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WEB GIS FOR URBAN CLIMATE

INTEGRATED TURBAN PROJECT KNOWLEDGE
THROUGH THEMATIC MAPS
THAT LINK URBAN LANDSCAPES AND VARIOUS URBAN FEATURES

by

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REPORT

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SUMMARY

Web-GIS for urban climate is a key element for effective aggregation and communication of the geolocated environmental information. We integrate project knowledge through thematic maps into a web GIS framework that links urban landscapes and various urban features with quantitative information from model scenarios.

APPROVAL	
Project Leader: Igor Esau	*Director:* Tore Furevik

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Executive summary

The report describes the design and structure of TURBAN Web GIS. Web GIS for the urban climate is crucial for effectively aggregating and communicating geolocated environmental information. We integrate project knowledge through thematic maps into a web GIS framework that links urban landscapes and various urban features with quantitative data from model scenarios. The Web GIS is built on the cloud-based ArcGIS (online) software to create and share interactive web maps. Web-based interactive urban maps serve as a visual tool for urban air quality and the spatial and temporal characteristics of different aspects of the urban environment. The application was developed for Bergen, Norway, with a potential extension of the Praha case study. The Web GIS consists of two elements: WebStory maps of urban climate and pollution and interactive WebGIS presenting a thematic layer of the urban environment.

Introduction.

In the 21st century, Europe and the rest of the world are experiencing an unprecedented number and severity of extreme weather events. Long waves of heat and cold significantly worsen the quality of the urban environment and thermal comfort. Furthermore, air pollution caused by local transportation, industry, heating, and other activities increases the morbidity and mortality of city dwellers. The TURBAN project explores data collection, data fusion, and local climate modelling to improve the urban environment and support the city's sustainability and movement towards smart cities' status.

Fusion of satellite remote sensing data, and high-resolution urban modelling in geographic information systems (GIS) develop advanced tools for assessing thermal comfort and air quality in cities to support the urban resilience and urban planning.

Web GIS is changing the way maps and spatial data are shared and accessed. We are developing a web-based GIS application for urban environmental assessment for project pilot cities. The app demonstrates the tool for planners and the public and create a spatial representation of different aspects of the urban environment. Modern cities are growing and rapidly changing systems that require periodic assessment of the geo-ecological state. An objective assessment of different aspects of the urban environment is a necessary guarantee of sustainable and stable development of territories. However, it is impossible without considering many factors represented by numerous parameters. The growing complexity of the urban environment leads not only to the need for accurate spatial information in real-time but also creates new challenges to obtaining information valuable for urban citizens. Therefore, citizen science can improve communication and understanding of people's lives. To date, a vast array of statistical cartographic analytical and other information has been accumulated, which can become the basis for a comprehensive analysis of the city's environmental problems and their timely solution. Web GIS technologies make it possible to combine all heterogeneous information about the ecological state of a city into a single data system that is available for use. A web GIS makes it possible to assess the state of the urban environment and present information in spatially visual forms. As online maps simultaneously become more and more research tools, citizen science activities are starting to implement web GIS applications to support research areas such as ecology and urban studies. The design of our web GIS combining open data, citizen observation and science data and can quickly present the results and participate in the process of city management.

The TURBAN (https://www.project-turban.eu) project grant from Norway and Technology Agency of the Czech Republic (TA CR). The project aims to improve the tools and methods used to assess the atmosphere in the urban environment and to support mitigation measures aiming to reduce thermal stress and air pollution.

Both Czech and Norwegian partners work towards urban environment quality assessment and modeling, and they share the joint modeling and data analysis approaches. The parallel validation of the model tools in conditions of the larger inland city Prague and the smaller coastal city Bergen will help generalization, universal applicability, and reliability of the proposed methodologies and instruments.

The project will achieve the following:

1) Collecting, processing, and publishing an extensive set of diverse atmospheric observations, including data from specific observation campaigns.
2) Advancing our knowledge and ability to manage the urban climate and air quality; foresee the impacts of policy actions and socio-economic decisions designed by urban authorities and the general public.
3) Contributing to the scientific understanding of complex, turbulent atmospheric flow and energy exchanges inside the urban canopy is essential to develop advanced tools for urban thermal comfort and air quality assessment.

The last type of the results represents specific urban studies of the actual areas, which will be conducted in coordination with relevant city authorities. The project results will help in urban planning, particularly in planning the mitigation measures for thermal stress and air pollution phenomena.

Data and Methods

WebGis presents urban structure and form data from Bergen, Norway. A web GIS is important because it easily communicates a great amount of information visually with the need for fewer words, links, and pages to navigate through. The TURBAN project already has webpages for reporting, an interactive map application would offer a practical complement that easily conveys data while keeping the user's attention through interactivity.

ArcGIS is a geographic information system (GIS) for working with maps and geographic information created by the company, Esri. They have a suite of software and digital applications, and StoryMaps is one of their online applications. StoryMaps can be saved, shared, and embedded. They can receive real-time data feeds and be combined with surveys and other GIS elements.

The GIS software used here is ESRI®ArcMap version 10.4.1 for Desktop. The workflow has three stages: data collection, preparation, and comparison. The steps proposed contributes to novel ways to identify and compare spatial configurations through efficiently aggregating and comparing data that are both spatial and non-spatial from different base units (i.e., levels of scales) and different sources. For example, the application of a buffer operation to better compare building level data with street network values is a combination of spatial and non-spatial data.

Geospatial input data

The spatial data consists of the object (a point, line or polygon with x-y coordinates) and an attached attribute table consisting of relevant information to the spatial object (i.e., shape, size, ownership information etc.).

The main input parameters describe:

Urban structure represented as line segments (from axial drawing) including attribute data such as network values of closeness and betweenness

Urban form is represented as polygons with building attribute data such as dimensions, age, and functions

Building density is calculated via the dimensions and spatial location of the land use plots

Road centre lines containing dimensions and spatial location of the network of roads, streets, paths, and alleyways

Transport use, the amounts of traffic and maximum speeds on the roads and streets to calculate transport energy usage

Part of the spatial data files are georeferenced axial maps hand-drawn by researchers and validated with local experts. The rest were secondary data downloaded from open-source online resources via ArcGIS Editor for OpenStreetMap (OSM). Information on transport capacity and building use were proprietary data provided on request by local authorities (Bergen Kommune) and national authorities (the Norwegian Public Road Administration)

The other input for WebGIS consist of:

1) Land cover layer (typically ESRI Shapefile)
Land cover is currently available only for cities covered by Copernicus Urban Altas geodatabase (UA2018; see https://land.copernicus.eu/local/urban-atlas). This approach classifies all the UA2018 classes to the Palm Input Data Standard (PIDS) classes which have a default setting. These data are intersected with an Open Street Map (OSM) layer with building footprints (freely downloadable e.g.on https://download.geofabrik.de/europe.html). Each polygon in the shapefile defines the type of the terrain (pavement, vegetation, water, building). Special case is sea, which was not considered in UA2018 and it was added manually.

2) Digital elevation model (raster in GeoTiff format)
A Copernicus EU-DEM (see https://land.copernicus.eu/imagery-in-situ/eu-dem) is a recommended Digital elevation model (DEM) input. Note that EU-DEM resolution is 25 m. If more detailed resolution is needed, use resampling. Up to 10m it provides good results, 5m is the lowest limit.

3) Building heights (raster in GeoTiff format, also vector format is possible) In the Capital cities in Europe are mostly covered by the Copernicus Building Height (BH) layer (see https://land.copernicus.eu/local/urban-atlas/building-height-2012). Freely available 10m high resolution raster layer containing height information generated for core urban areas of capitals. In cases when the BH layer is not available it is possible to use a parameterization based on UA2018 classes, PIDS types or any other source.

Remote sensing data

The ground surface temperature map was developed using Landsat data. Landsat B10 and B11 thermal channels with 100 m resolution were processed to obtain LST values. The distribution of vegetation and vegetation density was performed by distributing the Normalized Vegetation Difference Index (NDVI) in urban areas.

ArcGIS Server

ArcGIS server makes our data—such as features, tables, maps, tools, imagery, and locators—available to TURBAN project clients and, potentially, the entire Internet through web services.

Web services, essentially, are our data. They access the data in storage locations, allowing to share that data without giving people direct access to the storage locations. In the case of feature and imagery data, we can publish web services that access the data without duplicating it. If the data is relatively static, we can cache the data in a location separate from our data source to improve drawing performance.

The type of data we want to make available to others and what we want people to do with that data determined the type of web service we publish.

We publish web services to allow visualize and query our urban spatial data in a map format. The two main types of spatial data we share in this way are feature and imagery data. The map contained the feature information and allowed the user obtain information about object of interests.

Publish a map service

Map services allow other users to view and interact with GIS content on the web. Map services support rendering and querying and can be configured to draw dynamically from data or new or existing cached tiles.

This ArcGIS option was used to make thematic layers interactive for users. This makes it possible to switch between layers, zoom and access attribute information visually in pop-up windows.

Web GIS structure

Web GIS is consisting of two parts. First part is a web story of Bergen air pollution and local climate zones presenting as a set of interactive maps that display various urban environment characteristics, results of model and remote sensing studies. The second part is a Web GIS as a ARCGIS web server and presented an urban environment in form of the thematic layers and allow any kind of classification, evaluation, or analysis of metrics.

Bergen web story.

Bergen is the second-largest city in Norway surrounded by seven mountains, located on the west coast of Norway at 60° north latitude and 5° east longitude.

The central part of the city lies in a narrow, curved valley. The valley is oriented in the southeast and northwest directions and goes towards the large sea bay of Bergen fjord. The valley floor is at least 1 km wide, and the surrounding mountain peaks are 344 to 642 m height. The central make up 12% of the total built-up areas in the Bergen municipality.

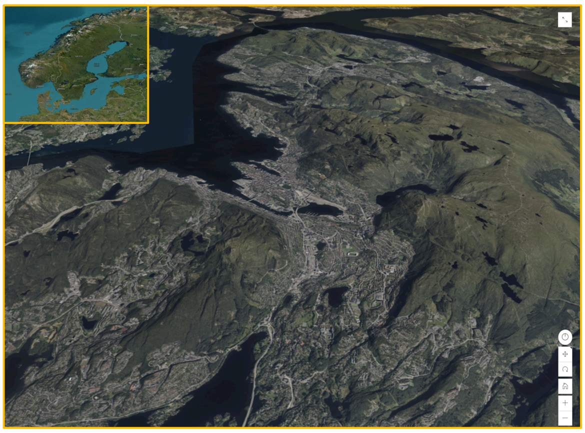

Figure 1. Map of Bergen.

The municipality of Bergen has 281,190 inhabitants, of which 83,669 live in these central areas. Currently, the population density of the whole city of Bergen is 630 inhabitants per km ^{2}, whilst the main areas have a population density of 2111 inhabitants per km ^{2} .

The municipality of Bergen aims to densify fifty percent of new housing within the city's central parts and increase by 10,000 new dwellings by 2030.

The recent shift in policy reflects a global trend of moving towards low-carbon, low-emission cities in the battle against climate change, global warming, and dwindling resources. Following national and local objectives aim to reduce urban sprawl into the countryside and transport energy usage by investing in public transport and increasing the building intensity and land-use mix around these public transport lines.

Bergen is a city with a history of poor air quality. While the valley shelters the city from extreme wind events, it also favors the existence of persistent ground-based temperature inversions during wintertime. In such conditions, prolonged NO accumulation from road traffic exceeds legally regulated air quality thresholds. The most severe documented and reported air pollution event occurred in January 2010, giving Bergen unfortunate national and international media attention.

Figure 2. Winter inversion in Bergen cause local pollution.

The model simulates complicated urban air motion and pollution transport pathways in a city with a high geographical resolution and characterizes street-level winds, temperature, moisture, and air quality.

Figure 3. Main source of air pollution in Bergen

This model simulates complicated urban air motion and pollution transport pathways in a city with a geographical resolution of 10 m. The model characterizes winds, temperature, moisture, and air quality at street level. For example, our demonstration study investigates an opportunity to reduce particulate matter (smoke) air pollution due to wood burning in households. The modelling revealed that almost no households would be exposed to dangerous levels (40 µg m-3 of PM2.5) if just two central Bergen districts, Bergenhus and Årstad, had cleaner wood-burning ovens installed. (Wolf et al., 2021)

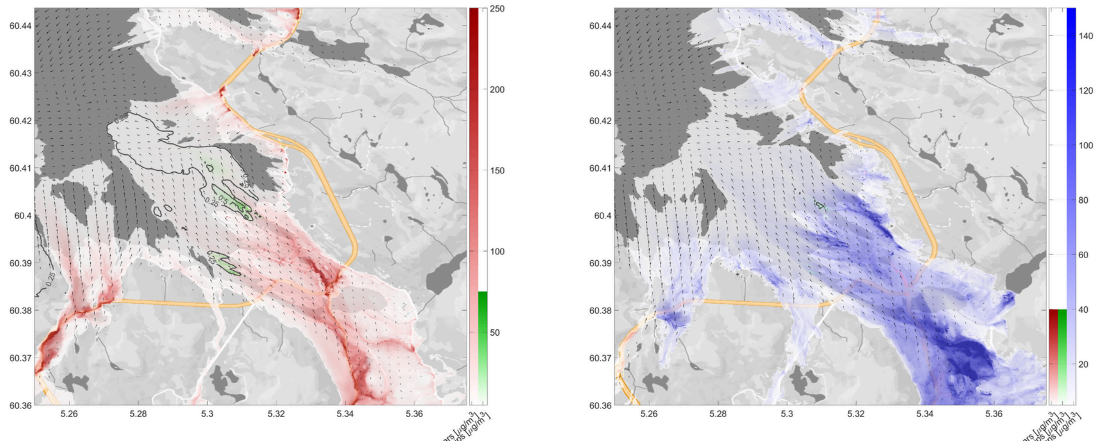

Figure 4. Concentration of air pollution in Bergen

Bergen is known as the "gateway to the fjords" and is set to receive about 300 cruise ships and 600 000 passengers a year, more than any other port in Norway.

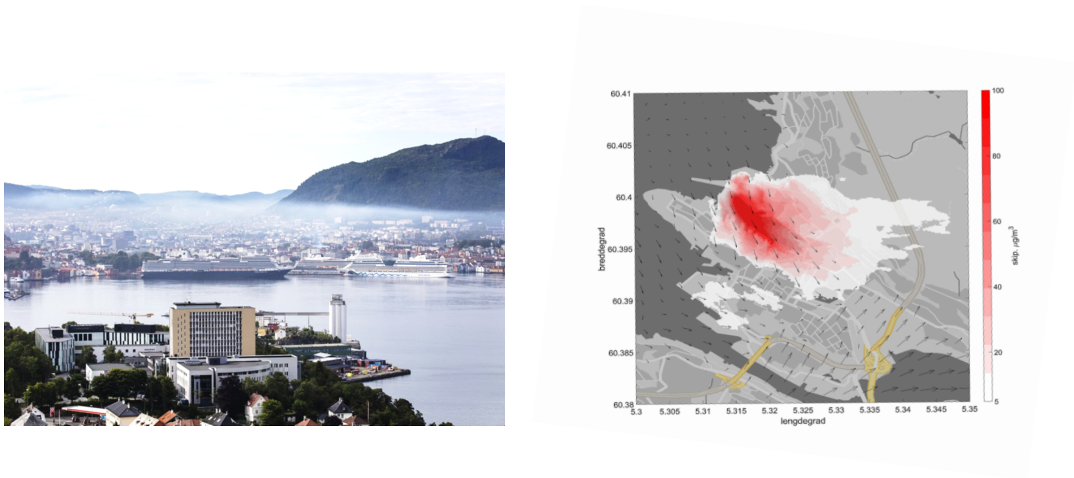

Figure 5. Localization of air pollution from cruise ships.

We discovered that the most influential meteorological situations are when persistent calm weather favors the accumulation of the Bergen air to dangerous levels. Under the same meteorological conditions, we observed the areas with high thermal stress formation.

For example, in the summer of 2019, during the Western European heatwave, the Bergen temperature reached its highest record 33.4 °C. A distinctive feature of urban climates is their high spatial heterogeneity, determined by a variety of urban forms, land cover types, anthropogenic activity on different spatial scales, and the complexity of the surface–atmosphere interaction in cities. As a result, various urban environments in the city create specific microclimatic conditions. The heat distribution in the city was uneven, and we observed local heat stress areas. Landsat Land Surface Temperature map zooms in on cities' hottest neighbourhoods to help combat the urban heat island effect.

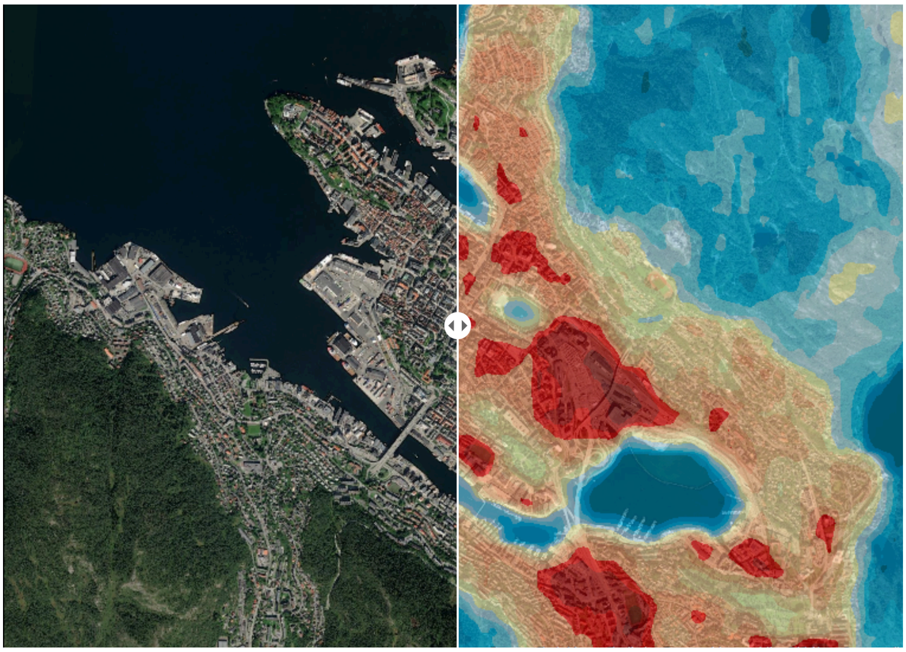

Figure 6. Land surface temperature map of Bergen

The heat distribution in the city is uneven, and we observed local heat stress areas with significantly higher temperatures than the surrounding ones.

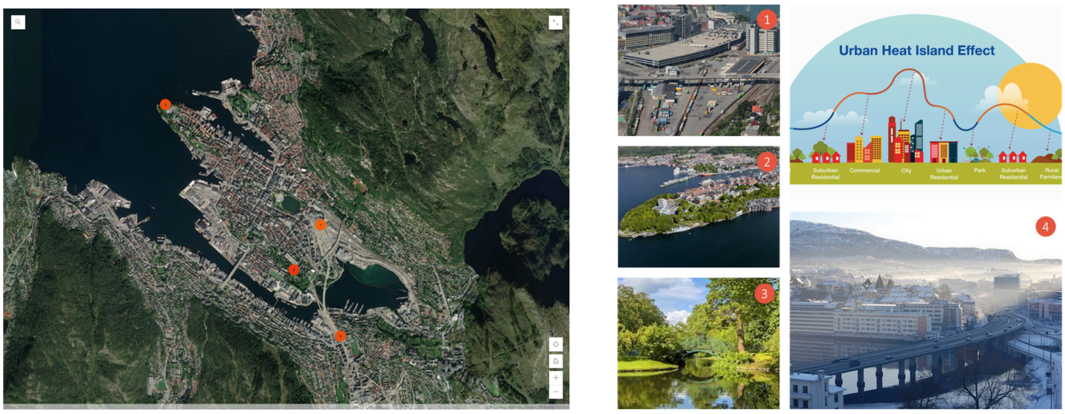

Figure 7. Varity of microclimate in urban environment.

Satellite remote sensing enables building scale mapping of the urban thermal environment. Buildings with black flat roofs, asphalt around them, and a lack of vegetation are typical environments for developing a local stress area.

Surface temperatures were negatively correlated to trees and NDVI-remotely sensed index of vegetation. The presence of green spaces composed of trees and water bodies reduces air pollution and temperature stress and creates a comfortable urban environment.

Figure 8. Mapping urban thermal comfort at building scale

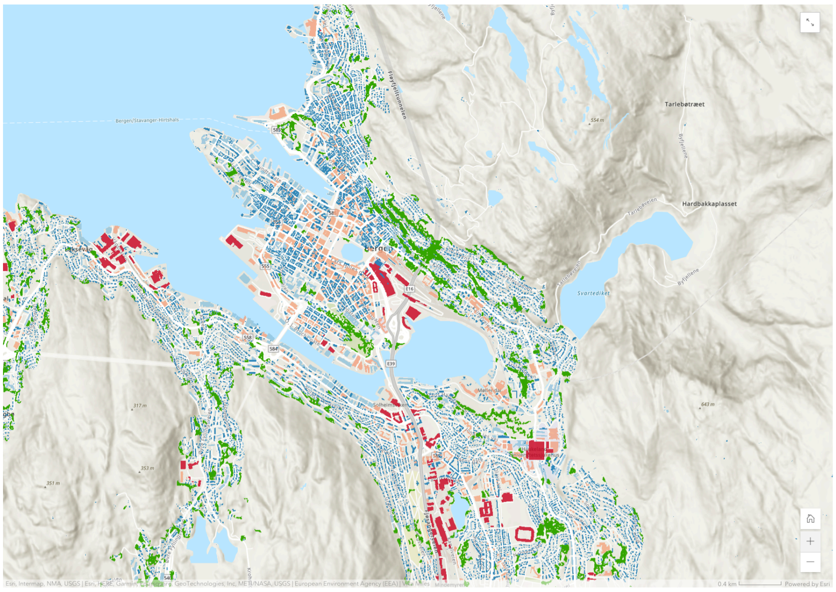

Figure 9. Distribution of vegetation and urban thermal comfort

Conclusions

Web GIS tells the story of air pollution developed by the TURBAN project. StoryMap describe and analyse the most influential factors contributing to the concentration of air pollution in Bergen such as: meteorology, urban structure, vegetation, effects of various sources of pollutions. Web GIS is built on a set of interactive maps that display various urban environment characteristics. These datasets are a set of static parameters input into the model.

The story map has a unique link and is viewable on any gadget.
(https://storymaps.arcgis.com/stories/513ab907157947fe89cbf8d97d9e70eb)

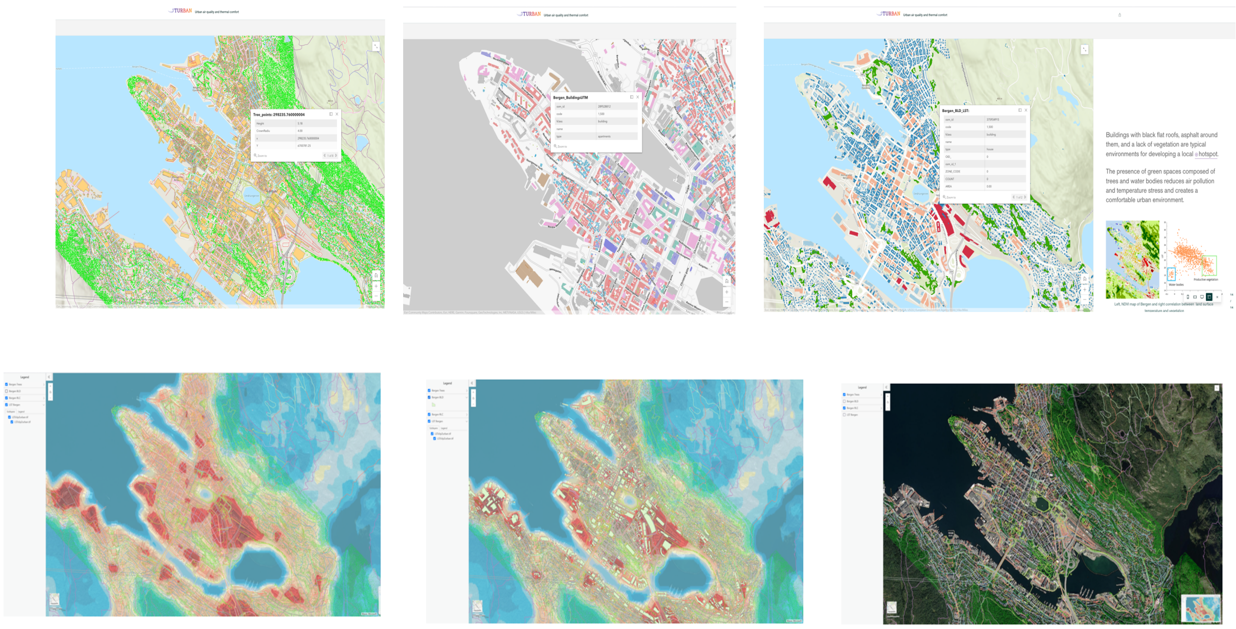

Figure 10. An example of interactive thematic layers in the urban environment of Bergen. The simulation results are presented in the form of overlays - combining different layers made it possible to obtain a more complete and complex assessment of urban areas.

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