐ 50-75%	Green facade garden in the street	5 points
☐ 75-100%	Green facade garden in the street	6 points



STEP 6. GREEN WALL

Green walls cover a house and keep the temperature both inside and out cooler in the summer. Green walls absorb water during rainfall and ensure a higher biodiversity in a street.

TASK: Walk through the street and estimate what percentage of the houses have a green wall.

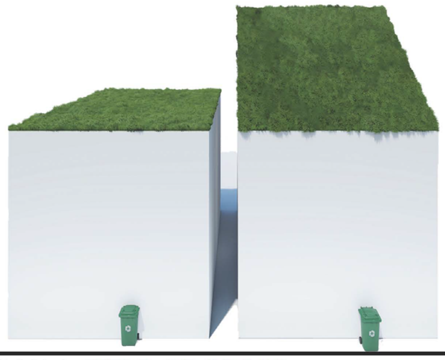
☐ 0%	Green wall in the street	0 points
☐ 1-25%	Green wall in the street	1 point
☐ 25-50%	Green wall in the street	2 points
☐ 50-75%	Green wall in the street	3 points
☐ 75-100%	Green wall in the street	4 points

STEP 7. GREEN ROOF

Green roofs have the same advantages as green front yards and facade gardens. What makes green roofs even better is that they don't take up any space on the street.

TASK: Walk through the street and estimate what percentage of the houses have a green roof. Use satellite view in the Google Maps app to spot green roofs in the street.

☐ 0%	No green roof in the street	0 points
☐ 1-25%	Green roof in the street	1 point
☐ 25-50%	Green roof in the street	2 points
☐ 50-75%	Green roof in the street	3 points
☐ 75-100%	Green roof in the street	4 points

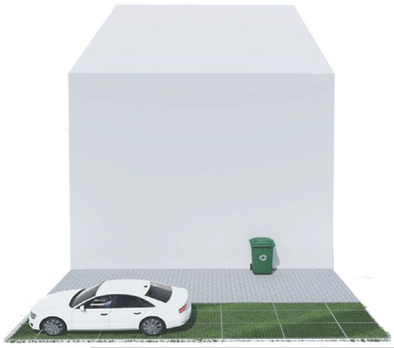


STEP 8. GREEN PARKING SPACE

A car and a parking space are important to many people, but the climate is also important. Green parking spaces allow rain to infiltrate into the ground and at the same time also provide parking space.

TASK: Walk through the street and estimate the percentage of green parking spaces in the street.

☐ 0%	No green parking in the street	0 points
☐ 1-50%	Green parking in the street	2 points
☐ 50-100%	Green parking in the street	4 points

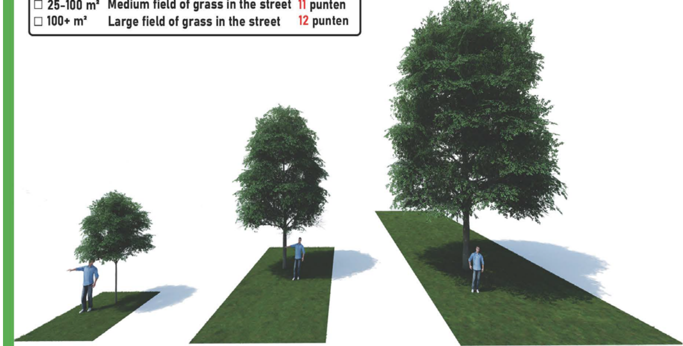


STEP 9. FIELD OF GRASS

A field of grass is generally good for a street.
The environment brightens up with it, people can use the field for sports or recreation and it is good against the changing climate.
A field of grass can absorb a lot of rainwater and let it infiltrate into the ground.
Grass generally also provides cooling in a street on a hot day.
The bigger the lawn, the better the climate in the street.

TASK: Walk down the street and estimate the size of the field of grass.

☐ 0 m²	No field of grass in the street	0 punten
☐ 1-25 m²	Small field of grass in the street	10 punten
☐ 25-100 m²	Medium field of grass in the street	11 punten
☐ 100+ m²	Large field of grass in the street	12 punten



STEP 10. BIOSWALE

A bioswale is a low-lying field of grass
Rainwater flows to the wadi after which it infiltrates into the ground.
A bioswale can absorb a lot of water, be full of water and therefore store a lot of water.

TASK: Walk down the street and look for a bioswale

☐	No bioswale in the street	0 points
☐	There is a bioswale in the street	5 points

STEP 11. THE TOTAL

TASK: Now add up all the points from steps 3 to 10 and fill them in on the score sheet. The climate labels are on the back of the score sheet.

Erase all your answers and now move on to the next segment of your chosen street or choose another street.

Figure 9.11. Street Climate Card 2.0 back side.

9.9 Final results description

There are two approaches which you can use to measure the street adaptiveness towards climate changes. The one, more sophisticated and the other one dedicated to higher education students and the other one simplified in order to be used by non professionals. The measures can be done manually or using an app and the results can be sent directly to the Climate Scan database.

For the version 1.0 use the scorecards: Street Climate Card ver.1.0, front.jpg, Street Climate Card ver.1.0, back.jpg and Street Score Table ver.1.0.xlsx.

For the version 2.0 use the set of files: Street Climate Card ver.2.0, front.pdf, Street Climate Card ver.2.0, back.pdf and Street Score Table ver.2.0.pdf.

For the presentation of the methodology you can use Street Scorecards presentation.pptx.

For the students' knowledge income verification use Street Scorecards pre-post test to print.doc and Street Scorecards pre-post test key.doc.

9.10 External materials

See: https://impetus.aau.at/outputs/

Folder: Street Scorecards

- Street Scorecards instruction.pdf
- Street Scorecards pre-post test to print.doc
- Street Scorecards pre-post test key.doc
- Street Climate Card ver.1.0, front.jpg
- Street Climate Card ver.1.0, back.jpg
- Street Score Table ver.1.0.xlsx
- Street Climate Card ver.2.0, front.pdf
- Street Climate Card ver.2.0, back.pdf
- Street Score Sheet ver.2.0.pdf
- Street Scorecards presentation.pptx
- Case Study Hillesluis.docx

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Author Contributions: Conceptualization, R.H.., P.D.R., E.O. and A.V.d.H.; Investigation, R.H.., A.I. and P.D.R.; Methodology, R.H..; Supervision, R.H.., E.O. and A.V.d.H.; Visualization, A.I.; Writing — original draft, R.H..; Writing — review & editing, F.C.B. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest: The authors declare no conflict of interest.

10 Geo-Questionnaire

10.1 Introduction

The research on human behavior can be conducted by interviews, discourse analysis open-ended questionnaires, documents, participant observation, and others. Questionnaire is one of the information-gathering techniques used frequently in mixed-method research that draws on quantitative and qualitative data sources and analysis.

- **Quantitative research deals with numbers and statistics,** and help to answer the question: HOW MUCH or HOW MANY? It is used to test or confirm theories and assumptions to establish generalizable facts about a topic. Ex. How many (approximately) people among alter people are afraid of climate change effects...
- **Qualitative research deals with words and meanings** and not numbers. It is used to understand concepts, thoughts or experiences and enables to gather in-depth insights on topics that are not well understood. Ex. How people perceive their social realities...

Questionnaire as the methods for gathering the feedback, opinion has several advantages such as:

- access to direct feedback,
- saving the time spent on surveying opinions in a different way, e.g. conversation, telephone, interview,
- possible online research,
- big respondents group.

But it very often happens that it takes a long time to collect the expected number of answers as it is not an easy task to encourage people to fill the questionnaire.

The geo-questionnaire combines the benefits of a standard questionnaire and a map, that is devised to provide information on the available space (spatial data). Responses to a geo-questionnaire may contain point, line, and polygon objects sketched by participants on a map or they can be used in the reversed method that the external questionnaire is linked to the map. So that the answers can be searched by the location using maps. For simple questionnaires the map can be also the way of visualization of the information gathered via the questionnaire – usually the location of the selected objects. There are also a very advanced systems for questionnaires using geographical information systems which combine different methods for acquiring the information via map sketching or marking on the map and by answering questions that are triggered by map interactions.

The research on human well- being can be conducted on the large scale [4,5], but also on smaller scales such as streets, districts or revitalized areas. In this case the usage of the questionnaire as the method of collecting information, next to field interviews, is more and more popular. Individual perception of citizens is one of the factors taken into account while shaping the local neighborhoods and designing them not only to make them economically attractive but also human friendly. The city developers collect public preferences and behavioral patterns to develop land plans, in the revitalization processes or adaptation of the areas to climate change. This spatially-explicit local knowledge is also used for academic research to find the rules and correlations between different elements of the space and human habits, choices and general well-being or health [1,2,3,6].

10.2 IMPETUS questionnaire

The IMPETUS geo-questionnaire is the tool to collect public preferences, behavioral patterns, and spatially-explicit local knowledge. "Neighborhoods are big enough to aggregate the interrelated components and give way to a coherent urban fragment, yet small enough to reduce some of the complexities of system integration and to see results in a shorter time period"[1]. Thus, the diagnosis of the neighborhood's condition and knowing the citizens' perception or well – being level can help to define the problems and find solutions. This knowledge can be used in the revitalization processes or land development design. It can be also used for research in the correlation between human well-being and specific locations designs of just to monitor different aspects of city life.

The aim of this ready to use questionnaire is to learn about citizens' perception of the neighborhood in terms of their well-being, awareness of climate change issues, environmental issues and urban design. As the definition for the well- being is still challenging, and the terms such as "happiness", "life satisfaction" or "quality of life" are often used in the same context, here for the questionnaire the

The questionnaire consists of sections devoted to different topics:

- Section 1 – Perception of living area. This part refers to your perception of neighborhood design. Good neighborhoods are the cornerstone of sustainable communities and the fundamental scale of people-centered urbanism. A good neighborhood is a place where people are willing to spend time and interact with their neighbors. To encourage this physical presence, it should be well connected, furnished in an attractive way, build the identity of the society and integrate it. Well-designed Area can strongly improve the well-being and health of people.
- Section 2 – Perception of subjective well-being. This part refers to your perception of your well-being.
- Section 3 – Neighborhood environmental condition. This part refers to your perception of pollution and disturbances you may experience in your neighborhood.
- Section 4 – Awareness of climate change effects. This section refers to your perception of climate change and exposure to climate change effects and your actions.
- Section 5 – Respondent's data.

For the research one can use the whole set of sections, preferable when respondents can answer the questions for example at home and have enough time or use the ready short set available via the app, preferable in field research when interviewing the respondents. better adjustment to the respondents' capabilities: the survey does not take much time, it is clear and easy to fill. You can also access it virtually anywhere via the app using your smartphone, tablet or computer.

When conducting a survey research and after the collection of the completed questionnaires, it is essential to interpret this information. We do this to estimate the magnitude and direction of effects which exist out there in the real world. The data from the survey research are complementary to the data we collect through the Climate Cafes in different cities in the scope of the IMPETUS project. For that reason, in order to add spatial data of the questionnaires on a map, the survey research data were combined with the rest of the data.

To do that, developments were made in the already existing website tool ClimateScan. The questionnaire is added to the ClimateScan data base via the app. You can also add this

[1] https://www.neighbourhoodguidelines.org/why-neighbourhood-design

questionnaire to google disc and collect information by google questionnaire and then add it to the database via https://www.climatescan.nl/ by creating a new project or joining an already defined project.

10.3 External materials

See: https://impetus.aau.at/outputs/

Folder: Geo-Questionnaire

- GG instruction.pdf
- GG questionnaire.doc

10.4 Literature

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11 Sketching & Storytelling

11.1 Instructions on how to use the materials and intellectual outputs of Sketch&Draw in the impetus project

With the focus on a teaching session about the needs of climate adaptation impetus developed two booklets for students. One textbook describes the needs for urgent change and helps to spot the point of possible change to discuss in the classroom. The second booklet serves as a sketchbook with walks in the cities of Coimbra, Rotterdam, Klagenfurt, Gdansk, Groningen, Bern, Zurich, Chur where students can apply their knowledge.

These two booklets can be used in any city, but have special strolls in the cities named above.

Classes need about three hours.

First is the teaching with the texts and images. This takes one to two hours. All needed stuff for teaching is in the textbook.

After this, the teacher has to explain, how it works to scan the QR-Tag and follow the walk. The second part of the course is the stroll. The sketchbook contains a full description of steps so that the students can do the walk on their own. After the walk, the task of sketching needs 30-45 minutes.

By doing this work, students learn to spot areas of intervention for climate adaptation. Sketching leads to closer looking and empathy for needs in sustainability in the city.

Booklets:

https://www.dropbox.com/s/p59ufd44a7twv21/booklet_climate_adaption_gzd_onine.pdf?dl=0

https://www.dropbox.com/s/6eq40lt7nie7l14/booklet_climate_cognitive_mapfini_3_online.pdf?dl=0

Full video tutorial find here:

https://youtu.be/XjPs0GHiKcU

What is the impact of sketching on tablets, tackling climate change adoptions?

Sketching on digital devices like tablets are of increasing relevance for today's students who get help from smart drawing apps for visual notetaking to develop climate change awareness. Because of the lack of paper as a playground to depict, the tablets act like the entry point to digital communication media and nourishes the communicative way of sharing ideas.

Sketching on tablets is a multimedia and convergent method that trains students in perception and case analysis, clear observation and reasoning, giving supportive peer reviews by shared content via the digital output channels, and guided reflections. This approach includes the proved research method of sketching and leads this to the digital communication channels. This is an important gain of innovative potential even in the era of online learning and teaching.

The method applies "digital sketching with the ten Sketch&Draw rules for non-artist-skechers" and lets students gain experience of visual research sketch notes and observations and it leads with these drawings to possible scenarios for effective climate adoption. The visual story with hand drawn sketches works excellent in communication because men are highly interested in "handmade", meaning sketched products.

Critics may question the digital production of sketches on tablets in the digital production chain and digital communication chain. But it is highly regarded as an efficient way of social media sharing, that you post what you have already on your device.

Whoever has tried sketching on a digital device knows the advantages in the field of "how to draw a line?" Furthermore, are the advantages of layers, blending layers, digital helps like smart grids and streamlines line, geometric Forms and even photo-layers. There are endless tooltips to enhance your sketch.

The impact of sketching on tablets enables students to personally engage with knowledge and help each other to master the art of sketching itself and sharing knowledge.

Showing images of sketch city student exchange. Moodboard of images. ❧

Ideasketching Storyboard for Urbanists

Storyboard for Urbanists

This Booklet is an introduction to the most important points of storytelling for visuals like films. The booklet is made for sketchers, that want to develop a story with the pencil like a professional. Because a clever drafting of a plot for a story is important for effective call for actions.

This book can be read by students and teachers and discussed among the class. In the second part, there is space to develop an effective story with the plot of a hero's journey. It takes up to one day to read and understand and sketch a story.

Booklet Storyboard for Urbanists

https://www.dropbox.com/s/y5bi6s9tip8hbva/storyboard_engl_sketchbuch_mai_2020_longforme_de_mix_updated_logos.pdf?dl=0

What is the benefit of visual Storytelling in Social Media by ideasketches?

Through visual idea design, diverse urban needs in a city can be made visible and thus flow directly into the complex urban development and its planning. The spectrum ranges from "good ideas" to comprehensive portfolios with concrete solutions. Citizens should thus be included in the planning processes and the diverse approaches to solutions coordinated by online systems, made transparently and access to influential data material supported.

This is exactly where Sketch&Draw comes in: the urban population or those directly affected by specific urban development processes sketch out imaginative solutions and planning criteria. The sketch of an idea can outline the future by possible scenarios. These necessary images and scenarios of a possible future and thus support innovative solutions. In the best case, it can even create a future-relevant design or concrete solutions for complex problems.

In European cities, the threats of climate change are crucial for urban development and human security. Although cities are increasingly experiencing new approaches to local adaptation planning, there are still significant barriers and limits, such as:

- Limited availability of up-to-date data on local conditions.
- Lack of awareness and civic attitudes of ignorance of climate change and its impact on basic well-being and local conditions in our streets and neighbourhoods, lack of public interest, and finally ...

- The lack of interdisciplinary approaches and public action to solve local problems, and often the inability to choose optimal solutions from a set of alternative measures.

These limits could be overcome by introducing an extended holistic, interdisciplinary approach.

This consists of a combination of technical and scientific expertise. Here we use sketches made on smart devices, that depict the real world. Stories must be told that explain possible scenarios after one symptom has been observed and sketched in the real world.

But why is this all so challenging? Why do we lose so many people on the way to a climate adapted world?

And how can problems be conveyed to the broader audience? It needs the skills of Storytelling.

But why does storytelling seem not to work in the climate change adoption and sustainability discussions?

With Sketch&Draw we open the toolbox of image making? And from image making to storytelling, there is more than one thing to know.

This is new here: We reverse-engineer the storytelling by starting at the very beginning of the image: the sketch

Sketching stands like a root of a plant at the beginning of image creation and further on it determines the visual Storytelling and its effects.

There is only one answer to this question: Do we want to deal with climate change adoption?

This is actually the wrong question, because the answer has to be: we have to adopt! And even more: without each and every country in the world from Asia to Africa and Europe to America and Australia – we all have to deal with this problem immediately. And for this reason we need the power of social media driven storytelling and its snowball effects.

So, the way of climate change adoption leads us to a story, and it is a thriller, with all the ingredients of thrill and death, villain and protagonists. But this time, we are not only the audience. The climate crisis has changed to a climate catastrophe. And if we do not cope with the tackling of the problem, … why isn't this a thriller?

After some doubtful decades of endless climate discussion, now the time is ready for actions. Because if we do not reach the Paris goals of temperature reductions, we will be lost. But it could look like we have an immense gain of interest at the moment, even on tik-tok or Instagram, platforms, some months ago not known for such discussions. And social media knows no borders or climate zones. These platforms are now spreading all over the world.

Former stories worked with the scenario of anxiety. But we should face the positive options like digitalization and artificial intelligence … and we need them all.

We need a vision of the better. Because dystopia needs to become positive scenarios. We need to become aware that this tiny and fragile range of climate, let's call it our temperature range for liveability, defines our lives. Only small changes make our planet hostile, landslides, hurricanes, floods show us, that our lives are bound to climate. And it is not the world that will end, it's us. Because we can't live in a world with a climate that is out of range. This is, what we endanger by not reacting to the needs of climate adoption.

We have already stretched this range of global warming. We are in the discussion from two to three degrees … and some start to think of even five degrees augmentation.

So let's look closer: When we look at this picture, we all are able to find out – this is a war picture. Even, when we have never seen such a thing in real life. We have such pictures for war, for flooding, for wildfires, even meteorites collisions. No one doubts and everyone agrees. These pictures are iconic and given.

But there is no such picture for climate change. And why? Because climate change is complex. We can see climate change by symptoms, all open for interpretation. If we have a wildfire, one says: It's climate change! The other says: this is a wildfire, and we have had wildfires ever since.

But it has always been the great trick of the devil, to make man believe, he didn't exist.

And like the devil, the climate crises are not visible, but the symptoms are. And therefore, we have no image of climate change. And no idea of life on a planet with a climate of 3 degrees plus. We can't imagine a world, where we can't escape to a good climate zone, because there is none.

We actually have to look at all the individual subsystems and see when they tip over. We have to see when they develop irretrievably in a direction that we no longer like, or even more, when these changes are no longer reversible.

And this is what sketches are for. They help us to observe the world in detail, these tiny individual subsystems.

We need to see the symptoms first, and from them, we go to the possible scenario. We have to break up these two things in two steps. And the manifold scenarios, each in its own way, is important to understand. And the whole complexity of climate change is only to be understood as an array of possible detailed scenarios, but not as a whole.

If we do not understand a threat, then we cannot confront it. So we need to have understood what the threat is by observing what the trigger of the scenario is, then we can respond. So we need to create this space for action so that we can master climate adaptation.

And that's why storytelling is important. You have to explain these symptoms and a single scenario. But always again. That's how you can initiate understanding.

So we have to start before the climate deniers. Nowhere is science more in agreement than on climate science. And yet there are deniers. The observation by sketching starts significantly before the fronts of climate deniers.

It is common sense: there are only possible scenarios. Scenarios are paths, correctives for predictions. Here it is important to show the options for action. They give us the sovereignty to shape the future. So we have to start with the options for action and the sovereignty to shape them. That is why communication through stories based on observations, sketched, individual and in-depth observations is so important.

Pointing out creative space, knowing how to face climate change, that's important. We should be able to experience ourselves as creators. So all we have to do is open the toolbox. Choose something! Flex your muscles! You are challenged! Do something, experience yourself positively as a creator for the future climate adopted world. ❧

Character Design for Animation & Game

The aim of this booklet is to lead through the process to develop a game. Every game has its story and its character.

It serves as a help during a game jam, 24 hours of a game hackathon. It is self-explaining and leads students to develop characters for the field of sustainability and games in this field.

Plan your game or animation by this game design document for character design. The story will be developed later, but it shall be in our mind already. Some first questions have to be answered.

This document is important for the communication between the ideators and the designers as well as the game developers. Get your character by answering those questions first. Doodle and sketch details. Think always of iterations. It will be a rolling process.

You need at last three characters: a protagonist and a second character to talk to. And another character for the drive of the story.

Booklet Character Design for Animation and Game

https://www.dropbox.com/s/ye7hcn7o3zyrp48/Characterdesign_for_animation_game_impetus_fini_fini.pdf?dl=0

Why is sketching a research tool for climate adoption perception?

To know all the different places, where we can see symptoms of climate change, is the first step to efficient visual storytelling with sketches. The digital pencil and the needed time to draw helps to look closer and detect more details. And during this time awareness grows. Critical thinking is of increasing relevance for today's students who have to develop these skills.

Looking closer by sketching trains students in precise observation, case analysis, clear reasoning and notation, giving supportive peer reviews, and guided reflections. Because only a deeper perception of the first symptoms of climate change opens the frame for calls for actions.

Sketching as a research tool has always been applied and will furthermore apply on "drawing is thinking". Since climate change is visible in symptoms of environment, weather, plants and more, these signs can be shown by being depicted. This is the reason for the depicting.

It may be challenging to deconstruct the environment into symptoms, already detectable and not be overwhelmed with all the complexity. But it will be a rewarding thing when symptoms become part of the visual storytelling in climate adoption via social media, because like this, we can show where we can change our behaviour.

Other techniques like photos may work louder than sketches, but they miss the human approach of looking closer and to understand the whole complex system of climate change.

The greatest power of drawing is that it can simply represent in this way of visual storytelling for climate adoption the future. Drawing becomes together with storytelling the powerful tool for understanding the needs of climate adoption. ❧

The why of sketching global warming and climate adaption

This booklet is made for class use. It takes you in the city and asks you for communicative entry points to sustainability in the city. You need about 3-4 hours to go through this booklet in the city.

How can we draw attention to the problem of climate change in cities so that the urgency is recognized early enough? And how can we take initial measures in the future.

This sketchbook serves as a tool for raising awareness of the current climate change situation. In order to be able to perceive the major impacts of climate change, the small signs in the immediate vicinity must be recognized.

For this purpose, sketching is a good tool, because it forces you to look closely. And even more the visual analysis of the situation by means of diagrams or illustrations helps to see the connections.

And it is important to observe the changes over a certain period of time. ❧

Booklet Climate Scan Gdansk

https://www.dropbox.com/s/o6jyrw3qjpvd37j/booklet_climatescan_marec_danzig_fini_fini.pdf?dl=0

Urban Sketching

Sketch your own Circle Selfies

Why is there a need to rethink the way we live in the city?

If we send out our students with the task to make a selfie, they think more about their surroundings.

Taking a photo means always dealing with perspective. What shall be in the picture around you? With what do you identify?

This is why we send the students out to depict themselves. It takes one afternoon to three days to sketch these images.

- Because Corona has shown us that we need new models of free areas.
- Because the back-yards are too good for hot air conditioners and their exhaust.
- Because trees reduce particulate matter.
- Because parks are pricelessly important for children and their urge to move.
- Because cities with the paradigm "cars first" provoke less social interaction.
- Because medical costs become unaffordable.
- Or simply because it gets too hot and too cramped in the cities.

11.2 External materials

See: https://impetus.aau.at/outputs/

Folder: S&S

- S&S Visual instruction.pdf
- S&S instruction.pdf
- S&S Character design for animation.pdf
- S&S Booklet sketching Gdansk.pdf

- S&S Booklet cognitive map.pdf
- S&S Booklet adaptation steps.pdf
- S&S Storyboard for urbanist.pdf

12 Drones

12.1 The aim and introduction

Air pollution is not a recent phenomenon - it has always existed, but before that it was only due to natural causes in the environment. Later on, pollution was also caused by humans, but it was not significant and noticeable in the long run. Over the past centuries, different industries started to develop at different speeds. People thought about how to make a certain thing or improve it without considering the long-term effects. The Industrial Revolution that began in the 18th century saw the growth and transformation of existing industries and the creation of new offshoots. It was hard not to notice the already existing problem of air pollution. It is only since a relatively short period of time, when the cleanliness of the air deteriorated severely and the predictions for the coming years were critical, that there has been a significant increase in interest in the subject of smog and a closer look at it. For the past few decades, there has been thorough testing of pollutants in the air and strict restrictions have been put in place. Recent years have also been a period of rapid technological development, with innovative solutions being sought more intensively to improve the situation.

Particulate matter is a mixture of liquid and solid particles suspended in the air. These particles are of natural origin, such as sea salt aerosols or Sahara sand clouds, or of anthropogenic origin, such as pollution along traffic routes. Commonly used indicators are described as PM (particulate matter), indicating the content of dust with a diameter equal to or smaller than the number given in the name in micrometres. Due to the size of the fraction, it is mostly divided into PM10 and PM2.5, sometimes PM1 is also distinguished here. PM10 (particulate matter 10) are particles with a diameter of up to 10 μm. It is suspended in the air for up to several hours and consists, depending on the conditions of formation, of small particles of smoke, ash, soot, inorganic compounds such as asbestos. It is mainly formed in the combustion processes of liquid and solid fuels. Wind helps to carry and lift the particles from industrial and utility chimneys, bare soil, unpaved roads or mines. Traffic also contributes, creating dust and air turbulence.

The aim of this procedure is to describe and specify the steps for mobile air pollution (PM10, PM2.5), temperature and humidity measurements.

The measurements can be carried out either by mobile sensor attached to ground vehicle (bicycle, car, scooter) or aerial vehicle (drone). The mobile sensor is self-sustainable and do not require any external data output. Based on collected environmental data the three dimensional visualizations and spatial maps are created. The maps allow for innovative detection of heat sources, suspended dusts (smog), which contributes to the improvement of the atmosphere.

12.2 Indication of the area to be measured

The aim of this section is to point the right procedure for data collection within the specified area. The mobile measurements are to be adapted to the type of the area, human and technical resources. As the pollution harms humans at the breathing level (up to 2 meters) the measurement tool can be attached to the bicycle or backpack. By walking or riding the area of interest the parameters can be measured. The aerial measurements are very useful for large area and source seeking, as the source is usually at the chimney level (15-25 m).

The procedure covers following use cases for data collection:

- the air pollution source seeking within urban area (housing estate) (ground, aerial),
- the single air pollution source investigation (ground, aerial),
- the heat source detection (ground, mobile).

12.3 The air pollution source seeking

The air pollution source seeking case is intended for searching the source of air pollution, mainly in the area of single-family buildings (detached houses). In such areas it often happens that individual households have outdated burning stoves, in which solid materials such as wood, coal or often waste are burnt. In this case, particulate matter is released into the air, the source of which can be identified on the basis of the map. In this case, an aerial measurement using a drone can be used for the measurement, alternatively a mobile measurement can be successfully performed from the ground by placing the sensor on a bicycle or backpack.

Aerial measurement

The aerial measurement is based on single grid flight plan (Figure 12.1).

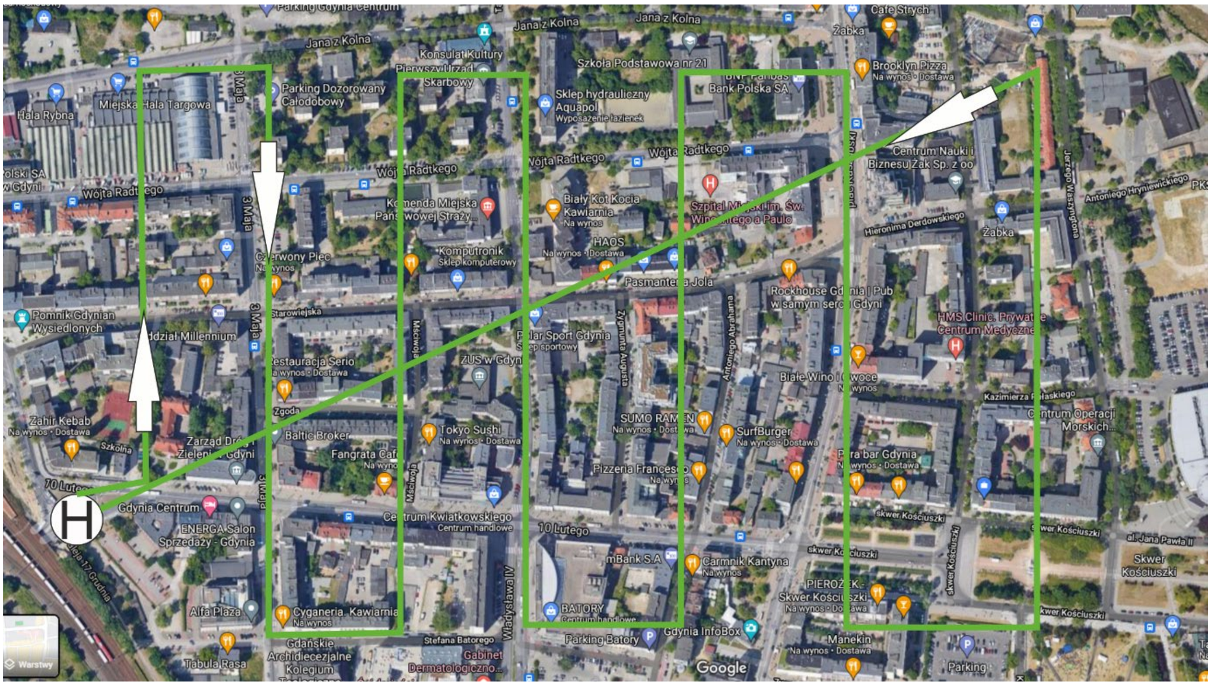

Figure 12.1. Single grid flight plan.

A single grid plan is used to regularly monitor the situation in an area. The flight plan must be programmed into the UAV system in accordance with the UAV operating manual. The flight altitude should be chosen according to the local airspace conditions, but possibly a dozen or so meters above the highest buildings.

The execution of the flight starts at the place of take-off and landing (H). The UAV performs the flight along a pre-programmed route while recording pollution sensor readings. After landing, data is downloaded and archived.

Ground measurement

Mobile ground measurements, alternatively, can be used to measure pollution in a designated area and to regularly monitor the situation in the area. For mobile measurements you can use any means of transport such as bicycle, scooter, scooter, or place the sensor on a backpack and make measurements while walking.

The realization of the measurement starts at the starting point (S) and ends at the ending point (E) (Figure 12.2). After starting the sensor, move the sensor around the measurement area. Track density and length should be adjusted to local conditions and availability of a convenient transportation route.

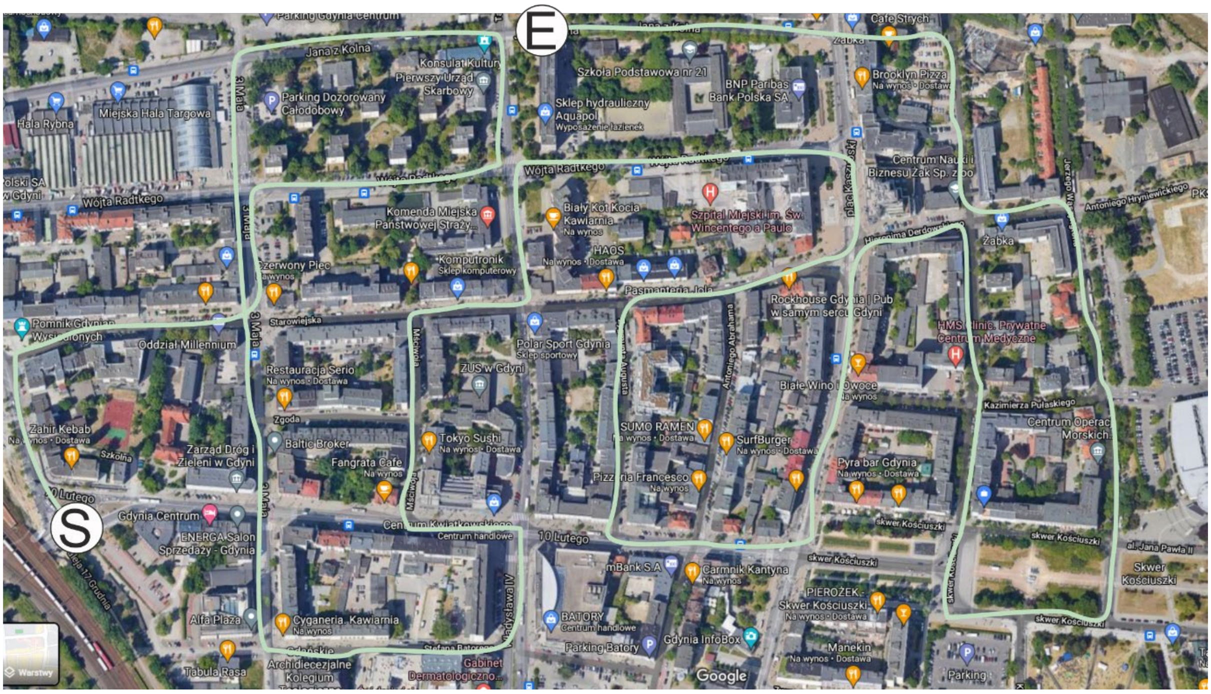

Figure 12.2. Ground measurement patch - example.

12.4 The single air pollution source investigation

In some situations, there is a need to verify a detected or known source of contamination, such as a single house, factory, or chimney. Such a measurement is based on cyclic circling of a known source position. During this time, samples are collected and readings taken by the sensor, from which the composition and concentration of the contaminant can be determined.

The flight starts at the starting point (H) (Figure 12.3). The operator arrives at the measurement location in a straight line flight and circles the position several times. During this time the readings are recorded.

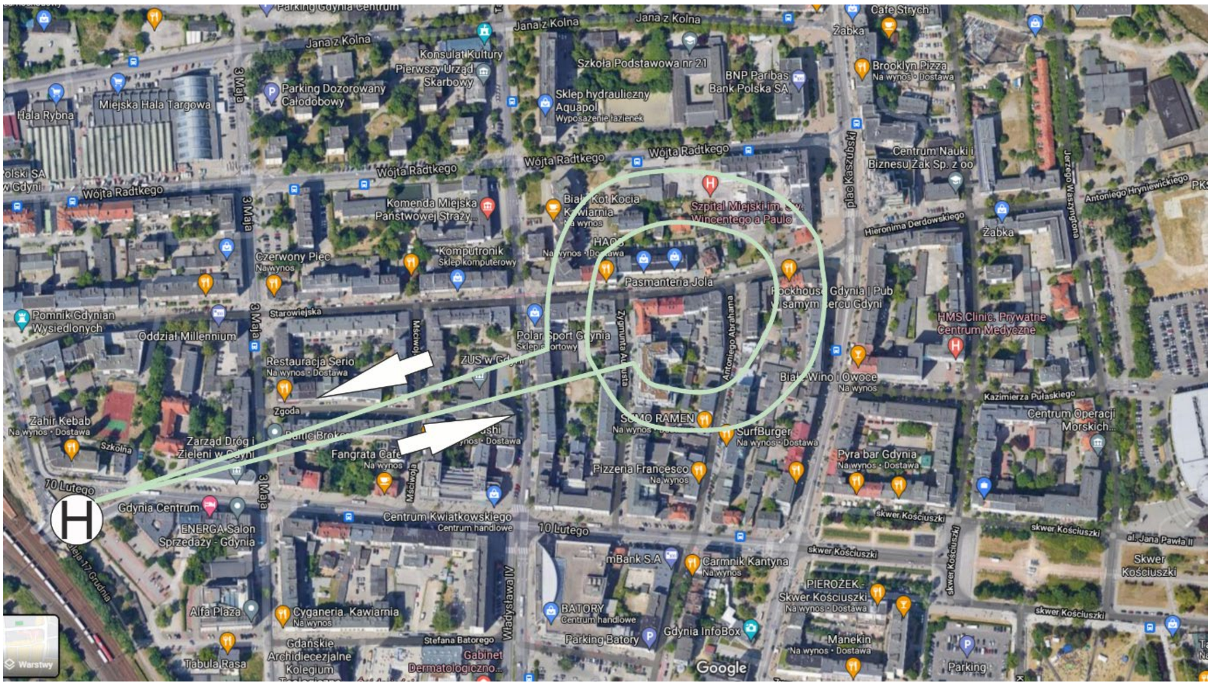

Figure 12.3. Single pollutant data collection.

12.5 The heat source detection

Measurement of heat sources is analogous to measurement of air pollution. It should be noted that in an urban area, ground-based measurement will be the preferred measurement technique. The sensor records air temperature simultaneously with other parameters, which can be used to visualize potential heat islands and heat sources in the area.

12.6 Sensor description and manual

Figure 12.4. Air pollution sensor.

Air pollution sensor is a device that records the measurement of pollution, air temperature, atmospheric pressure and humidity. Each measurement is tagged with a GPS position so that the measurement location can be tracked. Additionally, the sensor records measurement time and GPS status (number of satellites). The sensor is equipped with an inlet tube, through which the tested air flows. Do not cover this tube or block the access of air to this inlet tube. In addition, please note that the sensor must not be covered or in any other way covered, which will prevent the GPS signal from being received.

The best place to mount the sensor is on a bike rack, backpack, carrying in hand or mounting on a drone.

Procedure:

1. Connect the power supply.
2. Make sure the SD card is in the slot.
3. Check SD card status (see: LED status 1, 2).
4. Wait for the internal GPS to receive satellite signal (see: LED status 3).
5. Enable recording – long press on the button (see: LED status 4).
6. Perform measurement.
7. Turn off recording – long press on the button (see: LED status 5).

Other functions:

1. Recording for 15 seconds – two short button presses.
2. Recording every 3-4 seconds: continuous button presses.

Table 12.1. Air pollution sensor LED status.

No.	Red LED	Green LED	Status
1	On	On	No SD Card
2	1 blink/Off	Off	SD card OK
3	Off	On	GPS Fix OK
4	On		Recording data
5		Blinking	GPS signal invalid

12.7 Collection of validation data

Validation of the mobile sensor data is done by comparing the data with reference data. The reference sensor can be another measuring station. In mobile measurements, the sensor correction can be determined by stationary measurement in the vicinity of the reference sensor of another station. The reading is calibrated by establishing a constant correction (difference) between the mobile sensor and the reference sensor. The reference measurement is read online, from data presented by the owner of the reference sensor.

A map of reference sensors is available at airly.org or other local national service presenting values online.

12.8 Archiving of data and export to spatial information systems

The sensor with which the information is collected saves the data on the SD card in a .txt file. The data is semicolon separated, so it is easy to import into spatial information systems or other software. A sample data file is shown in the Table 12.2.

Table 12.2. File structure - example.

```
SAT;Lat;Lgn;alt_amsl;spd_kph;Date;Time;Press;Hum%;Temp.C;PM2.5;PM10
12;54.339680;18.360588;113.50;0.05;2019/5/30;20:4:31;1009.13;49.79;19.98;11.50;30.00
12;54.339680;18.360588;113.70;0.09;2019/5/30;20:4:32;1009.16;49.69;19.99;11.50;30.60
12;54.339680;18.360588;113.90;0.17;2019/5/30;20:4:33;1009.12;49.59;19.99;11.50;31.00
12;54.339680;18.360588;114.20;0.04;2019/5/30;20:4:34;1009.14;49.50;20.00;11.50;30.80
12;54.339680;18.360588;114.50;0.10;2019/5/30;20:4:35;1009.13;49.41;20.01;11.50;33.30
12;54.339680;18.360588;114.90;0.10;2019/5/30;20:4:36;1009.14;49.31;20.02;11.60;35.10
12;54.339680;18.360588;115.20;0.08;2019/5/30;20:4:37;1009.12;49.22;20.02;11.70;35.70
12;54.339676;18.360588;115.50;0.03;2019/5/30;20:4:38;1009.14;49.14;20.04;11.80;36.20
12;54.339676;18.360588;115.70;0.39;2019/5/30;20:4:39;1009.12;49.10;20.03;11.70;35.20
12;54.339668;18.360592;115.70;2.53;2019/5/30;20:4:40;1009.14;49.03;20.05;11.70;35.60
```

The data in the file is sorted into appropriate columns. The Table 12.3 shows the meaning of each column.

Table 12.3. Data description.

SAT	number of visible GNSS satellites
Lat	latitude according to WGS 84
Lgn	longitude according to WGS 84
alt_amsl	ellipsoidal altitude
spd_kph	speed in km/h
Date	measurement date
Time	measurement time
Press	atmospheric pressure
Hum%	humidity
Temp.C	air temperature
PM2.5	particulate matter 2.5
PM10	particulate matter 10

Archiving data involves placing the file in a new, created directory on your computer or on a dedicated server. Change the name of the file to a new one, starting with the name of the region and the date of measurement.

In order to import data into a spatial information system add new layer based on text delimited data. In QGIS software it is a place in menu Layer→Add Layer→Text Delimited Layer.

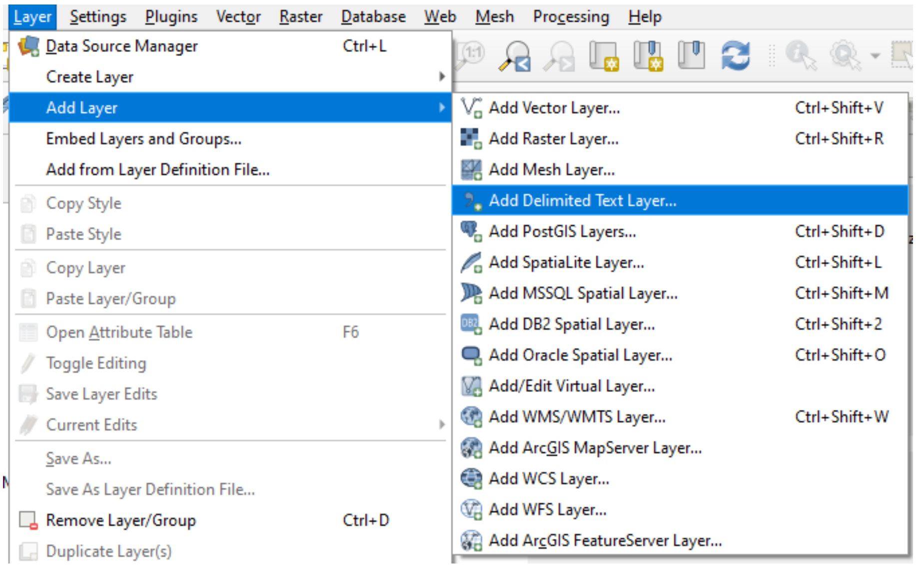

Figure 12.5. Adding new layer based on delimited text file.

This function will open a window (Figure 12.6) where we can set all the relevant data for import. If you are not familiar with QGIS, later in this manual you will find a link to a video showing in detail all the steps, i.e. how to import data and display it.

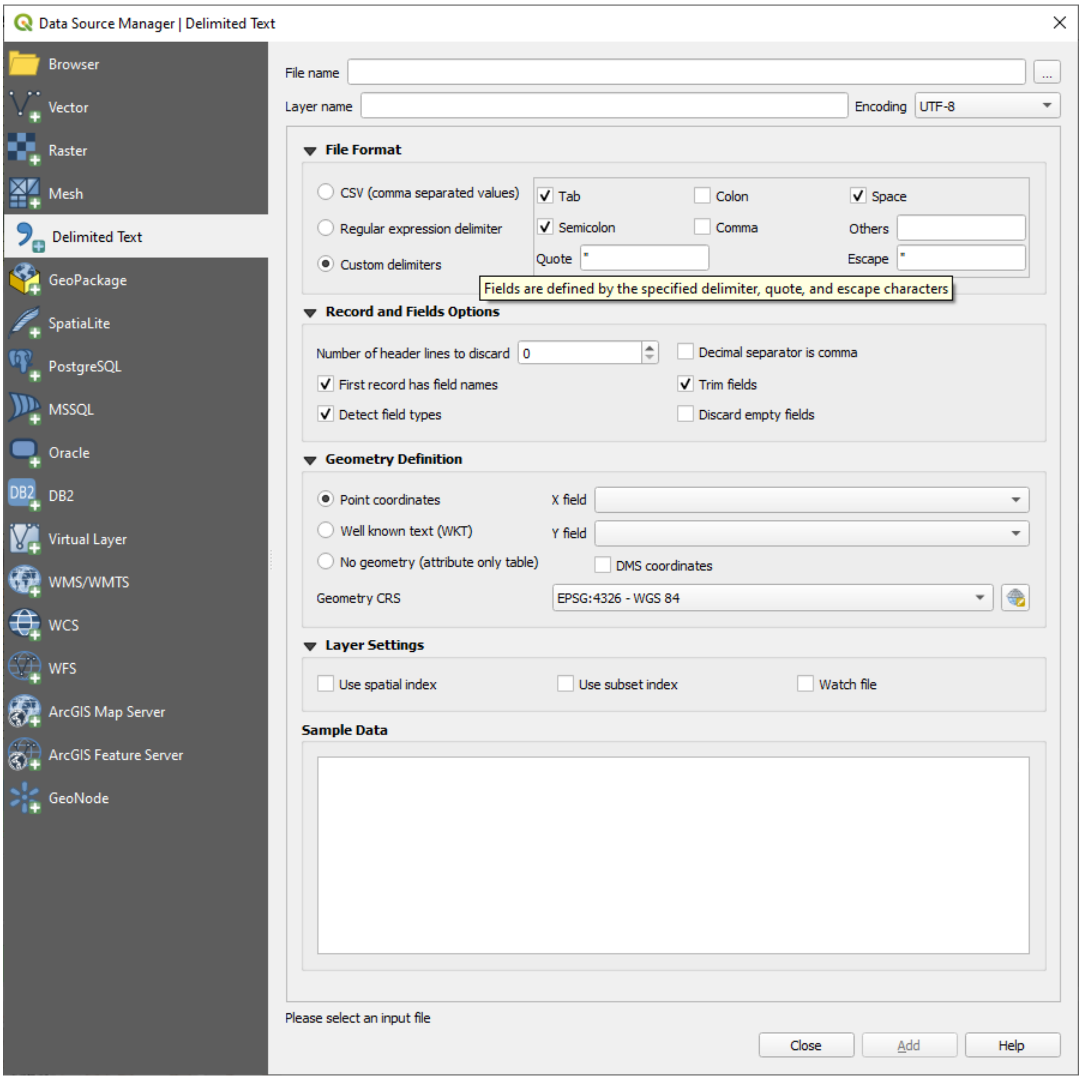

Figure 12.6. Data importing window - QGIS Data Source Manager Delimited Text.

12.9 Development of maps and visualization

The use of geo-information software makes it possible to perform visualization of measurement data, and helps in their interpretation. Pollution data taken by the sensor are recorded along with their geographical position, which makes it possible to display them in GIS software. The data are collected in points, so when working in GIS, it is necessary to interpolate them for a selected region.

The Inverse Distance Weighting (IDW) interpolation algorithm can be used to interpolate the data. A simple explanation of the algorithm can be found at (https://gisgeography.com/inverse-distance-weighting-idw-interpolation/). In GIS, the algorithm interpolates the data and presents it as a raster. Therefore, during the analysis, a transformation is made from the numerical data you recorded to raster data, in the form of a *.tiff file. Raster data displayed on a map background (Figure 12.7) is a powerful source of information about the spatial distribution of pollution. Values and colors can be adjusted accordingly to meet established norms (Figure 12.8).

Figure 12.7. Raster IDW interpolation, grey scale.

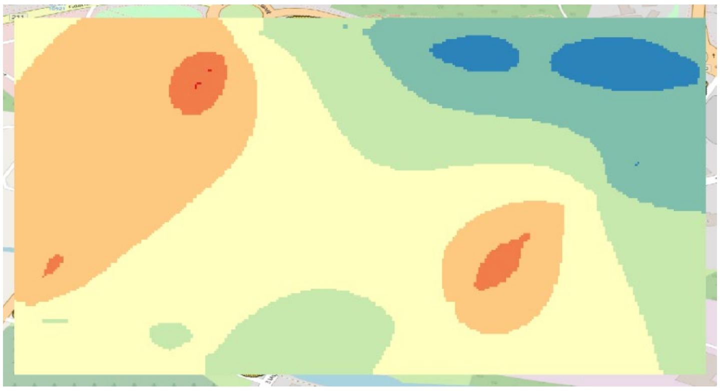

Figure 12.8. Colors and range adjusted.

The visuals and color scheme can be determined depending on the level of pollution. Based on the pollution coverage proposed in Europe for PM2.5 and PM10, the color scheme and coverage as in the Table 12.4 can be adopted.

Table 12.4. Pollutants name, range and recommended colors.

Qualitative name	Index or sub-index	Pollutant (hourly) concentration in μg/m³	
		PM_{10}	$PM_{2.5}$ (optional)
Very low	0–25	0–25	0–15
Low	25–50	25–50	15–30
Medium	50–75	50–90	30–55
High	75–100	90–180	55–110
Very high	>100	>180	>110

At the current stage, the data visualisation is developed based on QGIS software. QGIS software is a free and open source geographic information system. Can be downloaded and installed form the web page: https://qgis.org/en/site/.

The video tutorial for development of maps and visualization using QGIS Software and data collected by the sensor is available at: https://youtu.be/sg_uH6lFxpk.

12.10 Final results description

For the presentation of the methodology you can use the Drones measurements presentation.pptx. During measurements, the results will be collected using sensors and send the results to the Climate Scan database. Students should prepare a full report of data collection and data analysis. Report should include analysis of weather conditions and area description and collected data. The last step should include conclusions and summing up regarding the visualization of the results. For the knowledge income verification use the Drones measurement pre-post test to print.doc.

12.11 External materials

See: https://impetus.aau.at/outputs/

Folder: Drones measurements

- Drones measurements instruction.pdf
- Drones measurements pre-post test to print.doc
- Drones measurements pre-post test key.doc
- Drones measurements presentation.pptx

12.12 Literature

Air quality guidelines for Europe World Health Organization. Regional Office for Europe. (2000): https://apps.who.int/iris/handle/10665/107335.

CAQI Air quality index – Comparing Urban Air Quality across Borders – 2012" Common Information to European Air (2012-07-09): https://www.airqualitynow.eu/download/CITEAIR-Comparing_Urban_Air_Quality_across_Borders.pdf.