ESPON

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CASE STUDY REPORT //

SOPOT

Poland

Case Study Report // January 2026

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Abbreviations

EAFRD	European Agricultural Fund for Rural Development
EEA	European Environmental Agency
ESS	Ecosystem Services
ERDF	European Regional Development Fund
EU	European Union
GI	Green infrastructure
GCP	Greening Cities Partnership of the Urban Agenda for the European Union
JRC	Joint Research Centre
KPM 2030	National Urban Policy 2030
KPZK 2030	National Spatial Development Concept 2030
KRK 2050	National Development Concept 2050
MAP	Adaptation Plan of the City of Sopot to Climate Change up to 2030
MPZP	Local spatial development plans
MPZP Studium	Study of conditions and directions of spatial development of the city of Sopot
KSRR 2030	National Strategy for Regional Development 2030
PEP 2030	National Environmental Policy 2030
PZPWP 2030	Spatial Development Plan of the Pomeranian Voivodeship 2030
SOM GGS	Strategy of the Gdańsk-Gdynia-Sopot Metropolitan Area until 2030
SOR 2030	Strategy for Responsible Development to 2020 (with a perspective to 2030)
TPK	Trójmiejski Park Krajobrazowy
LAU	Local Administrative Unit
CLMS	Copernicus Land Monitoring Service
SHC	Stakeholder Consultation
LULC	Land use/land cover
CN	Curve Number

ESPON GILL Project

ESPON GILL responds to the content outlined in the GCP Action Plan and indirectly supports other actions in the plan. The project has supported the six committed territories in the development, delivery, and implementation of the ESPON GILL Methodology, which is intended to be transferable and applicable to other regions across Europe. The task consists of multiple consultation and interaction, where the case studies teams were able not only to provide access to local knowledge, relevant documents, and data, but also to share their insights, pro-vide guidance, compare their progress, and consequently to apply the method in their policy processes.

The contributions of the case studies in setting the scene, identifying needs, providing data, and validating the methodology were essential to the success of ESPON GILL. However, **it is important to note that the inputs provided by the participating municipalities – expressed in form of analysis, expectations, or preferences – do not constitute any formal commitment. The information shared is not legally binding in any way.**

Their involvement is aimed exclusively at validating the methodology and providing insights for its improvement by testing it in a real-world environment. This approach ensures that the ESPON GILL Methodology becomes as useful and relevant as possible for any municipality wishing to apply it in its own territory.

The municipalities designated as the Six ESPON GILL Case Studies are: Târgu Mureș (RO), Roeselare (BE), Tampere (FI), Imola (IT), Jastrebarsko (HR) and Sopot (PO).

This report focuses on Sopot, Poland.

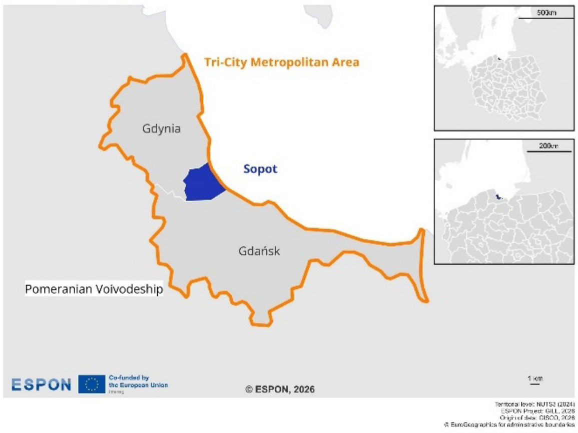
1 Sopot: general overview

1.1 Context

The city of Sopot is in northern Poland, in the Baltic Sea. Administratively, it belongs to the Pomeranian Voivodeship. It is part of the Tri-City metropolitan area, together with Gdansk and Gdynia. The city has a population of 31 440 inhabitants (2024), which has been steadily declining since the early 2000s (from 42 350 inhabitants in 2001) [1]. There is not official subdivision of the city into districts.

As shown in Map 1 The city is surrounded by:

- Gdańsk to the southeast / east of Sopot
- Gdynia to the north
- The Baltic Sea to the East, with around 4.5 km of coastline
- Trójmiejski Park Krajobrazowy (TPK) to the southwest, a protected area of nearly 199 km² that covers forested landscapes across Gdańsk, Gdynia, and Sopot. It was created in 1979 to preserve the natural, historical, and cultural values of the landscape. This area provides ecological functions (water retention, soil protection, and biodiversity conservation) and offers recreational and health benefits to residents. Sopot administers around 200 ha of forest areas, most of which is part of the park. Urban development is limited in these protected areas to maintain their natural character, and the city administration aims to establish formally a nature reserve, "Lasy Sopockie" [2] to strengthen protection of these valuable green areas.



Map 1 - The Tri-City Region

As part of the Tri-City metropolitan area there is a strong interplay of urban development and natural / protected forest, as illustrated by the Metropolitan Strategy 2030 (SOM GGS - Strategia Obszaru Metropolitalnego Gdańsk-Gdynia-Sopot) [3].

1.2 Green Infrastructure – Policy Overview

1.2.1 National Planning Framework for Green Infrastructure

Poland does not have a single, dedicated national strategy for Green Infrastructure (GI). Instead, GI principles are embedded across a range of strategic planning and environmental policy documents, guided by the EU 2013 Green Infrastructure Strategy [4]. The National Spatial Development Concept 2030 (KPZK 2030) [5] was the most influential framework, promoting the integration of natural ecosystems, ecological corridors, and landscape protection into spatial planning. It introduced measurable indicators such as the share of open and green areas in functional urban zones and establishes the Polish Ecological Network, connecting Natura 2000

[1] Central Statistical Office Poland (GUS) - BANK DANYCH LOKALNYCH for Sopot (code 2264011) last update 29/10/2025

[2] As part of the Forest Management Plan (PUL) for 2025-2034 for the Gdańsk Forest District, currently under review site: https://www.gov.pl/web/regionalna-dyrekcja-lasow-panstwowych-w-gdansku/plan-urzadzenia-lasu-pul-na-lata-2025-2034-dla-nadlesnictwa-gdansk

[3] Obszar Metropolitalny Gdańsk-Gdynia-Sopot (2015): *Strategy of the Gdańsk-Gdynia-Sopot Metropolitan Area until 2030*

[4] European Commission (2013): *Green Infrastructure (GI) Enhancing Europe's Natural Capital*, (COM (2013) 249 final)

[5] Council of Ministers of the Republic of Poland (2011): *National Spatial Development Concept 2030 (KPZK 2030)*

sites and other protected areas. In July 2025, the National Development Concept 2050 (KRK 20250)[6] was formally adopted by the Council of Ministers, which recognises that GI is a key tool for climate change adaptation, especially in urban and metropolitan areas (specifically for flood mitigation, heat-island reduction and water retention) and it is "*becoming critical for [GI] to be recognised as a critical resource by the state legal system*"[7].

Complementary national strategies also address GI indirectly:

- The National Urban Policy 2030 (KPM 2030)[8] prioritises urban greenery and blue-green infrastructure as part of sustainable land use and climate adaptation, encouraging nature-based solutions like green roofs, facades, and rainwater retention systems.
- The National Environmental Policy 2030 (PEP 2030)[9] and Water Law[10] promote sustainable water management, flood prevention, and biodiversity enhancement through blue-green systems.
- The Strategy for Responsible Development (SOR 2030)[11] and National Strategy for Regional Development 2030 (KSRR 2030)[12] link GI with regional cohesion and resilience objectives.
- The Programme for the Conservation and Sustainable Use of Biological Diversity (2015–2020)[13] is the only document explicitly defining blue-green infrastructure, though it lacks binding legal power[14].

The spatial planning governance is multi-level but fragmented. The Act on Spatial Planning and Development[15] (2003) delegates implementation to municipalities, making local spatial development plans (*Miejscowy Plan Zagospodarowania Przestrzennego - MPZP*) the key legally binding tool for GI deployment. National and regional authorities provide coordination and EU funding alignment (ERDF, EAFRD), while scientific institutions and NGOs increasingly shape policy and practice through research and advocacy[16].

GI principles are reflected across multiple sectors (spatial planning, water management, transport, agriculture, forestry, and climate adaptation) though integration in health, finance, or cultural heritage sectors remains limited[17]. Data accessibility and GIS-based tools provided by the General Directorate for Environmental Protection support planning, but inconsistencies in data quality, definitions, and scale continue to hinder coherent implementation.

Overall, Poland's GI framework relies on a multi-policy, cross-sectoral approach, supported by EU directives and funding instruments, but constrained by fragmented legal bases and decentralised responsibilities. As recognised by the newly adopted KRK 2050, the challenge ahead lies in strengthening coordination between

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[6] Council of Ministers of the Republic of Poland (2025): *National Development Concept 2050 (KRK 2050)*

[7] Idem p.37 in English version (Retrieved from https://www.gov.pl/web/funds-regional-policy/national-development-concept-2050)

[8] Council of Ministers of the Republic of Poland (2022): *National Urban Policy 2030 (KPM 2030)*

[9] Council of Ministers of the Republic of Poland (2019): *National Environmental Policy 2030 (PEP 2030)*

[10] *Act of 20 July 2017 on Water Law*

[11] Council of Ministers of the Republic of Poland (2017): *Strategy for Responsible Development to 2020 (with a perspective to 2030) (SOR 2030)*

[12] Council of Ministers of the Republic of Poland (2019): *National Strategy for Regional Development 2030 (KSRR 2030)*

[13] Council of Ministers of the Republic of Poland (2015): *Programme for the Protection and Sustainable Use of Biodiversity along with an Action Plan for the Years 2015–2020*

[14] Antoszewski, P., et al. (2024). *Legal tools for blue-green infrastructure planning - Based on the example of Poznań (Poland).* Sustainability, 16(1), 141. https://doi.org/10.3390/su16010141

[15] Act of 27 March 2003 on Spatial Planning and Development

[16] KSRR 2030

[17] KPM 2030

national, regional, and municipal levels and embedding GI more systematically into spatial and climate planning.

1.2.2 Regional and Local Policies regarding Green Infrastructure

At the regional level, the Regional Spatial Development Plan for the Pomeranian Voivodeship 2030 (PZPWP 2030)[18] integrates GI into territorial planning by promoting ecological corridors, sustainable land use, and blue-green systems along the Baltic coast. It explicitly supports climate adaptation measures, including flood prevention and coastal protection, which are highly relevant for Sopot's low-lying urban areas. A new plan for 2050 is currently under preparation[19].

At the metropolitan scale, Sopot collaborates closely with the neighbouring cities of Gdańsk and Gdynia under the Metropolitan Strategy 2030 (SOM GGS). This joint strategy focuses on expanding blue-green infrastructure, strengthening biodiversity networks, improving air quality, and creating green corridors that connect urban parks and protected areas across the Tricity region.

At the city level, Sopot's Sustainable Development Strategy 2022-2030 (Strategia Zrównoważonego Rozwoju Sopotu)[20] aims to preserve and expand urban greenery, integrating parks, coastal green spaces, and green roofs, while promoting public participation through community-led biodiversity initiatives.

Implementation is through the Local Spatial Development Plan (Sopot MPZP) and its accompanying *Studium*[21] (MPZP Studium), which serve as the city's legally binding instruments for spatial management. The MPZP requires the integration of green spaces and sustainable drainage features in new developments, aligning land-use decisions with environmental and climate priorities. The Sopot Climate Adaptation Plan (Plan adaptacji Miasta Sopotu do zmian klimatu do roku 2030 - MAP)[22] complements these measures by linking GI development to broader resilience objectives, ensuring that nature-based solutions underpin the city's response to climate risks such as flooding, heat stress, and biodiversity loss.

A Blue-Green Infrastructure Plan was submitted for funding (ERDF) late 2024[23] to further operationalises these goals by introducing rain gardens, permeable surfaces, and retention systems to reduce urban flooding and improve water management.

1.3 Sopot Objectives on Green Infrastructure

Sopot is already a very green city, with 61,2%[24] of the area occupied by forests, parks, and lawns, more than 41 000 trees in the public domain under the direct management of the city, and 430 000 trees overall.

[18] Instytucja Samorządu Województwa Pomorskiego (2016): *Spatial Development Plan of the Pomeranian Voivodeship 2030 (PZPWP 2030)*

[19] *Resolution No. 783/LXIII/24 on the commencement of preparation of an amendment to the Spatial Development Plan of the Pomeranian Voivodeship*

[20] Rada Miasta Sopotu (2022b): *Sopot City Development Strategy 2022–2030*

[21] Rada Miasta Sopotu (2018): *Study of conditions and directions of spatial development of the city of Sopot (MPZP Studium)*

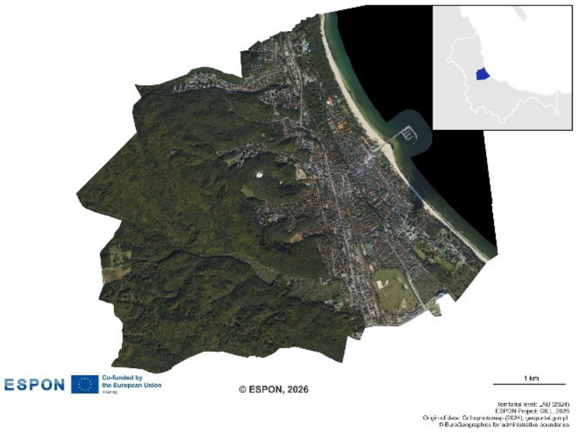
[22] Rada Miasta Sopotu (2022a). *Adaptation Plan of the City of Sopot to Climate Change up to 2030 (MAP)*

[23] Rada Miasta Sopotu. (2024). Resolution No. IX/94/2024 of 19 December 2024 on authorizing the Mayor of Sopot to submit an application for funding from the European Funds for Infrastructure, Climate and Environment 2021-2027 Programme and to accept for implementation the project entitled: "Development of the urban stormwater management system in Sopot – stage II"

[24] Rada Miasta Sopotu (2018), p. 236.

As part of Sopot's Sustainable Development Strategy 2022-2030, GI is identified as an instrument to support all three operational goals (3.1 climate neutrality, 3.2 biodiversity and 3.3 ecological safety) of Strategic Objective 3 'Foundations of the Future', with planned activities relating to:

- Improved management of natural areas (forests and coastal areas)
- Changes in the governance of the management of TPK
- New protected natural elements
- Increased water retention
- Development of new blue and green infrastructure elements



Map 2 - Orthophoto

Sopot's Climate Adaptation Plan (MAP) targets 9 specific impacts of climate change: coastal flooding, rain flooding, temperature changes (both high and low), strong winds, storm risks, water shortages and droughts, and air pollution.

The municipality also aims to mainstream biologically active areas and green areas in local spatial development plans and other planning works.

1.4 Data Context

At the national level, datasets accessible through the Polish National Geoportal provide spatial layers for as administrative boundaries, land use distribution, orthophotos, soil susceptibility to drought, soil quality, and flood risk zones. (more about granularity probably needed)

At the municipal level, the Sopot Geoportal offers detailed, up-to-date spatial information on buildings, streets, parks, and bicycle paths, which allows for fine-grained mapping of urban structures and mobility infrastructure.

This is complemented by the city's greenery management system, a dedicated digital tool that maintains an inventory of urban trees (including canopy coverage, health condition, and species composition), as well as data on streams and local topography.

The city also has a hydrological analysis dataset, which provides insight into existing water retention capacities

Socio-economic data are obtained from the Local Data Bank (Bank Danych Lokalnych), offering demographic indicators that help link environmental planning to population needs. The Gdańsk-Gdynia-Sopot Meteorological Authority provides precipitation and climate data for modelling hydrological behaviour.

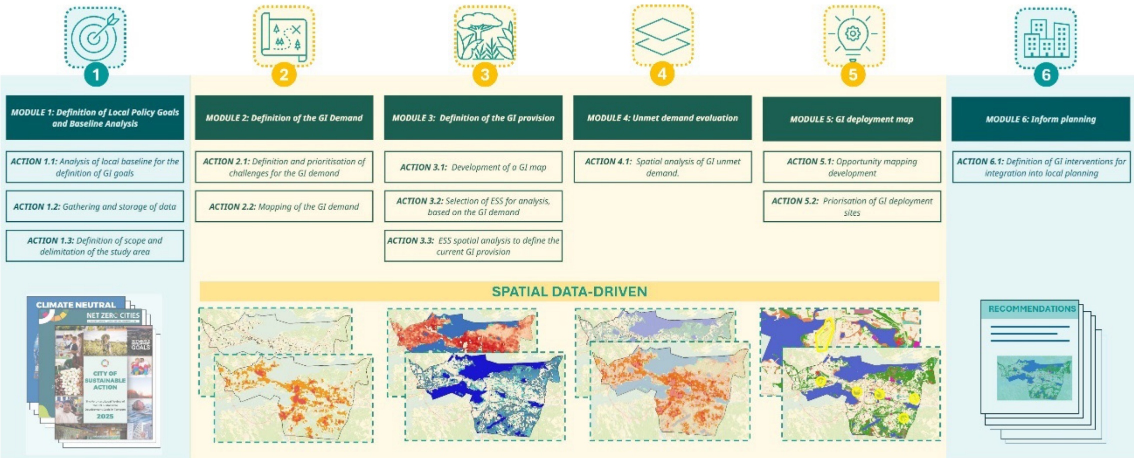
2 Implementation of ESPON-GILL Methodology in Sopot

2.1 ESPON-GILL Map of Modules

ESPON GILL project aims to develop an **evidence-based, robust, scalable, and user-friendly** **methodology to guide policymakers and practitioners in quantifying the demand for Green Infrastructure (GI) at the local level**. The **ESPON GILL Methodology** emphasises the multifunctional, interconnected, and strategically planned nature of GI, facilitating its integration into urban planning processes. It links biophysical data—such as land-use, GI delineation, and characterisation of GI components—with both quantitative and qualitative expert assessments of ecosystem services (ESS) provision and demand, while also accounting for governance and socio-economic contexts.

The methodology is organized into standalone yet interconnected modules, each addressing a key component of the methodological process (Figure 5.1). This modular structure enables users to apply the methodology either sequentially or independently, depending on local priorities, available resources, previous work, and policy objectives. Each module generates specific outputs that can inform subsequent modules, facilitate collaboration with municipal departments, and support engagement with external stakeholders and civil society.

Figure 5.1
Modules of ESPON GILL Methodology



The ESPON-GILL methodology has been applied at the city level in Sopot, where modules 1, 2, 3, and 4 were successfully implemented, enabling a comprehensive assessment of GI provision and demand. Module 5 and 6, however, could only be partially developed due to, on the one hand, challenges in collecting useful data for feasibility and opportunity assessment, and, on the other, recognised time-constraints intrinsic from the project.

2.2 MODULE 1: Definition of Local Policy Goals and Baseline Analysis)

2.2.1 Action 1.1. Analysis of local baseline for the definition of GI goals

Municipal plans and legislative instruments at both the local and national levels were identified, and their relationship with GI was assessed. These documents were also screened for objectives related to GI at the municipal level.

Methods applied / Resources used

Key documents were collected, reviewed and analysed to identify GI-related content:

- Review of National Planning Framework: Act on Spatial Planning and Development (2003), National Spatial Development Concept 2030 (KPZK 2030), Strategy for Regional Development (KSRR 2030)
- Review of sectoral policies at national level: Act on Nature Protection and Water Law (2017), 2030 National Environmental Policy (PEP2030), National Urban Policy 2030 (KPM 2030)
- Review of regional plans: Regional Spatial Development Plan for the Pomeranian Voivodeship, Metropolitan Strategy 2030 Gdańsk-Gdynia-Sopot
- Review of municipal plans: Sopot Sustainable Development Strategy, Local spatial development plans (MPZP), Climate Change Adaption Plan (MAP)

For the definition of the objectives for the ESPON GILL Sopot Case-Study, several meetings were hold with the municipality to identify which policy objectives they wanted to focus on.

Secondary sources were also reviewed to better understand the Polish context for the development of GI.

Results

GI is not directly defined in the national planning system, and the responsibility for their development lies with the municipalities (via the MPZP - Local spatial development plans)

Sectoral policies promote GBI for:

- National Environmental Policy 2030 (PEP 2030) and the Act on Nature Protection and Water Law (2017) promotes sustainable water management, rainwater retention, and flood prevention through blue-green infrastructure solutions.
- The National Urban Policy 2030 (KPM 2030) prioritizes integrating green and blue infrastructure into urban planning and sustainable land-use strategies

The concept of GI is embedded into national planning legislation without a clear national definition spelt out: it refers to the EU GI Strategy (2013) and is rather further detailed through the functions GI can provide.

In Sopot Sustainable Development Strategy, several actions target the development of GI:

- 3.2.2. Improving the management of green areas (including forests) and coastal areas (including dunes)
- 3.2.3. Change of objectives, tasks and methods of forest management in TPK
- 3.2.4. New areas and objects of nature protection (reserves, ecological sites, nature and landscape complexes and natural monuments).
- 3.2.1. Increasing the retention area of the city
- 3.3.6. New BGI elements to support ecological safety

Sopot Climate Adaptation Plan (MAP) is articulated around nine objectives:

- Overarching objective: ensure a high quality of life for Sopot residents
- Increasing resilience to coastal flooding and sea-level rise

- Increasing resilience to flash floods and torrential rains
- Increasing resilience to higher maximum temperatures
- Increasing resilience to extremely low temperatures
- Increasing resilience to strong and very strong winds
- Increasing resilience to storms and hailstorms
- Increasing resilience to water shortages in the summer
- Increasing resilience to air pollution

In bilateral consultation with the municipality, they define GBI as '*every solution using plants or based on nature that improves quality of life*', which is akin to the definition of nature-based solutions. Specifically, the municipality mentioned thermal regulation, rainwater management, adaptation and mitigation, and coastal flooding (the latter being less of an immediate concern).

A blue-green infrastructure investment plan[25] was presented to the municipal council in December 2024, which included proposed investments for:

- Daylighting of the Karlikowski stream in the square at Króla Jana Kazimierza Street
- Construction of a rain garden at the intersection of Na Wydmach and Bitwy pod Płowcami streets
- Retention analysis for the entire city

2.2.2 Action 1.2. Gathering and storage of data

This action consisted of the systematic collection, consolidation, and organization of relevant socioeconomic, biophysical, and land-use data that can be georeferenced and processed to assess the demand for GI within the municipality. The activity built upon the completed data inventory and roadmap, incorporating verified information from European, national, regional, and local sources.

Methods applied / Resources used

Information layers were gathered from EU, national and local sources.

Level	Sources
Local	• Sopot Geoportal: building footprints, cadastres, spatial plan, • Green management system: Operationally, the city has an extensive GIS-based green management tool, covering 40k+ individual trees, providing information on their species and health status, amongst other. • Hydrological analysis
National	• Polish geoportal (https://www.geoportal.gov.pl/en/data/): satellite imagery, soil data • Polish Central Statistical Office (https://stat.gov.pl/en/): population data
EU	• Copernicus Land Monitoring Service (https://land.copernicus.eu/en) : Soil imperviousness, Urban Atlas , LUISA • EEA data catalogue: WISE Freshwater data • JRC data catalogue: KIP Inca datasets

[25] Rada Miasta Sopotu. (2024)

Level	Sources
Others	• OpenStreetMap: forests, shrubs, grass, gardens, playgrounds, sports areas

Table 1 - Data sources

The sources were systematised and organised according to the following parameters: ESPON GILL Module, Source, Level, Time Series (latest), Spatial Resolution, Availability, Link, Format.

Results

A centralised GIS repository was developed, compiling a large amount of data related to the development of GI at the local level. This repository was organised into thematic categories: administrative boundaries, buildings footprints and roads, cadastre and plots, natural features and green Infrastructure, topographic data, and land use.

2.2.3 Action 1.3. Definition of scope and delimitation of the study area

This action involved the selection of specific study area(s) within the municipality, based on planning priorities, spatial relevance, and data availability. The process aimed to ensure that the chosen areas would effectively represent areas in alignment with municipal competences, planning priorities, and the ecosystem services most relevant to local challenges (particularly stormwater management and flood risk).

Methods applied / Resources used

Delimitation of the study area was carried out using a GIS-based spatial analysis, combining several datasets

- Administrative boundaries: Local Administrative Unit (LAU) boundary of the City of Sopot, as the primary legal and planning reference.
- Land-use and land-cover data to distinguish built-up areas, urban green spaces, forests, and semi-natural land.
- Planning and functional information: Local spatial development plans (MPZP)
- Stakeholder input: Initial exchanges with Sopot services to validate priorities

Solutions implemented

A two-level analytical approach (landscape and urban) was explored, using the municipal boundary as the reference frame. The analysis showed that:

- more than 50% of Sopot's municipal territory is covered by forested areas, forming part of larger natural system (the TPK)
- the forest areas, while crucial for ecosystem services at the landscape level, are not the primary focus of Sopot municipal intervention in relation to stormwater management and flash flood risk,
- the forest areas in some cases fall outside direct municipal management competences

Therefore, the decision was made to focus the ESPON GILL Methodology application on the urban core, where:

- flood risk from heavy rainfall and run-offs is most acute
- GI can be directly planned and implemented by the municipality
- Interactions between grey infrastructure are most pronounced.

Within the urban core, attention needs to pay to the "green fingers" structure of Sopot (linear green and blue elements connecting forested hinterlands to the coastal zone, often with elevation differences), which play a role in water regulation, ecological connectivity, and urban cooling.

Results

The urban study area was delineated in GIS, based on land-use and satellite imagery.

The analysis of unmet demand (module 4), the opportunity mapping (module 5) and the mainstreaming in planning (module 6) is to be conducted primarily at the urban level, with the broader landscape context (within the administrative boundaries) used for GI demand (module 2 and 4).

2.3 MODULE 2: Definition of the GI Demand

2.3.1 Action 2.1. Definition and prioritisation of challenges for the GI Demand

Through this action the main challenges to be addressed through GI were defined. These challenges serve as a framework for identifying priority areas where GI can generate the highest environmental and social benefits. Furthermore, they provide guidance for the development of targeted actions and the assessment of potential impacts at the urban scale.

Methods applied / Resources used

- Desk-based review of policy and strategic documents, including MAP, MZPZ, Sopot Sustainable Development Strategy 2030 to identify officially recognised challenges and priorities related to GI.
- Second Stakeholder Consultation (SHC2), organised using an interactive MIRO board, where the municipality identified and discussed urban and environmental challenges
- Bilateral follow-up meetings with the case study municipality, to confirm priorities and feasibility
- Cross-reference to available data compiled in the repository (Action 1.2) to assess which challenges could be supported by existing or feasible-to-develop datasets.

Solutions implemented

An initial list of GI-relevant trigger questions was presented to stakeholders during SHC2 to identify most important challenges and the municipality was invited to prioritise them.

The ESPON GILL team initially proposed a focus on urban heat island (UHI) effects and coastal flooding, based on regional climate risks and European policy priorities.

However, the municipality indicated (both during SHC2 and a subsequent bilateral exchange) that pluvial flooding caused by heavy rainfall represents the most immediate and pressing challenge for Sopot.

The municipality was able to provide hydrological analyses to support the ESPON GILL Methodology.

Results

Rainwater management and water retention were selected as the primary challenge for defining GI demand. This priority reflects Sopot's urban morphology (steep topography, soil sealing patterns), and the concentration of damage caused by intense rainfall events rather than coastal flooding.

The aligns with the priorities of Sopot:

- climate change adaptation
- blue–green infrastructure development for stormwater management,
- Environmental quality improvement

The availability of hydrological analyses, spatial datasets on drainage systems and green areas, further confirmed the feasibility of defining and quantifying GI demand related to water retention.

2.3.2 Action 2.2. Mapping of the GI demand

Methods applied / Resources used.

To identify and spatially characterise the demand in relation to the challenge identified in Action 2.1, a multi-source and multi-scale analytical approach was implemented, combining desk research, local hydrological datasets, national and European geospatial data, and spatial analysis in GIS to map observed events and structural susceptibility factors:

- Desk research: identification of recent flood events in the news and identification of areas referenced under the Floods Directive (if relevant)
- Data provided by the Municipality of Sopot: hydrographic areas, hydrography polylines and sub-catchment areas (with average elevation, delta elevation)
- Data from Polish Geoportal: DEM 2024
- Data from Copernicus: soil imperviousness

Solutions implemented

Desk Research

Flood events in local news

A desk-based review of local news sources was conducted to identify recent rainfall and flooding events affecting Sopot between 2015 and 2024. This qualitative screening aimed to locate areas affected by intense rainfall.

Two main types of events were identified:

- June 2019[26] night storms, during which intense rainfall caused local flooding across the city. Reports highlighted the combined effect of heavy precipitation and coastal backflow (*cofka*), leading to overtopping of streams temporary flooding in low-lying urban areas.
- Heavy rainfall event in 2024[27], during which floodwaters were reported along several key streets.

Based on these sources, specific locations of reported flooding were georeferenced and digitised as a new point layer ("flood sites"), including:

- flooded railway underpass at Wejherowska Street
- overflow of Potok Kamienny near Powstańców Warszawy Street
- drainage issues along Mamuszki Avenue
- Floodwater clearance locations reported in 2024 (Wejherowska, Kopernika, Podjazd, Chrobrego, and Wojska Polskiego Streets)

Flood Risk Designations under the Floods Directive

Datasets developed under the EU Floods Directive were consulted, specifically the Areas of Potential Significant Flood Risk (APSFR)[28].

[26] Miasta Sopotu. (2019). *The situation in Sopot after the night's downpour (Sytuacja w Sopocie po nocnej ulewie).* Retrieved January 9, 2026, from https://www.sopot.pl/aktualnosc/7600/sytuacja-w-sopocie-po-nocnej-ulewie

[27] Zarząd Dróg i Zieleni w Sopocie. (2024, July 17). *The effects of the downpour in Sopot (Skutki ulewy w Sopocie).* Retrieved January 9, 2026, from https://zdiz.sopot.pl/skutki-ulewy-w-sopocie

[28] European Environment Agency (2025). *Floods Reference Spatial Datasets reported under Floods Directive - version 3.0, Mar. 2025.* https://sdi.eea.europa.eu/catalogue/srv/api/records/f0606e9f-0ce2-4c1b-93b0-0af0ce0725e4

The review confirmed that Sopot is included within designated flood risk areas (three polygons intersect the study area with two related to coastal flooding and one associated with the Swelinia River catchment), confirming the role of coastal backflow and identifying the Swelinia River catchment as a flood-prone (the later lies in the north of Sopot, at the administrative border with Gdynia.

Analysis of Hydrological and Topographic Data

Using the hydrographic data provided by the Municipality of Sopot and a high-resolution Digital Elevation Model (DEM 2024) obtained from the Polish Geoportal, the following was conducted:

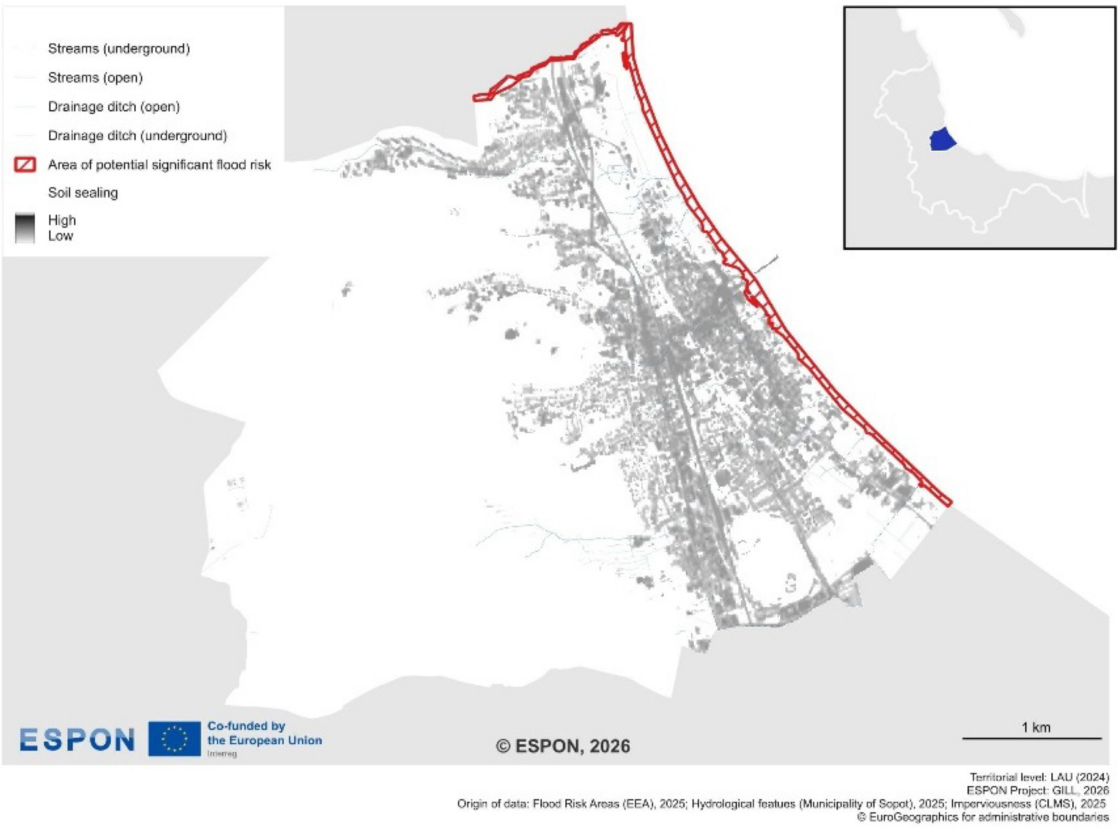
- identify elevation gradients, slope patterns, and low-lying areas prone to water accumulation
- average elevation and elevation difference to characterise the potential for rapid runoff concentration
- map the existing water / drainage / retention system

Assessment of Soil Sealing and Imperviousness

To capture the role of urbanisation in the demand, soil imperviousness data from Copernicus were integrated into the analysis to:

- map the spatial distribution of impervious surfaces across Sopot
- identify areas with high sealing intensity, where rainfall is more likely to generate immediate runoff
- overlay imperviousness patterns with sub-catchments, flow paths, and reported flood locations

These steps provided a terrain-based understanding of where rainfall is likely to concentrate and how surface water is routed through the urban landscape (Map 3).



Map 3 - Soil sealing and flood risk

Results

Key streams / catchment areas

Role of several surface water systems in flood events:

- terrain analysis indicates that surface runoff generated in upstream catchment areas converges toward the Karlikowski Stream (steep elevation gradients and a dense urban fabric, which limits infiltration and accelerates surface flow)
- Potok Kamienny is a critical drainage axis: overtopping of this stream has contributed to localized flooding
- Potok Elizi and Kuznicky, that flow directly through the dense urban core
- Swelinia catchment as flood prone

Influence of Coastal Backflow

In addition to inland runoff processes, research indicates possible strong interaction between surface runoff and coastal dynamics. Areas near the coastline are subject to coastal backflow effects, where elevated sea levels during storm conditions reduce the capacity of streams to discharge into the sea.

This backflow mechanism in Sopot lower coastal terrace can exacerbates flooding risk by:

- Slowing or temporarily reversing stream discharge,
- Increasing water levels in downstream stream sections,

The lower coastal terrace as a stormwater accumulation zone

This zone combines:

- low elevation,
- reduced drainage capacity during flooding events, exacerbated by coastal backflow
- high levels of soil imperviousness

Elevation and spatial distribution of observed events

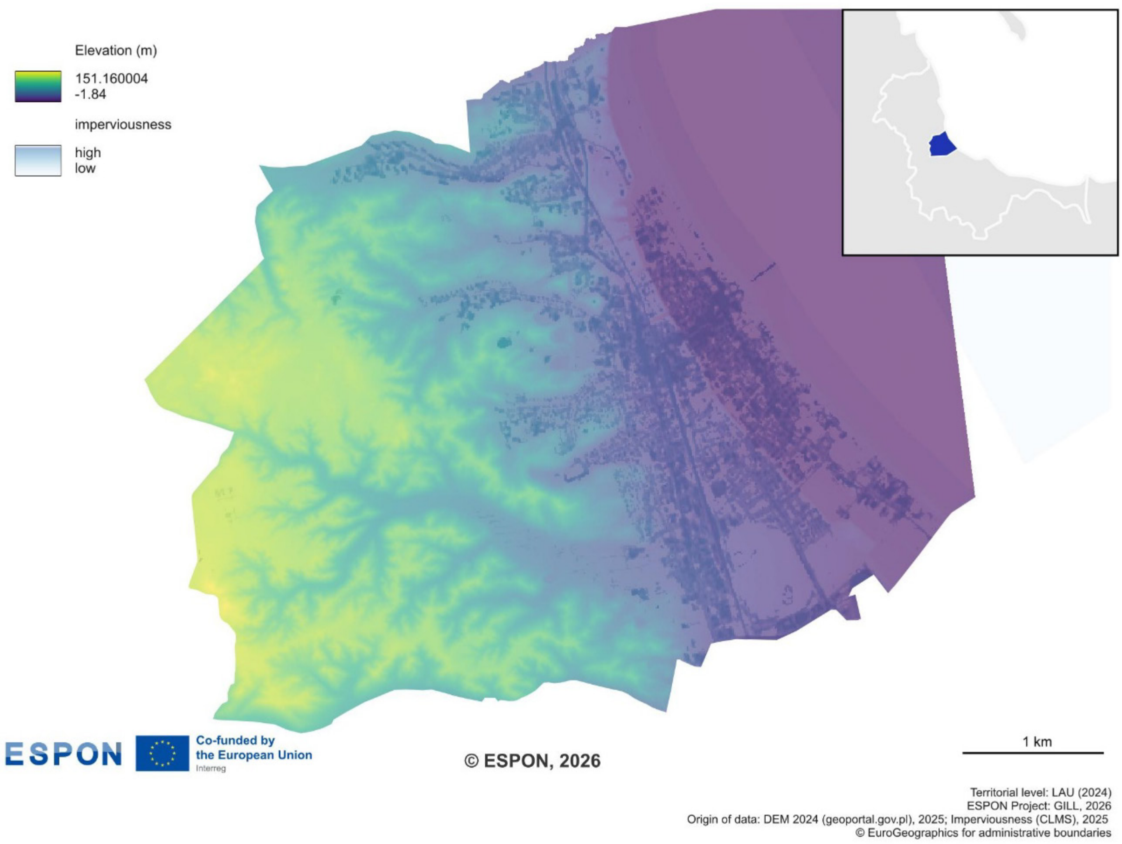
Areas with the highest differences between maximum and minimum elevation (ΔH) are systematically associated with accelerated surface runoff: in Sopot the water flows downslope toward the coast following natural gradients (Map 4).

Consequently, runoff is directed towards the railway lines and major roads.

Reported flood locations are concentrated:

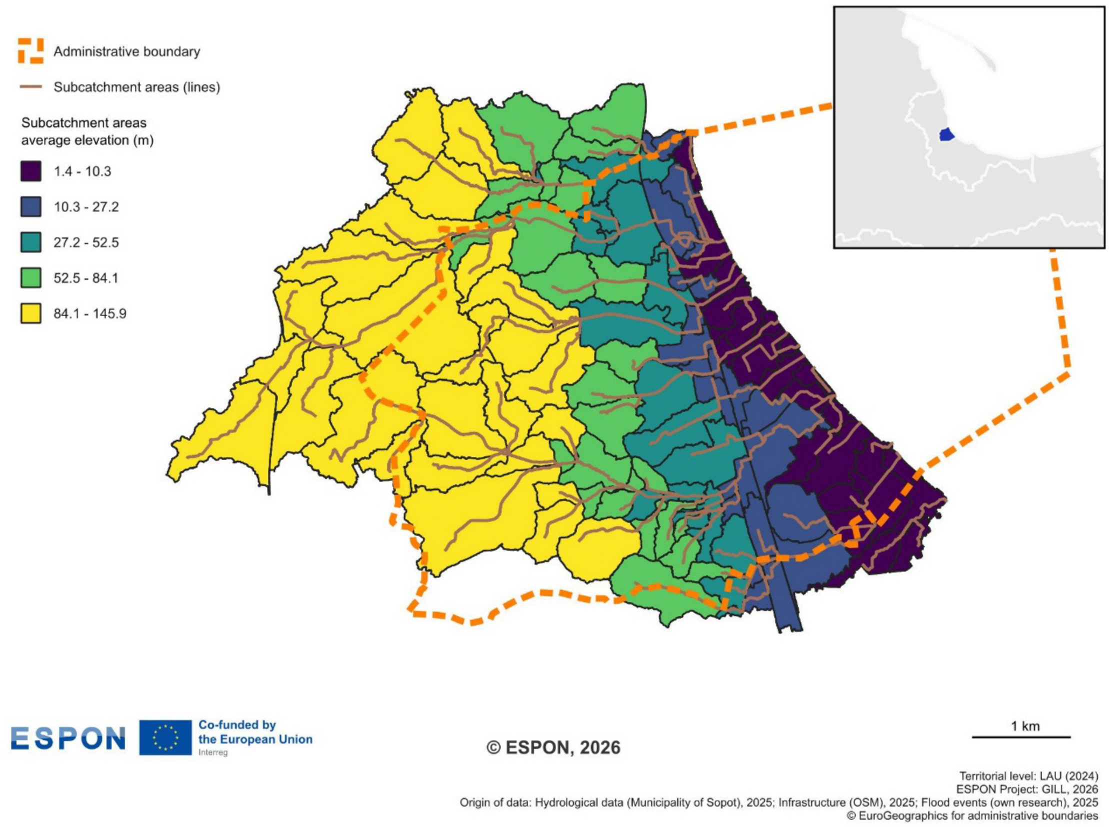
- Along major transport corridors, including railway underpasses and main roads,
- In the lower coastal terrace

These locations correspond to areas where surface runoff can be channelled by infrastructure, with a potential role of linear urban features (railways, roads) in flow paths.



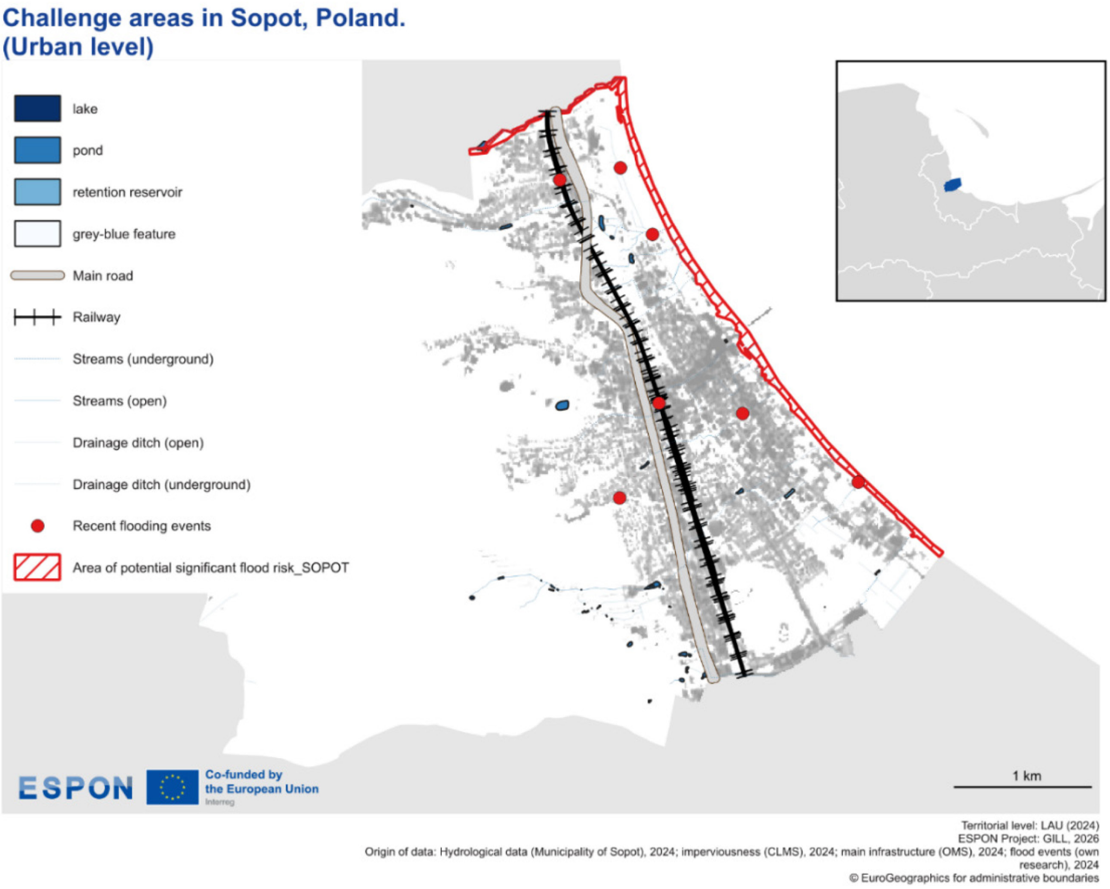
Map 4 - Elevation gradient and soil sealing

Flood risk in the study area is driven by the interaction between **upstream surface runoff processes** and **downstream coastal constraints**. Terrain and catchment analyses show that surface runoff generated in **upstream catchment areas with** steep slopes converges towards key streams and the urban core (Map 5). These upstream areas could benefit from measures aim to **reduce runoff volumes and flow velocity** before water reaches the lower coastal terrace, where flooding occurs.



Map 5 - Elevation of catchment areas

In this downstream zone, interventions could focus on **increasing water retention and temporary storage capacity** to manage peak flows and mitigate flooding impacts. These findings highlight the need for a **catchment-based approach**, targeting upstream areas to limit runoff generation and downstream coastal zones to enhance retention where flooding is most acute (Map 6).



Map 6 – Result Module 2: Challenge areas in Sopot, Poland

2.4 MODULE 3: Definition of the GI Provision

2.4.1 Action 3.1. Development of a GI map

Through this action, a comprehensive spatial dataset of existing GI assets for Sopot was created and standardised into a consistent typology applicable across the municipality, with the goal of assessing the current provision of GI within Sopot. This process involved identifying, collecting, harmonising, and classifying multiple spatial datasets into the GI types identified by the project.

Methods applied / Resources used

A multi-source spatial data collection and harmonisation workflow was used to map and classify GI. The methodology relied on the integration of official regional, metropolitan, local, and open-source datasets into a GIS under 1 main layer. The main methodological steps included:

- Data collection:
  - collection of spatial datasets from public geoportals: CLMS (Urban Atlas 2018 Land cover and Street tree datasets), Sopot municipal geoportal
  - integration of OpenStreetMap (OSM) as complementary data source
  - specific datasets provide by the municipality (hydrological features, tree inventory)
- Harmonisation into the pre-defined GI typologies to create the GI inventory

Solutions implemented

Due to the multi-source data approach adopted, an initial assessment based on spatial comparison between satellite imagery and the identified datasets to develop the GI inventory showed that none provided a complete or fully consistent representation of green (and blue) infrastructure in Sopot. As a result, dedicated efforts were made to integrate, harmonise, and cross-validate multiple spatial sources to produce a coherent (and policy-relevant) inventory. Specifically, the following points were given particular attention:

Integrating tree-related data

Sopot is characterised by a very high density of trees, but this was only partially captured in standard land-use and green space datasets.

- Street trees were largely absent from land-use layers
- Soil imperviousness data revealed missing geometries for non-sealed areas, especially green verges, tree alleys, and roadside greenery. This is particularly relevant for water-related ecosystem services, as soil sealing is a key determinant of stormwater runoff and infiltration capacity

The Urban Atlas "Street Tree Layer (2018)" was incorporated to better identify tree-covered areas directly connected to grey infrastructure and to distinguish them from broader urban green spaces. As does not cover forested areas, it was used primarily to refine the classification between GI types "semi-natural green spaces" and "urban green areas connected to grey infrastructure".

This improved the representation of Sopot's urban greenery, but this layer alone provides an imperfect proxy for spaces formally planned or managed as GBI. Therefore, the inventory was tested both with and without the street tree layer, to compare between a "structurally defined" GI inventory (e.g., by land-use categories) and a more functionally connected one.

Blue infrastructure and water retention focus

Given the focus on stormwater management and retention, blue infrastructure required particular attention:

- hydrological analysis and related GIS layers provided by the municipality from the Sopot hydrological analysis were used to include streams, ponds and drainage systems as linear features; only non-covered (open) watercourses were retained and buffered by 0.5 m on each side to reflect a theoretical spatial footprint and ecological function

Identification of rain gardens and retention reservoirs

These layers were cross-checked against qualitative sources, and complemented with green areas explicitly designed for water management, including rain gardens and sustainable urban drainage systems (SUDS)

- the 19 water retention reservoirs listed by the Municipal Roads and Greenery Authority (ZDiZ)[29] were manually verified (and integrated into the spatial inventory if missing)
- 4 known rain gardens listed by ZDiZ were identified and spatially validated using a combination of desk research and spatial analysis (Urban Atlas, Sopot Geoportal, or OSM data), including:
    - Rain garden at Primary School No. 1 (ul. Armii Krajowej 50–54)[30], originally classified as a formal park in Sopot spatial plan data, and reclassified to reflect its retention function

[29] Zarząd Dróg i Zieleni w Sopocie (2024). *Reservoirs and ponds (open, closed) (Zbiorniki i stawy retencyjne (otwarte, zamknięte))*. Retrieved January 9, 2026, from https://zdiz.sopot.pl/zbiorniki-o-stawy-retencyjne

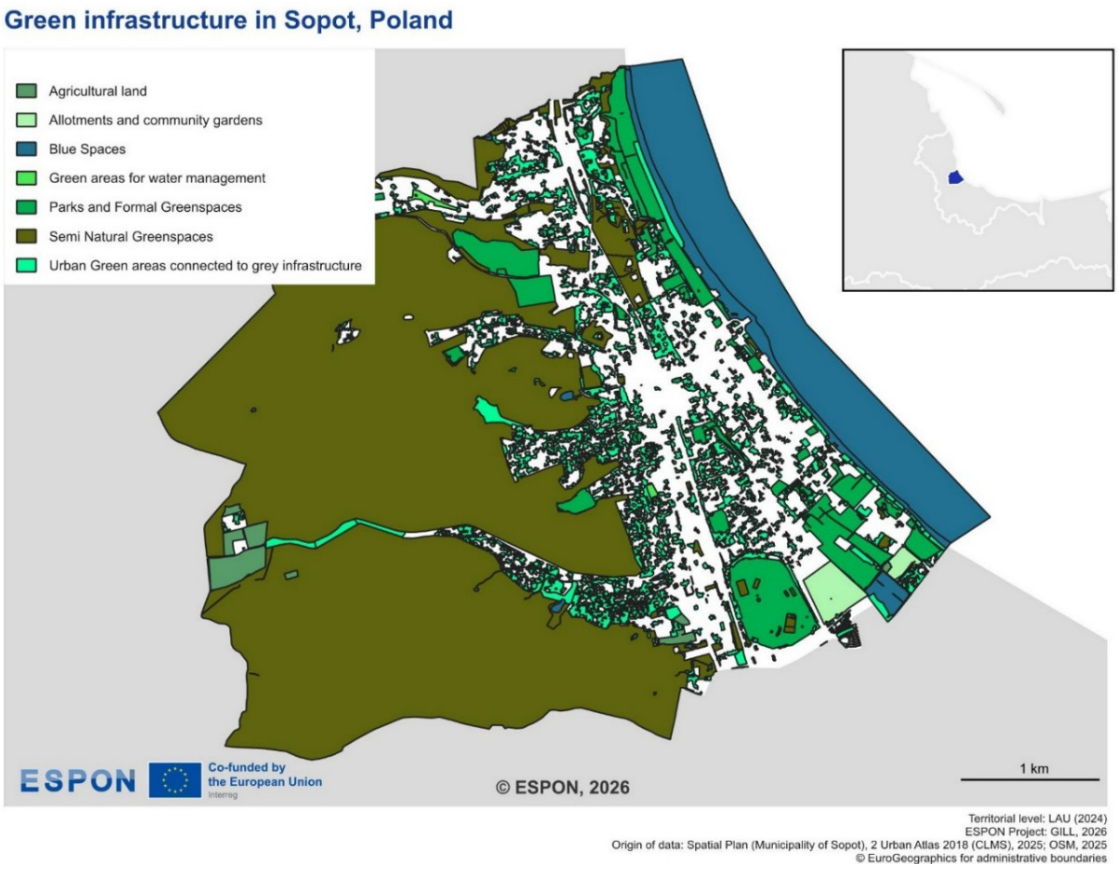
[30] Zarząd Dróg i Zieleni w Sopocie (2021). *Ecological Sopot. We're creating a rain garden (Ekologiczny Sopot. Tworzymy ogród deszczowy)*. Retrieved January 9, 2026, from https://zdiz.sopot.pl/ogrod-deszczowy-przy-sp-nr-1

- Two rain gardens Plac Przyjaciół Sopotu[31], were identified through Sopot spatial plan data (formal park) and OSM water features, with additional retention elements added manually
- Rain garden at ul. Oskara Kolberga[32], identified via OSM

This resulted in the harmonisation between the different data sources across the different GI categories and sub-categories, as detailed in Annex 1.

Results

Limit: Due to the multi-source method used to develop this inventory, there are some minor overlaps between the geometry (especially blue infrastructure provided by the Municipality overlap with Urban Atlas land-use classes such as forest) (Map 7).



Map 7 - Result Action 3.1: GI inventory for Sopot, Poland

2.4.2 Action 3.2. Selection of ESS for analysis, based on the GI demand

Following the initial data baseline assessment and the identification of spatial dimension of the challenge (in action 2.1), we consulted the EEA Areas of Potential Significant Flood Risk map and confirmed that Sopot is

[31] Lisowska, K. (2023). *The Friends of Sopot Square in a new version (Plac Przyjaciół Sopotu w nowej odsłonie).* PropertyDesign.pl. Retrieved January 19, 2026, from https://www.propertydesign.pl/architektura/104/plac_przyjaciol_sopotu_w_nowej_odslonie%2C43686.html

[32] eSopot.pt (2022). *A rain garden is being built in Sopot! It's an investment worth nearly 70,000 PLN (W Sopocie powstaje ogród deszczowy! To inwestycja za blisko 70 tys. Zł).* Retrieved January 9, 2026, from https://esopot.pl/pl/11_wiadomosci/13074_w-sopocie-powstaje-ogrod-deszczowy-to-inwestycja-za-blisko-70-tys-zl-foto-.html

not classified as being at significant flood risk, beyond coastal risk and overflow of the Swelinia to the north. An examination of the KIP INCA flood control demand dataset[33] did not indicate any unmet demand for specific flood mitigation measures in the area.

Despite the absence of major flood designations, discussions with the municipality highlighted a rainwater management issue, particularly in the case of short-duration, high-intensity rainfall events (flash storms).

Methods applied / Resources used

- Stakeholder Consultation (SHC2): the main ESS were confirmed during the second Stakeholder Consultation (SHC) using a MIRO board. Participants were also asked to prioritise these ESS.
- Expert identification of ESS relevant to GI demand

Results

For resilience to flooding, the following ESS was selected: retention.

2.4.3 Action 3.3. ESS Spatial analysis to define the current GI provision

Methods applied / Resources used

The selected ESS motivated the use of the InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) Urban Flood Risk Mitigation model, a tool to assess the role of land use and land cover in regulating surface runoff during intense rainfall events.

For a designed storm, the Urban Flood Risk Mitigation model how rainfall is retained by the landscape versus converted into surface runoff, while also accounting for soil hydrologic groups, land cover characteristics, and connected impervious surfaces.

The model outputs are raster maps that allow for the identification of areas with limited areas with high runoff potential and limited flood mitigation capacity, which is relevant for Sopot focus on resilience to flooding due to flashflood.

Solutions implemented

Data preparation followed the official InVEST Urban Flood Risk Mitigation User Guide[34]. The model requires three raster inputs: (1) a land use/land cover (LULC) raster, (2) a soil hydrologic group raster, and (3) areas of interest in a vector file, together with a biophysical table and the rainfall depth for the designed storm. The biophysical table defines how each land-use class interacts with different soil hydrologic groups through curve number (CN) values, which control runoff generation and infiltration potential.

Source: Combination of the GI inventory from Action 3.1 and UA2018 (for areas not covered by GI).

Processing:

- In QGIS, GI polygons were subtracted from UA2018 to identify non-GI areas.
- The remaining UA2018 polygons were merged with the GI layer to create a unified land use layer.
- Each polygon was assigned a LUCode based on the GI subcategory, and where absent, based on the UA2018 classification.

[33] Vallecillo, Sara, et al. (2019). *INCA - Flood Control*. European Commission, Joint Research Centre (JRC). PID: http://data.europa.eu/89h/6b805df4-ee6e-4e42-a078-e0d6c72c40f7

[34] Stanford University - Natural Capital Alliance. *Urban Flood Risk Mitigation*. Retrieved January 9, 2026, from https://naturalcapitalalliance.stanford.edu/invest/urban-flood-risk-mitigation

- During rasterization, blue infrastructure (water/ponds/streams) was given priority, ensuring accurate representation of hydrological elements[35]
- The produced raster was given a 0.5x0.5 m granularity

Limitation: A new biophysical table must be developed to reflect the hydrological properties (HSG curve) of the GI subcategories and the remaining UA2018 land use classes.

Soil Hydrologic Group Raster (Raster 2)

Source: HYSOGs250m, a globally consistent, gridded dataset produced by NASA of hydrologic soil groups (HSGs) with a geographical resolution of 1/480 decimal degrees (projected resolution of approximately 250 m). These data were developed to support curve-number runoff modelling at regional and continental scales. Classification of HSGs was derived from soil texture classes and depth to bedrock provided by the FAO soilGrids250m system.

Processing:

- Reprojected to EPSG:2180 to match the PL coordinate system.
- Clipped to the Sopot administrative boundary.
- Raster band reclassified into 4 standard soil hydrologic groups (A–D).

Original code in HYSOGs250m raster	Soil group	Reclassed into 4 types[36]
1	A	1
2	B	2
3	C	3
4	D	4
11	A/D	4
12	B/D	4
13	C/D	4
14	A/B	2

Table 2 Reclassification in four hydrologic soil groups

- Vectorised for geometry alignment with the LULC raster (which is at a higher resolution for the study area)
- Rasterise

Limits: the HYSGOs250m data has a projected spatial resolution of 250 × 250 m. Soil data consulted through the Polish Geoportal WFS[37] does not propose finer granularity

Areas of interest

[35] For details on LUC and prioritisation, refer to Annex 1 (biophysical table)

[36] Reclassification of HSG followed InVEST User Guide: https://storage.googleapis.com/releases.naturalcapitalproject.org/invest-userguide/latest/en/data_sources.html#soil-hydrologic-groups

[37] Geportal.gov.pl: *Mapa Glebowo Rolnicza* https://mapy.geoportal.gov.pl/wss/service/pub/guest/MapaGlebowoRolnicza/MapServer/WMSServer

Subcatchment boundaries of Sopot watershed were used as the base polygons, clipped to the administrative boundaries of the Sopot, to align the hydrological framework with the defined scope of the GI inventory and the study area.

Limit: The resulting areas of interest represents only those portions of the Sopot watershed that fall within the municipal limits.

Biophysical table

Considering the land use raster was made combining the GI inventory from Action 3.1 with Urban Atlas 2018 data for areas not covered by GI, this required the creation of a custom biophysical table to reflect the hydrological behaviour of both:

- GI subcategories (e.g., rain gardens, tree meadows, green sport facilities, pocket parks)
- Non-GI UA2018 land use classes remaining after subtracting the GI polygons.

The biophysical table defines, for each land use class the curve number values (cn) for each soil hydrologic group (A–D). These were assigned by AI based on land-use imperviousness, vegetation cover, and typical hydrologic behaviour as reported in the InVEST documentation, EPA stormwater manuals, and European urban hydrology literature. Attributed values represent planning-level assumptions and were not locally calibrated.

The resulting biophysical table (Annex 2), with details land-use classes for each GI type, ensures that the model represents the diversity GI (and grey infrastructure) in Sopot, as well as the existing water retention features.

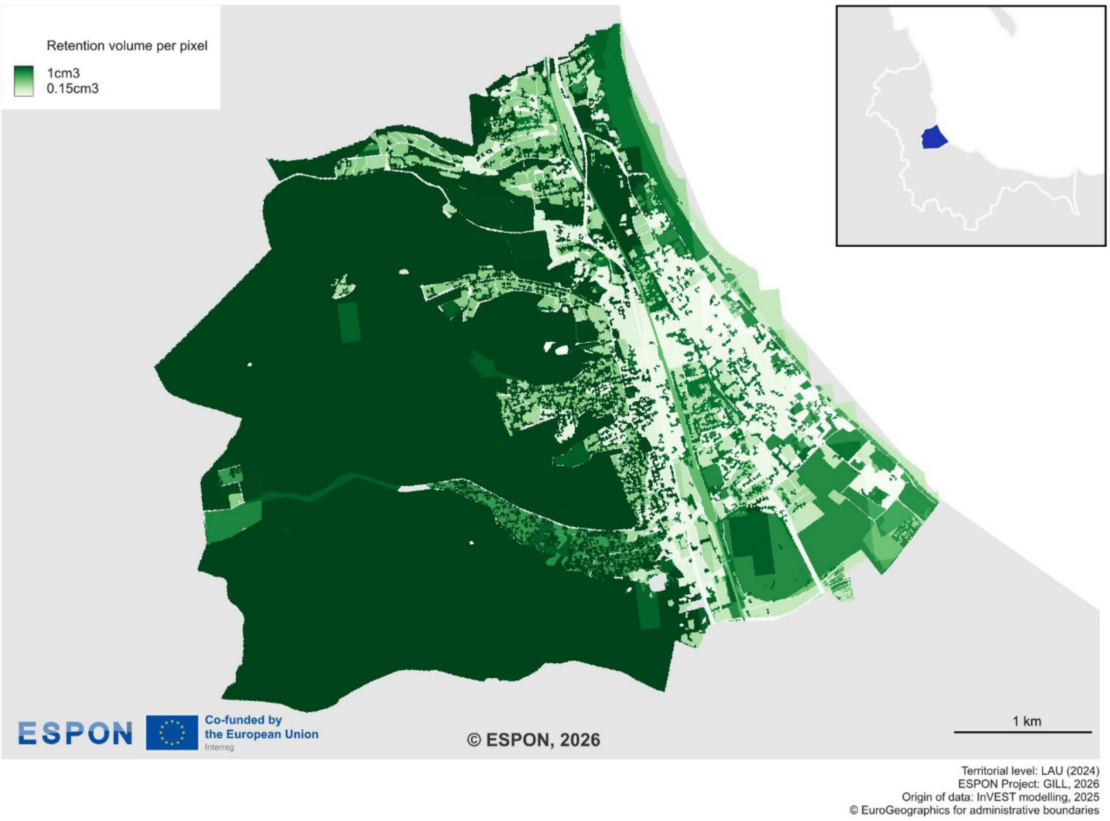
Precipitation level for the designed storm

For the precipitation input a representative extreme rainfall depth was selected based on documented local storm impacts (see Module 2), specifically, the storm event document in July 2024 with an approximate rainfall depth of 40 mm.

Results

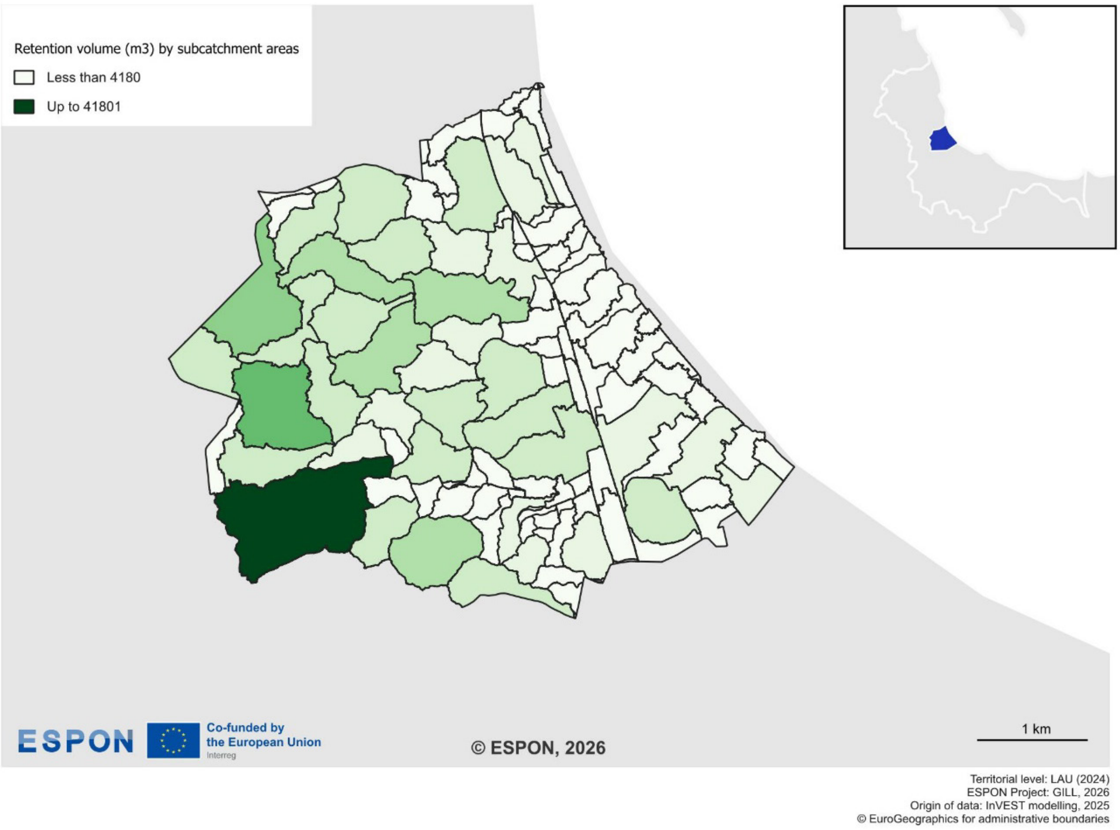
The InVEST model generated a series of spatial outputs that describe the retention of stormwater across the study area (Map 8):

- A raster with runoff retention index values (no unit, values of 0-1, relative to precipitation volume)
- A raster with runoff retention volume values (in m3)
- A raster with runoff values (mm)
- The area of interest shapefile within the attribute table:
    - average of runoff retention index values (per subcatchment area)
    - sum of runoff retention volumes in m3 (per subcatchment area)
    - flood volume in m3 (per subcatchment area)



Map 8 - ESS: retention

Limit: the ESS modelling was carried out within the administrative boundaries of Sopot, reflecting the spatial extent of the green infrastructure inventory developed in Action 3.1 (Map 9). In contrast, the hydrological catchment map provided by the Municipality cover a slightly different area (representing subcatchments draining into the Sopot water system). To ensure spatial consistency, the catchment map was clipped to the administrative boundaries of Sopot. This spatial adjustment affects the modelling results for the Swelinia stream specifically, whose subcatchment extends beyond the city limits.



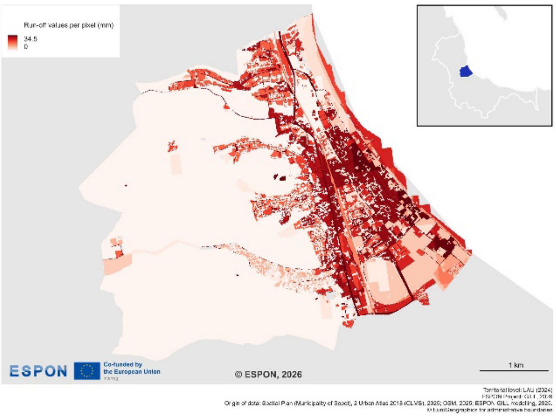
Map 9 - Result Action 3.3: ESS (retention) by subcatchment areas

2.5 Meeting demand evaluation (Module 4)

The aim of Module 4 is to identify spatial mismatches where GI demand is not fully addressed by existing GI. It provides a spatially explicit assessment of unmet demand.

2.5.1 Spatial analysis of GI unmet demand (Action 4.1)

Methods / Resources



Map 10: unmet demand (surface run-off)

The analysis of GI unmet demand focused on identifying areas where run-off exceeds the capacity to retain and infiltrate water. The main analytical input was the modelling result conducted in Module 3 using the InVEST Urban Flood Risk Mitigation model. This model also generated a spatially explicit runoff output (raster in mm per pixel, as well as aggregated by subcatchment areas in the shapefile), representing the depth or volume of surface runoff generated per pixel, accounting for land use and soil type (how much of the input rainfall (in mm) is converted to surface runoff).

These runoff outputs are effective for identifying areas with high runoff generation potential (due to low provision of retention), But run-off represents a *cumulative process* that propagates along hydrological paths. Therefore, analysing runoff solely at pixel level, or subcatchment area would not adequately reflect downstream accumulation effects. To address this, additional processing was necessary to integrate runoff outputs with the subcatchment structure of the study area.

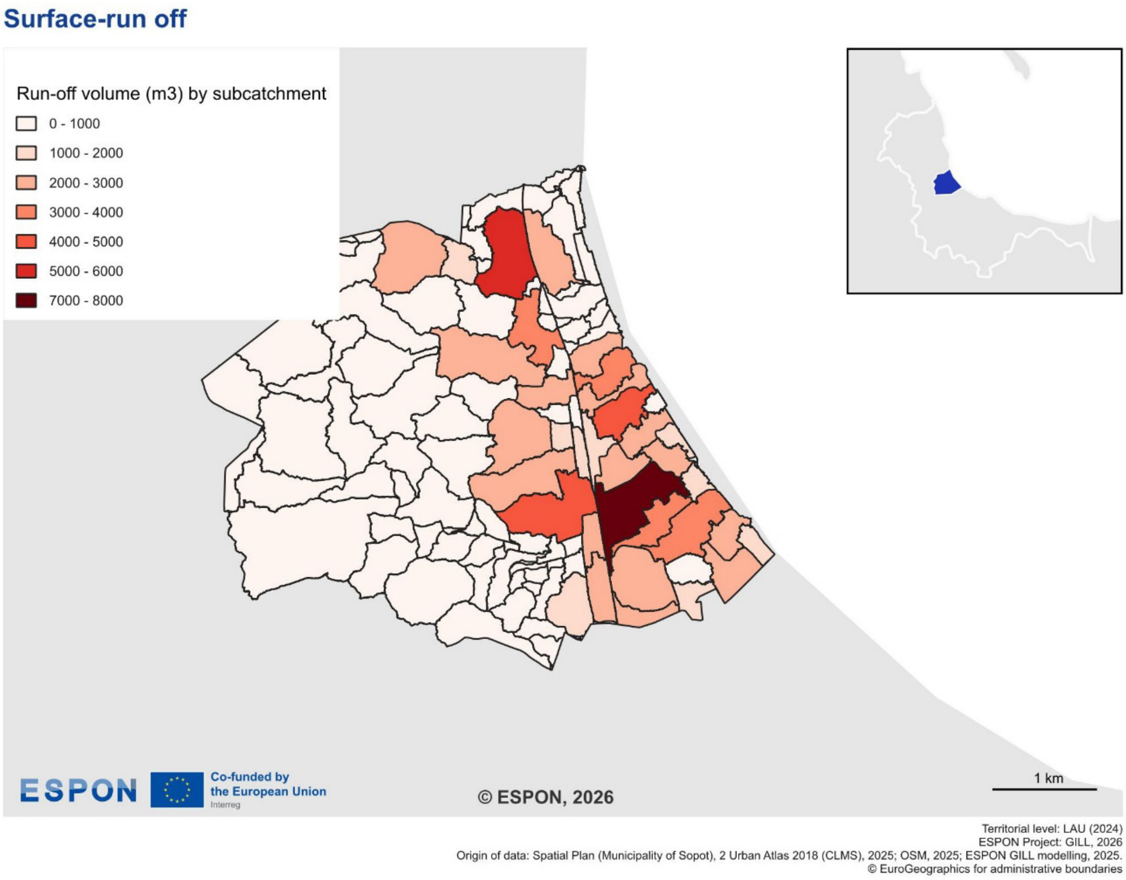
Solutions

ESS supply and demand by subcatchments

The outputs from InVEST were aggregated through zonal statistics to the hydrological subcatchment areas.

Run-off volume accumulated in subcatchments

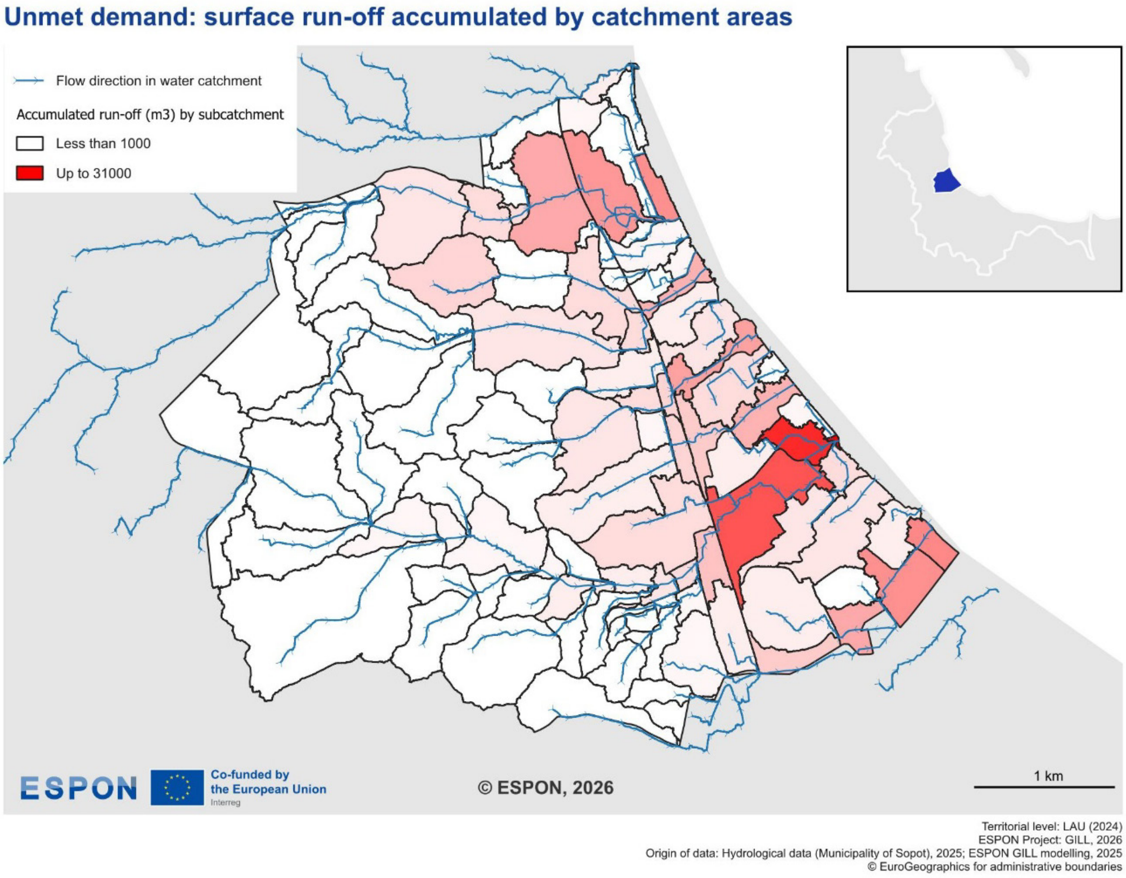
The run-off volumes by subcatchment areas were then processed through flow accumulation, summing run-off volumes within each subcatchment while respecting flow direction and stream hierarchy (Map 11). That way the runoff values per subcatchment, reflect both local runoff generation and upstream contributions following the flow order.



Map 11 - Run-off by subcatchment areas

Results

Map 12 show the identified areas where runoff generation and accumulation exceed retention capacity.



Map 12 – Result Module 4: Accumulated run-off by sub-catchment areas

2.6 MODULE 5: GI deployment map

2.6.1 Action 5.1 Opportunity mapping development (Action 5.1)

The aim is to identify areas where the deployment of green infrastructure (GI) is technically feasible and relevant to the challenge (namely stormwater runoff and flash flooding).

Methods applied / Resources used

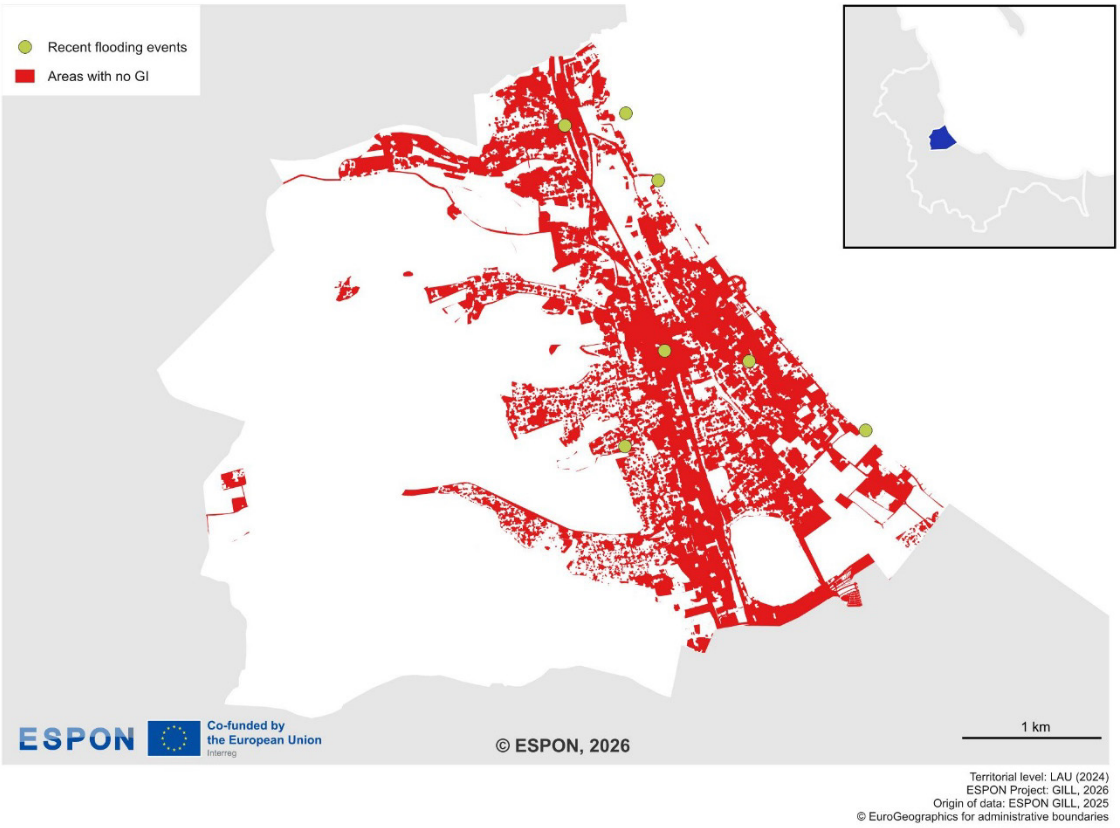
- the GI spatial inventory developed (Module 3)
- areas affected by recent flooding events and identified flood-prone zones (Module 2)
- runoff accumulation by subcatchment (Module 4)

Solutions implemented

The mapping was developed by identifying areas currently lacking GI and intersecting them with zones where stormwater-related challenges were identified: areas with no GI were extracted from the GI inventory and overlaid with the locations of recent flooding events.

Results

This produces a feasibility layer, highlighting locations where GI deployment is both physically possible (absence of existing GI) and functionally relevant (past flooding pressure) (Map 13).



Map 13 - Areas with no GI and past flooding events

2.6.2 Prioritisation according to deficit and opportunities (Action 5.2)

The prioritisation of GI deployment sites was based on the integration of unmet GI demand (Action 4.1) and the opportunity map (Action 5.1).

Methods applied / Resources used

- the opportunity map identifying GI-deficient areas in flood-prone zones (Action 5.1)
- accumulated runoff per subcatchment (Module 4)

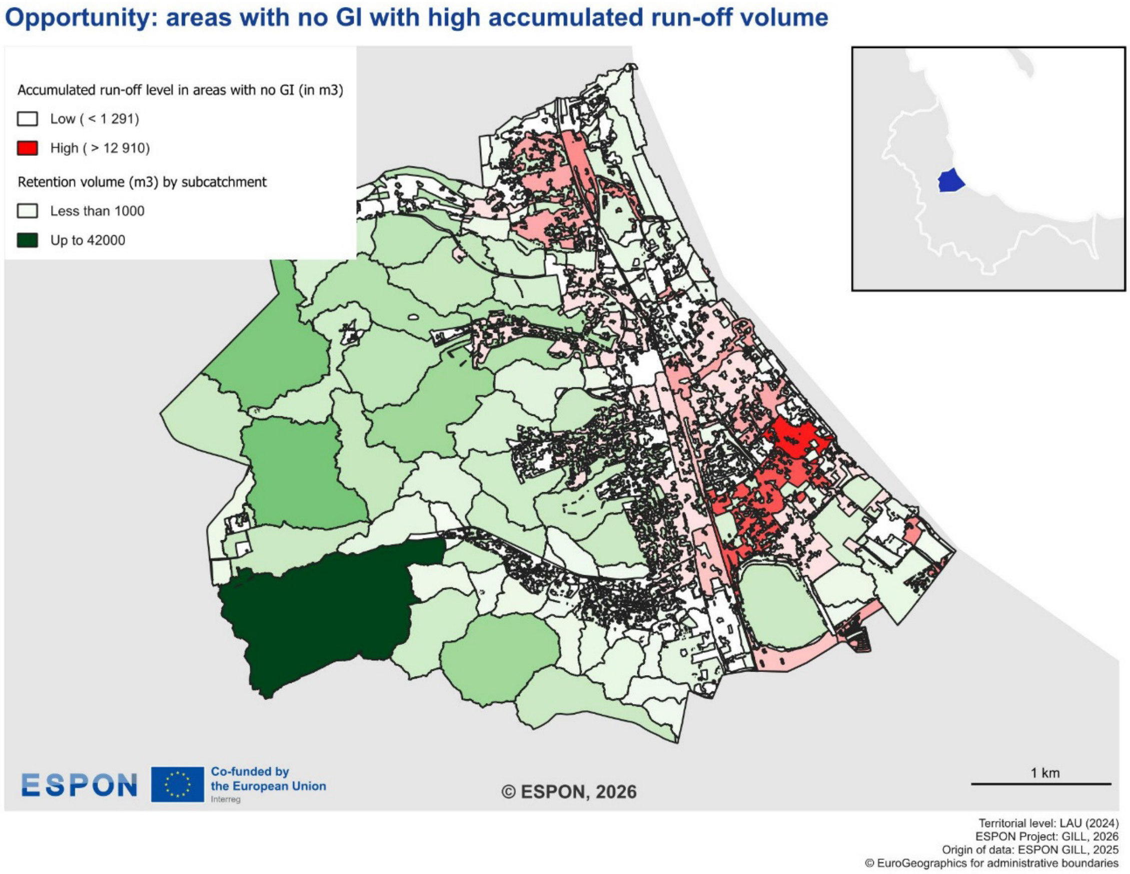
Solutions implemented

Within each subcatchment:

- areas were characterised by the level of ESS supply (relative to the run-off generation)
- areas without GI were graduated according to the accumulated runoff they contribute to, with higher runoff indicating higher priority for GI deployment.

Results

Intersecting accumulated runoff patterns with GI-deficient zones, this highlight locations where ecosystem service is needed and where GI interventions would deliver the value for flood-risk reduction (Map 14). GI deployment could focus on subcatchments with high runoff accumulation and limited existing retention capacity.



Map 14- Result Module 5: Prioritised GI deployment map, combining unmet runoff regulation demand and spatial opportunity

2.7 Inform Urban Planning (Module 6)

This case study only partially addressed this methodological module.

2.7.1 Formulate recommendations to integrate the development of GI in local planning (Action 6.1)

Methods applied / Resources used

- limited review of planned and ongoing municipal investments related to water management and green infrastructure,
- limited cross-referencing prioritised GI deployment areas (Action 5.2) with planned projects and policy objectives.

Solutions implemented

Planned projects already contributing to GI development include:

- daylighting of the Karlikowski Stream at Króla Jana Kazimierza Street (PLN 3.5 million), transforming a sealed drainage section into an open stream to improve rainwater management
- construction of a rain garden at the intersection of Na Wydmach and Bitwy pod Płowcami Streets (PLN 2 million), supporting rainwater retention and reuse

Furthermore: over the forest area: city administration aims to establish formally a nature reserve, “Lasy Sopockie”

Results

Three main catchment areas were identified as focal zones for GI integration into local planning:

- Kamienny Potok catchment,
- Karlikowski Potok catchment,
- Elizy Potok catchment.

Planning recommendations:

- upstream retention measures (rain gardens, vegetated swales, floodable green spaces) to reduce peak runoff before it reaches the urban core
- percolation and desealing strategies on the lower coastal terrace, where soil sealing contributes to rapid runoff and flooding risk

Sopot’s municipal strategy already promotes desealing and more water-sensitive street redesign: in practice, every street modernisation project includes partial desealing measures, while for areas under private ownership, GI-related requirements and recommendations are increasingly integrated into planning and permitting procedures to increase biologically active surfaces.

3 Barriers and enablers to Sopot GI development

	Enabling factors **Supportive policies, funding, and stakeholder engagement approaches that can accelerate GI adoption**	Barriers **Regulatory constraints, financial limitations, and lack of expertise that can hinder progress**
1. Institutional and organisational	• From 1 January 2026, an "integrated strategy" will be mandatory at the municipal level, which has the potential to better synchronise social, economic, and territorial elements[38] • As a spa resort city, the protection of health resort zones imposes minimum percentages for green areas (up to 65% in certain zones) for Sopot[39]	• Lack of a formal legal definition for GI and ecosystem services in Polish laws and policies, leading to inconsistent interpretations[40] [41] • Dispersed model where GI is managed under separate sectoral policies[42] • Sopot manages land under the strict protection of health resort zones[43] • In Sopot the management of local forests is split between different entities (Board of Roads and Greenery, Nadleśnictwo Gdańsk)

[38] Legutko-Kobus, P., et al. (2024). *Barriers in the green infrastructure governance in small and medium-sized cities in Poland. Economics and Environment*, 91(4), Article 900. https://doi.org/10.34659/eis.2024.91.4.900

[39] Sopot City Development Strategy 2022–2030 (2022)

[40] Legutko-Kobus, P., et al. (2024).

[41] Antoszewski, P., et al. (2024).

[42] Legutko-Kobus, P., et al. (2024)

[43] MPZP Studium

	Enabling factors **Supportive policies, funding, and stakeholder engagement approaches that can accelerate GI adoption**	Barriers **Regulatory constraints, financial limitations, and lack of expertise that can hinder progress**
2. Engagement and coordination	• KPM 2030 explicitly prioritises blue-green infrastructure and encourages Public-Private Partnerships (PPP) to manage urban resources[44] • Stakeholders can influence GI planning as part of mandated processes (for instance MPZP consultations)[45] • Participatory budgeting is important in Sopot: residents can submit and fund local greenery and small retention project[46] • Collaboration within the Gdańsk-Gdynia-Sopot Metropolitan Area for large-scale projects	• Institutional silos where city departments (infrastructure, environment, planning) have dispersed competencies and rarely collaborate effectively[47] • Participation is often treated by authorities as a legal formality rather than a genuine tool for BGI co-creation[48]
3. Political	• KPM 2030 proposes to move towards legally categorising GI as "critical infrastructure" (thus raising its status to match that of energy or transport networks for security and resilience)[49] • Sopot's political vision is of being a "green leader"[50]	• Economic investment preferred over natural capital, frequently leading to the issuance of zoning decisions (*Warunki Zabudowy* - WZ) which allow building on green areas not covered by a local spatial development plan (MPZP)[51] • Political tension is Sopot created by land scarcity[52]

[44] KPM 2030

[45] Antoszewski, P., et al. (2024)

[46] MPZP Studium

[47] Legutko-Kobus, P., et al. (2024)

[48] Antoszewski, P., et al. (2024)

[49] KPM 2030

[50] MPZP Studium

[51] Antoszewski, P., et al. (2024)

[52] MPZP Studium

	Enabling factors **Supportive policies, funding, and stakeholder engagement approaches that can accelerate GI adoption**	Barriers **Regulatory constraints, financial limitations, and lack of expertise that can hinder progress**
4. Socio-cultural	• Growing social appreciation for cultural ecosystem service (demand for GI for recreation and aesthetic well-being)[53] • High environmental awareness of residents often organising to oppose tree felling in the city and its forests[54]	• Cultural preference for "manicured" rather than natural greenery[55] • High car dependency
5. Biophysical	• Restoration of ecological corridors in specific regional plans to maintain biodiversity[56]	• Urban forests are managed as "productive" rather than ecological units, limiting their climate benefit[57]
6. Knowledge	• Sopot uses its own digital management application to monitor the condition of 380,000 trees, enabling proactive risk management against storm damage	• Lack of up-to-date inventories of natural resources at the national level[58]
7. Financial	• Funding is available via the European Funds for Infrastructure, Climate and Environment (FEnIKS) 2021–2027	• High initial costs and perceived long-term maintenance burdens are the most frequently cited financial barriers by municipal representatives[59] • Sopot has a shrinking population which creates a financial challenge for future tax revenue

[53] Zwierzchowska, I., & Stępniewska, M. (2022). *Green infrastructure and social perception of its ecosystem services within spatial structure of the city – Examples from Poznań, Poland*. In I. Misiune, V. Vasenev, & E. Dovletyarova (Eds.), Human-Nature Interactions (pp. 221–234). Springer. https://doi.org/10.1007/978-3-031-01980-7_18

[54] Sopot City Development Strategy 2022–2030 (2022)

[55] Legutko-Kobus, P., et al. (2024)

[56] PZPWP 2030

[57] Antoszewski, P., et al. (2024)

[58] Antoszewski, P., et al. (2024)

[59] Legutko-Kobus, P., et al. (2024)

4 Interactions along the project

Throughout the project, several interactions and meetings were organised with representatives from the Municipality of Sopot. Some were in a multilateral format (with other case-study representatives) where overcall project progress and context were shared, such as SHC; in other bilateral formats, the objective of was to incorporate the local perspective for the improvement or implementation of the methodology and the implementation of the case-study. Below are described the objectives, dynamics, and outcomes of each interaction with the case-study representatives from Sopot.

First bilateral meeting: 26th May 2025

During this first bilateral meeting, the participating teams were introduced, followed by a presentation of the project, definition of GI at the local level, and national definition. The conversation also touched upon planning instruments and focused on identifying suitable data sources.

For the development of the interaction, a MIRO board was used, divided into two sections: 1) Policy context and 2) Data Collection (further subdivided by date needs). The municipality provided inputs and feedback through the Miro before the summer.

Secon bilateral meeting 19th September 2025

In the second bilateral meeting, the focus was on reviewing identified data layers and presenting a possible selection of ecosystem service demand to analyse based on local challenges.

Stakeholder Consultation 2, 20th September 2025

In this exchange, the prototype of the methodology was presented and the main challenges for Sopot further discussed through a MIRO, with a focus on flooding issues.

Third bilateral meeting 2nd October 2025

Following on the SCH2 meeting, the case-study representatives confirm the focus on flooding issues and discussed with the ESPON GILL teams which data they could provide (include hydrological data).

As a next step, it was agreed that the case-study representatives would share the relevant geospatial data, which would then be integrated by the ESPON GILL team to model the relevance ESS demand (water retention)

Fourth bilateral meeting 21st January 2026

During this third bilateral meeting, the progress on the GIS implementation of the ESPON GILL methodology was presented. This included the development of GI map and the InVEST modelling of retention.

Feedback on these maps was requested through a Miro board to identify areas where adjustments was needed on some map outputs.

Additionally, a short discussion introduced Module 5 and 6, with the case-study representatives highlighting that several investments to improve retention are already planned.

Stakeholder Consultation 3, 22nd January 2026

The meeting was dedicated to presenting the ESPON GILL methodology modules, the supplementary resources, as well as outlining the overall structure of the manual and explaining its implementation across the six CSs. During the session, CS leaders shared feedback and insights gained from applying the methodology in their respective contexts. An exchange of experiences was also facilitated through a Mentimeter activity, in which participants were asked to assess the methodology's relevance, feasibility, measurability, effectiveness, and replicability. Finally, using a MIRO board focused on enablers and barriers encountered throughout the process, common challenges were identified, along with proposed improvements for future applications.

5 Results and Final Remarks

5.1 Summary of key results on GI demand

Policy context

Poland currently lacks a single, dedicated national strategy for Green Infrastructure (GI), with principles instead embedded across fragmented strategic planning and environmental documents. At the national level, the National Development Concept 2050 (KRK 2050) recently formally recognised GI as a tool for climate change adaptation and a "critical resource". Locally, Sopot's Sustainable Development Strategy 2022–2030 and its Local Spatial Development Plans (MPZP) serve as the legally binding instruments for spatial management, specifically requiring the integration of green spaces and sustainable drainage in new developments, showing a functional approach to GI development.

Challenges

Through consultation with the Municipality and historical analysis of flood events (2015–2024), pluvial flooding (flash floods) caused by heavy rainfall was identified as the most immediate and pressing challenge for Sopot. This risk is further exacerbated by the topography, where surface runoff converges from the hills toward the lower coastal terrace, and high soil sealing in the urban core. Additionally, coastal backflow during storms slows discharge, further increasing the risk of flooding on the lower coastal terrace.

GI Map

A multi-source GIS inventory was developed with data from Copernicus (Urban Atlas 2018), OpenStreetMap, and the Sopot Geoportal. Because Sopot is a very green city, with 61.2% of its area occupied by forests, parks, and lawns, no individual source sufficiently reflected this high greenery level, hence the need to compile from serval sources. A useful source was the Street Tree Layer (Urban Atlas 2018), to properly reflect the high tree number spatially, cross-checked against the local tree inventory. If updated, this resource would have potential as well for the monitoring of canopy coverage in urban ecosystems as part of the Nature Restoration Regulation.

ESS Map

InVEST Urban Stormwater Retention model was used to model Sopot's provision of retention. The modelling results, aggregated into sub-catchment units, as well as the GI inventory show high retention volumes in the forested southwest but significantly lower retention capacity within the densely built-up central and northern coastal areas. In general, InVEST is an accessible tool to model ESS and its adoption in municipal planning research could help the monitoring of urban ecosystems mandated by the Nature Restoration Regulation.

Met-Unmet Map

The unmet demand was identified by mapping accumulated surface run-off across hydrological sub-catchment. The use of datasets provided by the Municipality was critical to understanding the local water/drainage system.

Opportunity Map (hotspots)

This intersected the unmet demand with areas currently lacking GI. The insights provided by this Module is limited.

Insights on potential planning actions

Sopot is already a rather well-advanced city when it comes to green infrastructure maintenance and development. The insight from the GILL methodology to inform planning actions were therefore limited: there are plans already to develop upstream retention capacity and to support local desealing to improve percolation.

5.2 Final Remarks

A methodological takeaway is the challenge of the "moving demand": stormwater run-off is dynamic and accumulates along water catchment paths. Furthermore, the case-study demonstrated that standard land-use datasets are insufficient for understand GI at the local level; only a multi-source approach that includes high-resolution tree and stream inventories can accurately map the actual "green character" of a territory. Despite the lack of a formal legal definition of GI in Poland, Sopot has proven that local municipalities can champion nature-based solutions. The lack of national framework does not preclude from adopt a functional perspective and simply treating green and blue elements as any other infrastructure essential for improving climate safety and the high quality of life of its residents.

6 Annexes

6.1 Annex 1: Harmonisation table for the GI inventory (Action 3.1)

Key GI Category	Sub-categories	Sources: class/attributes
Agricultural land	Arable land	UA2018 class: arable land
	Tree meadow/orchard	OSM land-use class: orchard, plant nursery
	Biofuel production/agroforestry	No data found
	Grassland	UA2018 class: pasture; OSM land-use class: farmland, meadow; OSM nature class: grassland
	Horticulture	No data found
Allotments and community gardens	Allotment	No data found
	Community garden	Reclassification from specific geometry in UA2018 class: sport and leisure facilities (based on satellite imagery observation)
Blue Spaces	Sea coast	Sopot hydrological dataset class: morze; OSM nature class: beach
	Lake/pond	Sopot hydrological dataset class: jezioro, staw; OSM nature class: water;
	Wetland/bog/fen/marsh	OSM nature class: wetland; specific geometry in UA2018 class: pastures (based on satellite imagery observation and cross-checking)
	River/stream	Sopot green management tool: mieki
	Canal	No data found
	Delta	No data found
	Dry riverbed	No data found
	Estuary	No data found
Building greens	Atrium	No data found
	Balcony green	No data found
	Extensive green roof	No data found
	facade-bound green wall	No data found
	Green fences and noise barriers	No data found
	Green pavements and green parking pavements	No data found
	Ground based green wall	No data found
	Intensive green roof	No data found
Green areas for water management	Rain gardens or SUDS	Sopot hydrological dataset class: zbiornik retencyjny (correlated with OSM data and desk research); specific geometry UA2018 class: green areas, OSM class: grass and manual additions (based on desk research)
	Swales/ filter strips	No data found
Parks and formal green spaces	Green sport facility	UA2018 class: Sport and leisure facility; OSM land_use class: recreational ground
	Large urban park	Sopot spatial plan class: place; UA2018 class: Green urban areas
	Cemetery and churchyard	OSM land-use class: cemetery
	Botanical garden/arboreta	No data found
	Camping areas	No data found
	Historical park/garden	No data found
	Institutional greenspace	No data found
	Neighbourhood greenspace	No data found
	Pocket park/parklet	No data found
	Zoological garden	No data found
	Abandoned and derelict areas with patches of wilderness	UA2018 class: land without current use OSM land-use class: brownfield

Key GI Category	Sub-categories	Sources: class/attributes
Semi Natural Greenspaces	Forest	UA2018 class: forest OSM nature class: wood
	Sand pit/ quarry/ opencast mine	OSM nature class: sand
	Rocks	No data found
	Sand dunes	No data found
	Shrubland	No data found
Urban Green areas connected to grey infrastructure	Tree alley and street tree/hedge	UA2018: street tree layer; OSM land-use class: wood
	Street green and green verge	UA2018: street tree layer; OSM land-use class: grass, grassland, scrub
	Green parking areas	No data found
	Green playground/school ground	No data found
	House garden	No data found
	Railway embankment	No data found
	Riverbank green areas	No data found

Table 3 - Harmonisation table GI

6.2 Annex 2: Biophysical table (land use classes and curve numbers by soil group) used for InVEST (Action 3.3)

Source	name	lucode	Prior. for raster	cn_a	cn_b	cn_c	cn_d	Justification
GI Inventory (GI sub-categories)	Abandoned / wilderness	1		30	55	70	77	Natural vegetation, minimal compaction, high infiltration
	Arable land	2		67	78	85	89	Cultivated soils with reduced infiltration due to tillage
	Cemetery / churchyard	3		39	61	74	80	Managed grass with scattered trees and paths
	Community gardens	4		49	69	79	84	Intensively managed soils, partial compaction
	Forest	5		30	55	70	77	Dense canopy, leaf litter, good hydrologic condition
	Grassland	6		39	61	74	80	Continuous grass cover, moderate infiltration
	Green sport facility	7		49	69	79	84	Turf grass with frequent use and soil compaction
	Lake / pond	8	Yes	98	98	98	98	Open water surface, negligible infiltration
	Large urban parks	9		39	61	74	80	Mostly pervious with light recreational pressure
	Pocket park	10		49	69	79	84	Small parks with higher foot traffic and compaction
	Rain gardens / SUDS	11	Yes	20	35	50	65	Engineered infiltration and runoff retention systems
	River / stream	12	Yes	98	98	98	98	Open flowing water, full runoff contribution
	Sand pit / quarry	13		68	79	86	89	Exposed disturbed soils with low organic matter
	Sea coast	14		88	90	92	94	Sandy soils with wave impact and limited retention
	Street green / verge	15		49	69	79	84	Narrow vegetated strips, compacted soils
	Tree alley / hedge	16		36	60	73	79	Linear woody vegetation with partial ground cover
	Tree meadow / orchard	17		39	61	74	80	Trees with grass understory and moderate management
	Wetland / bog	18		70	80	85	88	Saturated soils with limited additional infiltration
UA 2018 classes	Sports & leisure facilities	19		74	82	88	91	Mixed impervious surfaces and compacted turf
	Railways	20		72	82	87	90	Ballast and compacted subgrade
	Other roads	21		98	98	98	98	Fully impervious paved surfaces
	Open bare spaces	22		77	86	91	94	Bare soil, erosion-prone, high runoff
	Land without current use	23		68	79	86	89	Disturbed unmanaged land with sparse cover
	Isolated structures	24		85	90	92	94	Buildings with surrounding impervious surfaces
	Industrial / commercial	25		89	92	94	95	High impervious fraction (roofs, pavements)
	Discontinuous medium urban	26		72	82	87	90	Mixed built areas with significant green space
	Continuous urban fabric	27		95	96	97	98	Very high imperviousness, minimal infiltration

Source	name	lucode	Prior. for raster	cn_a	cn_b	cn_c	cn_d	Justification
	Discontinuous dense urban	28		85	90	92	94	Dense built form with limited per-vious areas

Table 4 - InVEST biophysical table

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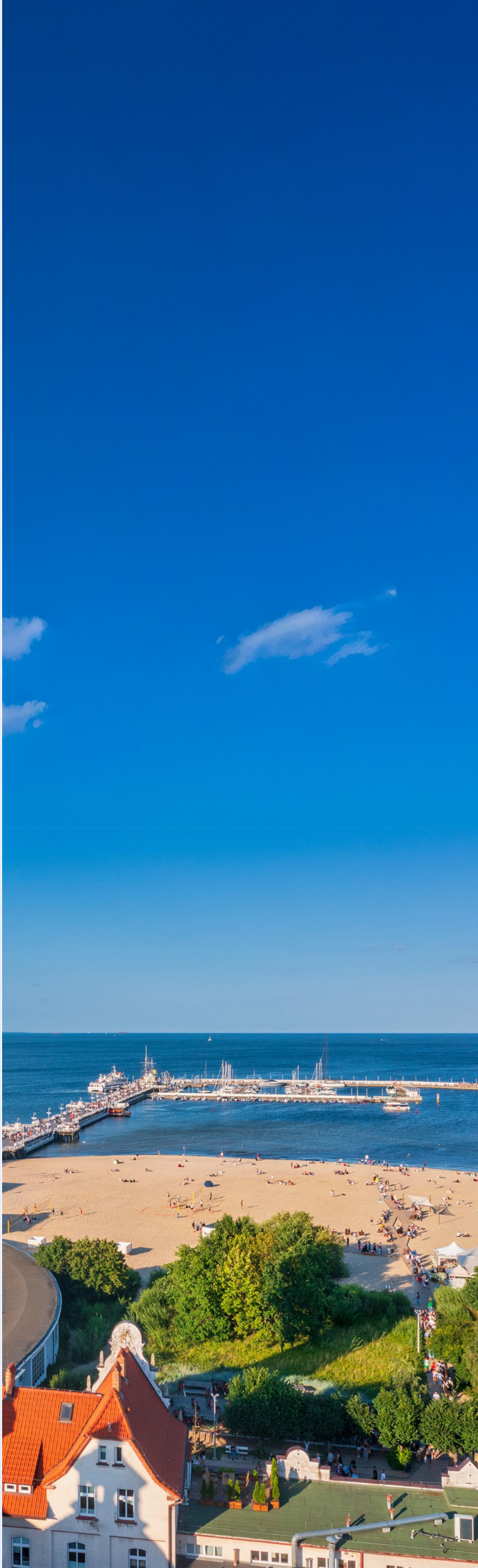

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