Deliverable Phase 2 – Climate risk assessment

Sustainable Climate Outcomes for People of Eastern Slovakia (SCOPE)

Slovakia, Košice Region

HORIZON-MISS-2021-CLIMA-02-01 - Development of climate change risk assessments in European regions and communities based on a transparent and harmonised Climate Risk Assessment approach

Funded by the European Union

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101093864. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

Document Information

Deliverable Title	Phase 2 – Climate risk assessment
Brief Description	
Project name	Sustainable Climate Outcomes for People of Eastern Slovakia (SCOPE)
Country	Slovakia
Region/Municipality	Košice region
Leading Institution	City of Košice
Author(s)	• Zuzana Jarošová • Eva Singovszká • Martin Kubáň • Marián Hudák • Mária Ház
Deliverable submission date	15/01/2026
Final version delivery date	dd/mm/yyyy
Nature of the Deliverable	R – Report
Dissemination Level	PU - Public

Version	Date	Change editors	Changes
1.0	15.01.2026	City of Košice	Deliverable submitted
2.0	…	CLIMAAX's FSTP team	Review completed
5.0	…		Final version to be submitted

Table of contents

Obsah

List of figures

List of tables

Abbreviations and acronyms

Abbreviation / acronym	Description
RP	Return period
Košice/KE UMR	Košice - Urban development area
CDS	Copernicus Climate Data Store
SHMÚ	Slovak Hydrometeorological Institute
CRA	Climate Risk Assessment
NOAA	National Oceanic and Atmospheric Administration
LST	Land Surface Temperature
CRM	Climate Risk Management
NDVI	Normalized Difference Vegetation Index
RPI	Risk Priority Index

Executive summary

This deliverable presents the results of Phase 2 of the Climate Risk Assessment (CRA) carried out within the SCOPE project for the Košice and functional urban area. It builds on Phase 1 outcomes by refining datasets, integrating stakeholder input, and expanding the assessment to better reflect local climatic, social, and infrastructural conditions. The objective of this phase was to transform preliminary risk screening into a robust, locally grounded assessment that can directly inform adaptation planning and decision-making. Phase 2 presents a comprehensive assessment of present and future climate risks in the Košice Urban development area (UMR), covering their spatial patterns, impacts on vulnerable population groups, and implications for critical infrastructure. It illustrates how European-scale climate projections can be systematically combined with national observations and local knowledge to underpin evidence-based climate resilience and adaptation planning. During Phase 2, the original CLIMAAX workflows for heatwaves and extreme rainfall were refined using improved local datasets and validated against measured observations from the Slovak Hydrometeorological Institute (SHMÚ). Based on stakeholder consultations and a regional survey conducted in 2025, two additional hazards—wildfires and droughts—were incorporated to reflect emerging and intensifying risks. The assessment focuses on the medium-term climate horizon (2021–2050), using EURO-CORDEX scenarios (RCP 4.5 and RCP 8.5), benchmarked against SHMÚ national climate projections. Key results confirm a significant increase in heat-related risks, including a marked rise in heatwave days, tropical days, and tropical nights. A refined heatwave workflow combining satellite-derived land surface temperature with in-situ measurements enabled the identification of persistent urban heat islands, particularly in densely built residential areas. High and very high heat exposure was identified at numerous critical locations, including kindergartens, hospitals, social-care facilities, and socially disadvantaged settlements, highlighting priority areas for intervention. The extreme rainfall analysis strengthened the local evidence base through a hazard-impact database, revealing an increasing frequency and intensity of high-impact precipitation events associated with flash floods and pluvial flooding. Wildfire risk mapping indicated growing exposure of critical buildings in forest-adjacent areas, while the drought assessment identified potential future revenue losses for key regional crops under warmer and drier conditions. Across all hazards, the assessment emphasized the heightened vulnerability of children, older adults, people with health limitations, and socially disadvantaged groups. This deliverable contributes to the overall CLIMAAX project by demonstrating the practical application of a harmonized CRA framework at the local level, while addressing data gaps, governance challenges, and equity considerations. The results provide a solid evidence base for prioritizing adaptation measures, aligning city and regional strategies, and supporting access to climate-adaptation funding. In conclusion, Phase 2 confirms that climate risks in the Košice region are intensifying and increasingly interconnected, with heatwaves emerging as the most critical hazard, compounded by drought, wildfire, and extreme rainfall impacts. Integrating local data and stakeholder knowledge substantially improves the relevance and usability of climate risk assessments.

1. Introduction

1.1. Background

The second deliverable builds upon the outcomes of Phase 1 of the Climate Risk Assessment conducted within the SCOPE – Sustainable Climate Outcomes for People of Eastern Slovakia project. While the first deliverable established a comprehensive overview of key climate-related hazards in the Košice region—particularly heatwaves, urban heat islands, and extreme precipitation—the second deliverable advances this work by refining datasets, validating findings with local stakeholders, and integrating more detailed vulnerability and exposure information.

Košice and its functional urban region represent a diverse territory with complex climatic, geographic, and socio-economic conditions. Previous analyses have confirmed accelerating trends in temperature increases, rising frequency of heatwaves, and a marked intensification of extreme rainfall events. These findings underline the need for a deeper, more localized assessment of climate risks that considers not only climatic projections, but also social vulnerability, infrastructure sensitivity, and institutional capacity.

A central component of Phase 2 preparation was the stakeholder survey and consultations, which involved surrounding municipalities. The survey, conducted in July 2025, revealed that heatwaves (91%), droughts (87%), flash floods (78%), strong winds (66%), and forest fires (22%) are the most frequently perceived risks. Adaptation measures already implemented include tree planting (73%), awareness and education campaigns (67%), rain gardens (49%), permeable surfaces (44%), and shaded public areas with drinking fountains (38%). Despite these efforts, municipalities highlighted persistent challenges such as limited financial resources, lack of technical expertise, and insufficient coordination between the city and surrounding municipalities. Importantly, 58% of respondents have already integrated adaptation into planning, 51% feel sufficiently informed, 39% cooperate with experts, and 32% have access to funding sources.

These insights provided important direction for prioritizing datasets, refining workflows, and identifying vulnerable groups for more detailed mapping. Based on the survey findings and stakeholder consultations, the project team decided to expand the initial CLIMAAX workflows by introducing two new thematic workflows dedicated to wildfires and droughts, reflecting their growing importance in the region.

The second deliverable therefore focuses on incorporating local knowledge, integrating improved datasets on vulnerable populations, critical infrastructure, and past hazard impacts, and preparing the groundwork for co-designed adaptation measures. The aim is to transform the preliminary findings from Phase 1 into an enhanced, locally grounded climate risk assessment that better reflects real conditions and strengthens the region’s capacity to implement effective adaptation strategies.

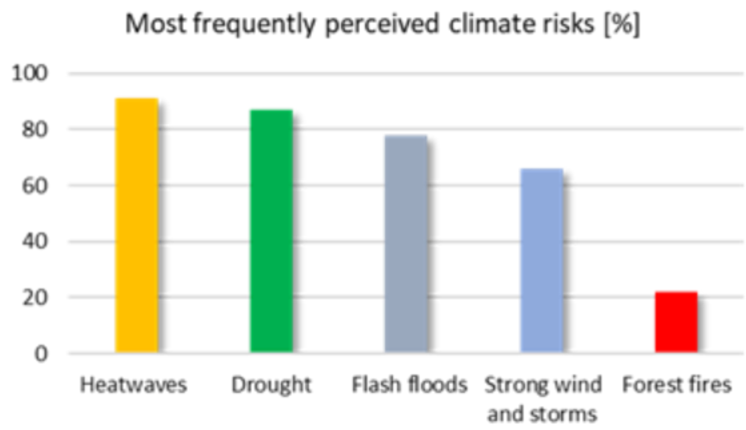


Figure 1-1 Most frequently perceived climate risk

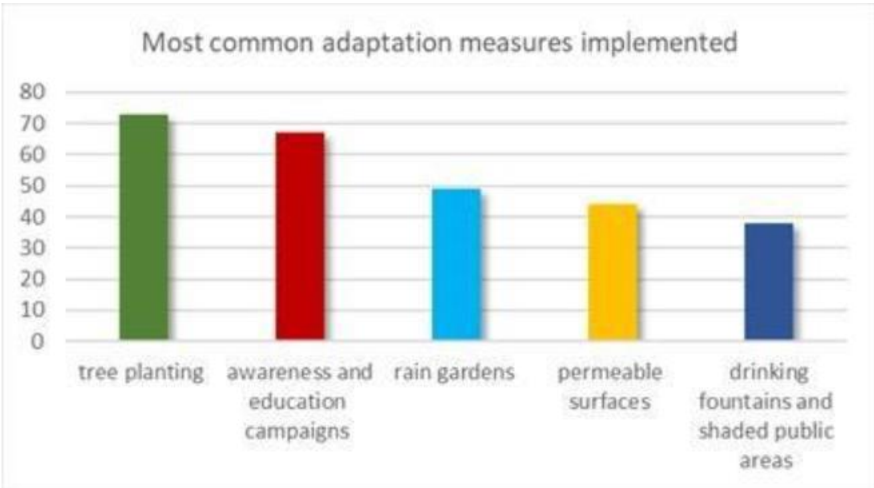


Figure 1-2 Most common adaptation measures implemented

1.2. Main objectives of the project

The SCOPE project within the CLIMAAX framework aims to strengthen climate preparedness and resilience in Eastern Slovakia by advancing risk assessment, developing effective adaptation strategies, and fostering regional cooperation. It deepens the scientific analysis of key hazards:

- floods,
- heatwaves,
- drought,
- wildfires,

while refining vulnerability mapping through socio-economic data and climate projections. Continuous integration of updated climate models and weather data ensures informed local decision-making. The project translates these findings into practical, equitable measures that enhance the preparedness of Košice and surrounding municipalities, supporting them in securing funding for adaptation and green initiatives. At the same time, it raises awareness of climate risks across the region, builds a transferable model of urban–rural adaptation planning, and delivers tangible solutions that improve the quality of life for residents.

1.3. Project team

The project was managed by the city's strategic development department and the data policy and analysis department. Since the strategic development department oversees the preparation and monitoring of the city's key climate policies and the data policy and analysis department is the data carrier in the city of Košice, work on the project began using existing experience and partnerships. The core team worked intensively on the project immediately after the completion of phase 1. Work on phase 2 began with a survey of the needs in the field of adaptation of the affected UMR municipalities. The results of the survey were presented to all municipalities on June 18, 2025, in Košice, where the results of phase 1 were also presented to the participants (Figure 1-3). Consideration based on survey results and climatological events records, it was decided to expand the original hazards (extreme rainfall and heat waves) to include two new hazards - wildfires and droughts. Subsequently, preparations began for deeper data collection not only within the competence of the city, but also of other organizations (district offices, civil protection department, Slovak Hydrometeorological Institute, Slovak Fire Department).

Figure 1-3 Presentation of results CLIMAAX Phase 1 and survey results

1.4. Outline of the document's structure

This document is organized to provide a comprehensive, step-by-step report on phase 2 of the climate risk assessment for the Košice city and surrounding urban development area, following the structured methodology of the CLIMAAX framework.

This report is more extensive than the Phase 1 deliverable, as two additional hazards were incorporated based on new insights and feedback from affected municipalities. It begins with an introduction explaining the purpose of the refined regional and local multi-risk assessment and its role within the broader project timeline. The following section presents the methodological approach, describing how the CLIMAAX workflows, local datasets, and stakeholder inputs were combined to produce high-resolution risk analyses. The core of the document is the results section, which details the prioritized climate risks, the spatial distribution of hazards, and the identified vulnerabilities and resilience gaps across the Urban development area.

Subsequent sections interpret these findings, summarizing the key insights gained, the challenges addressed, and the limitations that could not be fully resolved within this phase. The Monitoring and Evaluation chapter reflects stakeholder involvement, communication activities, and progress toward key performance indicators. The document concludes by explaining how the outputs of Phase 2 connect to the planned activities in Phase 3, including the development of adaptation strategies, policy recommendations, and expanded dissemination efforts. This structure ensures a logical flow from analysis to interpretation and finally to the strategic implications for the next phase of the project.

2. Climate risk assessment – phase 2

The Framework consists of a five-step process which forms an iterative cycle. The goal of the CRA Framework is to inform Climate Risk Management (CRM) strategies. The Framework is designed to estimate and contextualize Climate Risk that can be quantified through CRA workflows. It makes sure that the CRA process and its implementation are consistent with the highest standards and best practices as well as with state-of-the-art scientific findings.

The CRA framework identifies five operational steps – Scoping, Risk Exploration, Risk Analysis, Key Risk Assessment and Monitoring & Evaluation – and corresponding sub-steps. The Scoping phase defines objectives, sets the context, and identifies stakeholders and risk ownership. Risk Exploration is strongly informed by Scoping as it applies gathered knowledge, information and decisions and moves forward through more detailed hazard and risk exploration. This supports decisions on workflows and scenarios to use. After the risk workflow application in the Risk Analysis step, the individual risk outcome is evaluated and contextualized in the Key Risk Assessment step (severity and urgency of risk resulting in key and less urgent risks), thus identifying potential entry points for CRM and risk reduction. Monitoring & Evaluation puts emphasis on summarizing the CRA process and surveilling climate risks while gathering knowledge and data that is relevant for improvements in the next iterations of the CRA.

2.1 Scoping

The scoping phase defines the CRA objectives, implementation context, and identifies priority groups and experts involved in project preparation. In this phase, previous findings from Phase 1 were linked with new requirements identified during stakeholder consultations.

2.1.1. Objectives

The main objective of the SCOPE project's Climate Risk Assessment (CRA) is to perform a detailed mapping and analysis of climate-related risks specifically for the Košice region. By using advanced tools and methodologies from the CLIMAAX framework, the project aims to generate and regularly update accurate, localized climate risk data. The purpose is to enhance local resilience and raise awareness of climate hazards, building on previous efforts in local data gathering while creating a replicable model for effective adaptation in other regions. The expected outcome is a locally grounded climate risk assessment that reflects real-world conditions and provides actionable solutions, transforming preliminary findings into enhanced results that strengthen the region’s capacity to implement adaptation strategies.

To ensure these objectives are fed into policy and decision-making, the project develops recommendations in critical areas such as adaptation strategy, civil protection, urban planning, and building regulations. Outcomes are intended to support the integration of climate risk considerations into all aspects of local governance, ensuring that risk management is embedded within the broader framework of regional development and social welfare. These outcomes can inform upcoming local and regional development plans by identifying vulnerable sectors and populations and providing a solid evidence base for applying financing for specific adaptation measures.

The climate risk assessment faces several limitations and boundaries, particularly regarding the availability and resolution of data. A significant constraint is the 12x12 km spatial resolution of Euro-

CORDEX data, which is relatively coarse for a small territory. Furthermore, the project is bound by the current short-term focus of socio-economic and economic activity planning, which currently only extends to the 2030 horizon. Stakeholder involvement also presents a boundary, as different groups were invited for specific project phases depending on the expected outcomes.

Several challenges and bottlenecks were encountered during the process, including a disjointed governance context where differences in methodologies between municipal and regional assessments hindered unified planning. Another major bottleneck was the lack of detailed local hazard-impact data, especially concerning past extreme precipitation and flood events, as this information is not freely available in Slovakia. To address the governance gap, the project aims to align future assessments with both city and regional strategies to ensure policy coherence. To overcome data scarcity, the project team initiated the compilation of event databases from local newspapers, fire departments, and the crisis management office, while also purchasing necessary measured datasets from the Slovak Hydrometeorological Institute (SHMÚ) to validate and enrich existing models.

2.1.2. Context

The climate risk assessment for the Košice region has historically been conducted through a mix of national, regional, and local initiatives that aimed to address environmental hazards, though these efforts often lacked an integrated approach or data-driven cooperation across government levels. The City of Košice and its surrounding villages have significant experience in vulnerability assessments, having implemented measures such as tree planting, the creation of rain gardens, and the installation of drinking fountains in public areas. However, a major problem the project addresses is the discrepancy in methodologies between regional and city authorities, which complicates direct comparisons and hinders the effective implementation of adaptation policies across administrative boundaries. This issue is particularly critical within the Functional Urban Region, where strategic development requires aligned climate strategies to ensure that no part of the community is left behind as temperature increases and extreme rainfall events intensify.

The governance context for this assessment is shaped by the National Adaptation Plan (NAP), which serves as the foundation for risk assessment methodologies in Slovakia, and the regional Adaptation Strategy developed by the Košice Self-Governing Region. Locally, the City of Košice operates under its Adaptation Plan for Environmental Change (2022–2030) and the Sustainable Energy and Climate Action Plan (SECAP), while also being a member of the Covenant of Mayors with a target to reduce emissions by 40% by the year 2030. Relevant sectors affected by climate change in the region include public health, which faces risks from heat-related illnesses among vulnerable groups, and the infrastructure sector, where roads and sewage systems are often flooded during torrential rains. Agriculture and forestry are also under threat as rising average temperatures and irregular precipitation distributions lead to declining ecological services and an increased risk of forest fires during summer months.

Outside influences on the problem include the city's role as an international transport and cultural hub near Hungary, Poland, and Ukraine, as well as the presence of large industrial enterprises such as U.S. Steel Košice. Additionally, large-scale projects like the introduction of geothermal energy into the central heating system influence the city's broader energy and climate transformation efforts.

To meet project objectives, several adaptation interventions are possible, including the expansion of green infrastructure, the cleaning and capacity doubling of drainage devices by the Eastern Slovak Water Management Company, and the implementation of early warning systems for sudden events like flash floods.

2.1.3. Participation and risk ownership

The project is managed by the Strategic Development Department in cooperation with the Data Policy Department of the City of Košice. Responsibility for identifying and mitigating risks is shared between the city and other organizations such as the Veterinary and Food Institute, the District Office, and the Slovak Hydrometeorological Institute (SHMÚ).

2.1.4. Application of principles

- **Social Justice, Equity, and Inclusivity:**
    - The analysis specifically focuses on identifying and mapping critical locations with high concentrations of vulnerable population groups.
    - Priority groups include children in kindergartens, senior citizens, patients in hospitals, and residents of socially disadvantaged environments, such as Roma settlements.
    - The aim is to ensure that the proposed adaptation measures are equitable and prioritize the needs of those most at risk from climate change.
- **Quality, Rigour, and Transparency:**
    - The quality of the analysis is ensured by using a combination of European climate models: Euro-CORDEX (CDS, 2019a), EuroHEAT(CDS, 2019b) and validating them with local data measured by SHMÚ stations.
    - Transparency is supported by sharing all created outputs, datasets, and visual materials in the **Zenodo** repository.
    - The methodology for selecting Land Surface Temperature (LST) imagery was strictly tied to real-world measured tropical days, increasing the accuracy of Urban Heat Island identification.
- **Precautionary Approach:**
    - For the extreme rainfall analysis, the **RCP 8.5** scenario was chosen. This models an unfavorable development, allowing the city to prepare for the worst-case scenarios regarding the intensity and frequency of flash floods.
    - The introduction of two new workflows (wildfires and drought) responds to the expected increase in risks associated with warming in the city's surroundings, thereby expanding the preventative scope of the strategy.

2.1.5. Stakeholder engagement

Stakeholder engagement for the SCOPE project was conducted through a combination of personal consultations, online meetings, and formal presentations. A central component of the Phase 2 preparation was a stakeholder survey and consultation involving surrounding municipalities conducted in July 2025. The results of this survey and the findings from Phase 1 were presented to all municipalities on June 18, 2025, in Košice. The participants in these meetings and surveys included municipal departments, city-owned organizations like Municipal Forests and ZOO Košice, academic institutions such as the Technical University of Košice and UPJS University, and civic associations. To communicate project goals and intermediate results, the team used adapted channels including press releases, social media posts on Facebook and Instagram, and participatory processes.

Throughout the project, the Košice team held regular internal coordination meetings to ensure the effective implementation of planned activities, alongside monthly meetings with CLIMAAX SK aimed at strategic alignment and structured knowledge exchange. CLIMAAX SK serves as a national coordination platform responsible for the collection, harmonisation, and consolidation of data across all regions of Slovakia.

Project results were met with strong interest from participants, whose feedback underscored the need for enhanced cooperation between local governments, institutions, and communities to enable an effective response to climate-related risks. Participants also emphasized the importance of raising public awareness and expressed a willingness to contribute by sharing their expertise in data collection and analysis. The project outcomes are expected to support participants in the preparation of forthcoming local and regional development plans, inform urban planning and infrastructure investment decisions, and strengthen efforts to secure funding for green and climate-resilient initiatives.

2.2. Risk Exploration

This section focuses on risk screening and scenario selection based on the needs of local actors.

2.2.2 Screen risks (selection of main hazards)

Based on survey results and consultations, the project team decided to expand the original hazards (heatwaves and extreme rainfall) with two new thematic workflows: **wildfires** and **droughts**. The heatwave and extreme rainfall were renewed with incorporation of the local data and adjustments of the results and workflow steps to KE UMR needs.

With the increasing frequency of heatwaves, vulnerable groups are more often exposed to adverse heat impacts, reflected in a rising number of heat-related collapses (Kosice online, 2024; Teraz.sk, 2025). A new approach was applied in which LST images were selected based on purchased in-situ air-temperature measurements. This approach provides an input for estimating heat-risk levels for vulnerable locations within the KE UMR.

Persistent heat also exacerbated other hazards, including wildfires and droughts. The table of registered wildfires from minv.sk documents the adverse impacts of wildfire events. In addition, the Intersucho portal regularly reports drought impacts on agriculture and vegetation during the summer months in the KE UMR.

The impacts of extreme rainfall are summarized in the hazard impact database. In Phase 2, additional extreme precipitation events were identified using the purchased extreme precipitation intensity dataset, which helped with the detection of 16 more events compared with Phase 1. Phase 2 also applied CLIMAAX bias-uncertainty tool to support the selection of EURO-CORDEX (CDS, 2019a, CDS, 2019b). climate scenarios for estimating changes in rainfall intensity and return periods (RP).

2.2.3 Choose Scenario

In the second phase of the project, the selected time horizon for the climate scenarios was reconsidered. The assessment focuses on the 2021–2050 period, which aligns with the time horizon used in the SHMU national climate scenario products (SHMU, 2025).

SHMU projections are considered highly reliable for Slovakia because their bias correction is based on observations from 71 climatological stations across the country and is available for both RCP 4.5 and RCP 8.5. In addition, SHMU incorporates national expertise and local context in the selection and processing of climatological reference data.

However, these SHMU scenario outputs are not currently available in daily or monthly time steps suitable for direct use in the CLIMAAX tools; they are primarily provided as 30-year (2021–2050) mean values. Therefore, EURO-CORDEX data were used as the main input for the CLIMAAX workflows, while SHMU data were used only for benchmarking and comparison of 30-year mean climate conditions.

Heatwaves:

for heatwave days occurrence the EuroHEAT project (CDS, 2019b) results which comes as a bias corrected Eurocordex ensemble mean for RCP 4.5 and 8.5. was selected. The selection was based on the fact that these data are bias corrected and comes as multimodel ensemble mean. For tropical days and nights occurrence, the SHMU climate projections (SHMU, 2025) for climate normal periods 2021-2050.

Extreme rainfall:

Selection of the models were based on CLIMAAX bias-uncertainty tool the GCM: ICHEC-EC-EARTH, RCM: KNMI-RACMO22E, Member: r12i1p1 was the best performing for precipitation against the EOBS with the smallest bias of (0.76 %) for precipitation. The EOBS was selected because it is based on the measured data from rain gauges. The second best performing GCM and RCM combination was the GCM: MOHC-HadGEM2-ES, RCM: KNMI-RACMO22E, so the analysis was also performed with this data to verify results.

Wildfires and Droughts:

Selecting an appropriate GCM–RCM combination for wildfire and drought analyses was more complex than for precipitation or heatwave-only assessments, because both temperature and precipitation jointly drive these hazards. Therefore, the primary selection criterion was the best overall agreement with observed temperature and precipitation in the reference period based on CLIMAAX bias-uncertainty tool.

Since there were not any significant dynamics in the socio-economic development in the KE UMR in the last decades. For the 2021-2050 time period, the KE UMR did not consider any significant socio-economic developments.

Population is broadly stagnant to slightly decline, with urban concentration in/around Košice and decline in more rural districts. One recent regional profile notes that the population decrease is driven mainly by net out-migration, even when natural change is positive (Slovak statistical portal, 2025).

The assessment incorporated several socio-economic trends relevant to the Košice UMR. Demographic projections indicate a continued ageing of the population and a gradual decline or stagnation of population numbers in several municipalities, as described in regional development documents. These trends informed the identification of vulnerable groups, particularly young children and older adults, for the purpose of refining vulnerability mapping.

In terms of future economic and food-related activities, the analysis considered the general structure of the local agricultural sector and its sensitivity to climate change. Agriculture remains an important component of the regional economy, and climate projections suggest that increasing temperatures, more frequent drought periods, and irregular precipitation patterns may negatively affect crop productivity and the stability of local food systems. Although the region does not rely heavily on large-scale food production, climate-related impacts on agriculture may influence local supply chains, food availability, and the economic resilience of rural municipalities within the UMR.

Current socio-economic planning in the region is oriented toward the short-term horizon up to 2030, while the climate scenarios applied in this assessment extend to the period 2021–2050. This allows the analysis to capture medium-term implications for population dynamics, economic activities, and the functioning of local food systems, even though these aspects are not yet fully integrated into existing strategic planning frameworks.

Future climate conditions and future socio-economic developments were combined primarily at the scoping and workflow-selection stage. Climate projections for 2021–2050 (RCP 4.5/8.5) were used to identify hazards likely to intensify, while socio-economic trends and policy priorities in the KE UMR—especially the goal to become a climate-resilient, age-friendly city that can maintain population and service provision despite demographic ageing—were used to identify the most relevant exposed and vulnerable groups and assets (e.g., elderly population, health and social-care facilities, schools/kindergartens, critical infrastructure). This combined perspective guided the selection of CLIMAAX risk workflows and the interpretation of results for future conditions. Where quantitative projections of future exposure were not available, current exposure layers were used as a baseline and the implications of demographic change were discussed qualitatively

The SCOPE project mainly focusses on the medium-term climate scenarios. Based on the recommendations from SHMU and Slovak adaptation strategy focused mainly on the medium-term climate scenario 2021-2050.

2.3. Regionalized Risk Analysis

In Phase 2, the CLIMAAX workflows were regionalized for the Košice UMR by integrating local and national datasets to improve robustness and local relevance. SHMÚ national climate scenario products were used to benchmark the initial EURO-CORDEX (CDS, 2019a, CDS, 2019b) inputs and measured observations from SHMÚ climatological and rainfall gauge stations were used alongside scenario data to validate event timing/intensities and strengthen the local evidence base (e.g., hazard impact database). The selection of EURO-CORDEX model combinations was supported by the CLIMAAX bias-uncertainty tool, prioritizing models that best match observations in the reference period. Future climate conditions were represented primarily by scenario-based estimates for 2021–2050 (RCP 4.5/8.5). Future socio-economic developments were included through scoping consistent with the KE UMR pathway toward a climate-resilient, age-friendly city, which guided the prioritization of workflows and the selection of receptors (health and social-care facilities, education facilities, vulnerable communities, critical buildings).

Heatwaves:

In Phase 2, the CLIMAAX heatwave workflow was fine-tuned by integrating local in situ measurements and improving the selection and interpretation of satellite-derived LST products. Measured air temperature and precipitation data from SHMÚ were purchased. The air-temperature observations were used to verify the selection of LST imagery, because satellite scenes are not available for every day; in situ measurements make it possible to identify peak-heat periods and select only images representing the hottest days. A 5 class LST classification was applied, using a threshold of approximately 40 °C to delineate high heat hazard. Following Central European case studies (Farkas et al., 2024; Buzási, 2022; Geletič et al., 2016; Bečić and Gašparović, 2025; Veitengruber, 2023), LST-based heat-stress classes were used as the physical representation of heat hazard. High heat-hazard zones (upper LST classes; approximately ≥ 40 °C on selected hot days) were overlaid with locations with higher desity of vulnerable population like: hospitals, kindergartens, Roma settlements, and social service facilities to map heat exposure and indicate potential heat-risk hotspots. As an additional step, the KE UMR team used the Copernicus Browser NDVI tool to observe potential heat impacts on selected green areas (e.g., reduced greenness during hot periods).

Measured air temperature for the Košice Airport station is also available from NOAA (NOAA, daily observation data). Because SHMÚ could not confirm the reliability of the NOAA dataset, the purchased SHMÚ observations were used to benchmark the NOAA Košice Airport time series against official national records. Specifically, the NOAA Košice Airport data were compared with the SHMÚ Košice city-centre station and showed good overall agreement: over the tested six-year period, the average difference was 0.48 °C and the maximum difference was 1.7 °C. Therefore, NOAA air-temperature data can be used free of charge in future risk analyses as an alternative to purchased SHMÚ air-temperature data.

Impact metric/risk output: A heat-risk level map combining high LST exposure with vulnerable receptors (and, where available, capacity/importance of facilities).

Indirect impacts considered: land-use/land-cover change, and vegetation conditions can modify urban heat intensity and sensitivity**.**

Key limitations: station temperatures may not capture the hottest micro-locations within the urban area but are sufficient for selecting peak-heat LST scenes; LST is available only for cloud-free satellite overpasses.

Extreme rainfall:

Fine-tuning and data used in Phase 2, the CLIMAAX extreme-rainfall workflow was fine-tuned by integrating measured precipitation data from SHMÚ and strengthening the local evidence base through a hazard impact database. SHMÚ station observations provide key information on extreme rainfall intensities (e.g., mm/24 h) for the most severe events affecting the Košice UMR and its surroundings since 2000. These data supported the compilation and verification of reported event intensities (including cross-checking values reported in local sources) and the definition of locally relevant critical rainfall thresholds associated with high impacts (flash floods and pluvial flooding). Future changes in extreme rainfall occurrence were assessed using SHMÚ national climate scenario products, which were used to contextualize observed extremes and support interpretation of potential changes in hazard frequency/intensity. NOAA precipitation data were reviewed only as complementary information to the purchased SHMÚ precipitation dataset, because precipitation is highly spatially variable and robust local assessment requires a dense network of measurement stations.

Impact metric/risk output: a map of impacted locations from the hazard impact database to communicate the spatial distribution of affected places; tables summarizing changes in rainfall intensity and/or return period (RP) for selected events/scenarios.

Indirect impacts considered: drainage capacity and maintenance strongly influence pluvial flooding impacts; in forested areas, road density/design can increase runoff connectivity and erosion risk.

Key limitations: gauges may not capture local peak rainfall intensities; however, the selected stations were recommended by SHMÚ and represent the most reliable available option. Scenario uncertainty remains.

Wildfires:

The CLIMAAX wildfire ML workflow was enhanced using registered wildfire events in Slovakia (2014–2025) provided through CLIMAAX SK cooperation (Ministry of Interior), improving local realism and evaluation. Exposure layers included critical buildings (KE UMR) and supporting datasets (CORINE Land Cover, 2018, 100×100 m; DEM, 100×100 m). Climate forcing for hazard assessment used EURO-CORDEX. Vulnerability focused on critical buildings with evacuation constraints.

Impact metric/risk output: wildfire exposure/risk maps for critical buildings, emphasizing locations with higher concentrations of people with difficult evacuation; summary indicators such as change in area of high wildfire hazard can support interpretation.

Indirect impacts considered: vegetation composition and fuel structure strongly influence long-term risk; forest management and climate-resilient species selection (e.g., Seed4forest) can reduce vulnerability.

Key limitations: fire occurrence records may be incomplete, and detection/reporting can vary; spatial resolution of land cover and DEM (100 m) limits micro-scale interpretation.

Agricultural droughts:

Fine-tuning and data used: Crop selection was regionalized by prioritizing locally strategic crops based on the four largest agricultural companies in the KE UMR (Infoma, 2024). Hazard and impact calculations followed CLIMAAX inputs based on EURO-CORDEX climate indices 2021–2050(CDS, 2019a). Exposure used crop-specific information (CLIMAAX) and the local crop list; vulnerability used irrigation availability (CLIMAAX).

Impact metric/risk output: revenue loss outputs for prioritized crops (CLIMAAX).

Indirect impacts considered: crop and management choices (drought-tolerant crops, irrigation feasibility, adaptive practices) influence vulnerability under future climate conditions.

Key limitations: limited availability of spatially explicit future land-use/crop-area projections; scenario uncertainty affects yield/revenue estimates.

2.3.1 Hazard #1 Heatwave - fine-tuning to local context

Table 2-1 Data overview workflow #1

Hazard data	*Vulnerability data*	*Exposure data*	*Impact metrics/Risk output*
Heat days occurrence 1986-2085 EuroHEAT (CDS, 2019b)	Distribution of vulnerable population -5 +65	Heat exposure of buildings/places with high concentration of vulnerable population: kindergartens, Roma settlements, social services buildings, hospitals. (NEW)	Possible heat risk to vulnerable population
*Land surface temperature for summer months **from** RSLab (Parastatidis et.al, 2017)*	Capacity of vulnerable buildings and places with higher concentration of vulnerable population. (NEW)		Possible heat risk level for selected buildings/places with vulnerable population. (NEW)
*Tropical days/nights climate scenarios **from** SHMU NEW, (SHMU, 2025)*			
Measured air temperature (max min) from climatological stations (SHMU) (NEW)			

2.3.1.1.Hazard assessment

The heatwave hazard assessment was based on EuroHEAT (CDS, 2019b) indicators and SHMÚ climate scenario data (SHMU, 2025). The main objective was to quantify the potential future occurrence of heat events for the selected time horizon and scenarios, and to complement these projections with local observations by documenting overheating conditions through measured data and by assessing heat exposure at locations with high concentrations of vulnerable populations.

EuroHEAT heatwave definition:

For the summer period from June to August, heatwaves are defined as periods in which the maximum apparent temperature (Tappmax) exceeds its threshold (the 90th percentile of Tappmax for each month) and the minimum temperature (Tmin) exceeds its threshold (the 90th percentile of Tmin for each month) for at least two consecutive days. Apparent temperature is a measure of relative discomfort due to the combined effect of heat and high humidity, developed from physiological studies on evaporative skin cooling. It can be calculated from a combination of air temperature and dew point temperature.

SHMÚ heatwave definition:

According to the Slovak Hydrometeorological Institute (SHMÚ), a heatwave is defined as a period lasting at least 5 days, during which the daily maximum air temperature reaches or exceeds 30 °C (figure 2-1).

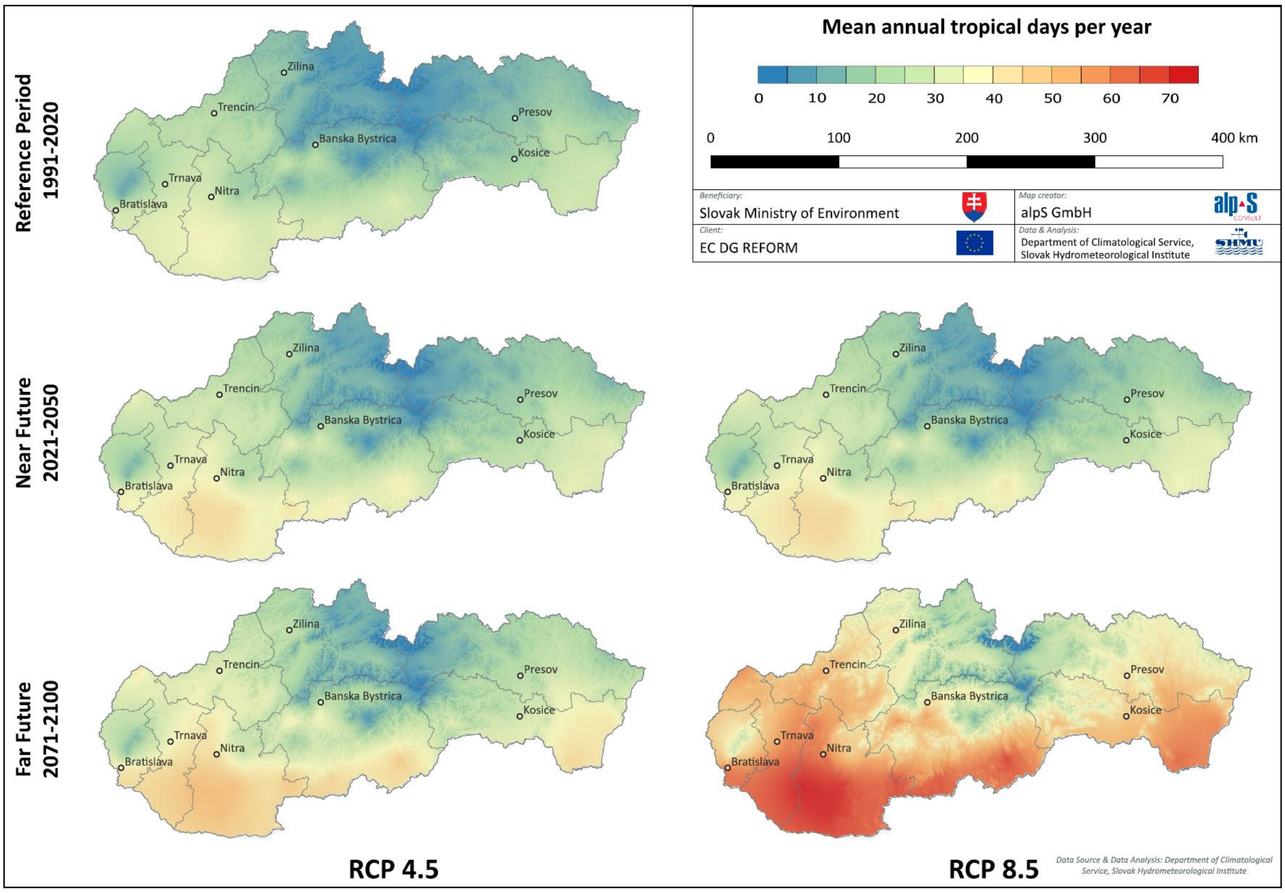


Figure 2-1 Mean annual tropical days per year, SHMU Future climate scenarios (SHMU, 2025)

Based on a visual comparison of the SHMÚ and EuroHEAT (CDS, 2019b) scenarios, both approaches project a significant increase in heatwave occurrence. Unfortunately, the SHMÚ climate projection, currently the only official national climate projections, are available only as PDF images, which prevents extraction of exact values (e.g., the number of tropical days); these values can only be read manually from the figures. However, the CLIMAAX SK initiative is encouraging SHMÚ to release the projections as georeferenced raster datasets, and SHMÚ has responded positively, indicating that such data should be released in the coming months. This is an encouraging signal for Slovak cities and regions that want to use SHMÚ climate scenarios in their climate risk assessments (CRA).

Table 2–2 presents the zonal statistics (mean, maximum, and median) for the Košice UMR, calculated from EuroHEAT climate-projection raster data. The results indicate a significant projected increase in heat occurrence for 2021–2050. Based on EuroHEAT, the mean annual number of heat days is projected to be 10 under RCP4.5 and 11 under RCP8.5.

Table 2-2 Comparison of the EuroHEAT and SHMU climate scenarios indices.

	scenario	period	mean	max	median	rel. change mean
EuroHEAT heatdays occurrence		1991-2020	5	7	5	
	rcp45	2021-2050	**10**	**13**	**10**	82
	rcp85	2021-2050	**11**	**16**	**11**	101

Selecting of the LST pictures only for the tropical days over 30 deg (based on the KE airport and KE Podhradova climatological stations) in Slovakia total of 7 pictures from the 1.6.2024 till 31.8.2025 was selected. The definition of the tropical day comes from the SHMU (SHMU, 2015). Total of 7 pictures from the 1.6.2024 till 31.8.2025.

The only last two years were selected for the analysis, because the KE UMR focuses mainly on recent changes in local infrastructure. The year 2024 was also the hottest year in the history of measurements in Slovakia. Based on the provided heatwave hazard assessment results in the coming years should be even hotter. Following Blöschl et al. (2007), climate-scenario projections should not be used in isolation. Impact assessments should combine scenario-based model cascades with analyses of long historical series and observed extremes, using the latter as a key reference for understanding variability and testing the plausibility of projected changes. Based on this, the year 2024 is suitable for observed extremes.

Calculates the median values map from these images. Since only the images for the tropical days were selected the median will provide robust results. Median provides multiple advantages against only maximum values. Using the median LST over all tropical days gives you a robust "typical hot-day" heat map that strongly highlights persistent urban hot spots while minimizing the influence of outliers from clouds, sensor errors, time-of-day differences, or unusual land-cover states (like freshly harvested fields) the results are displayed in the Figure 2-2.

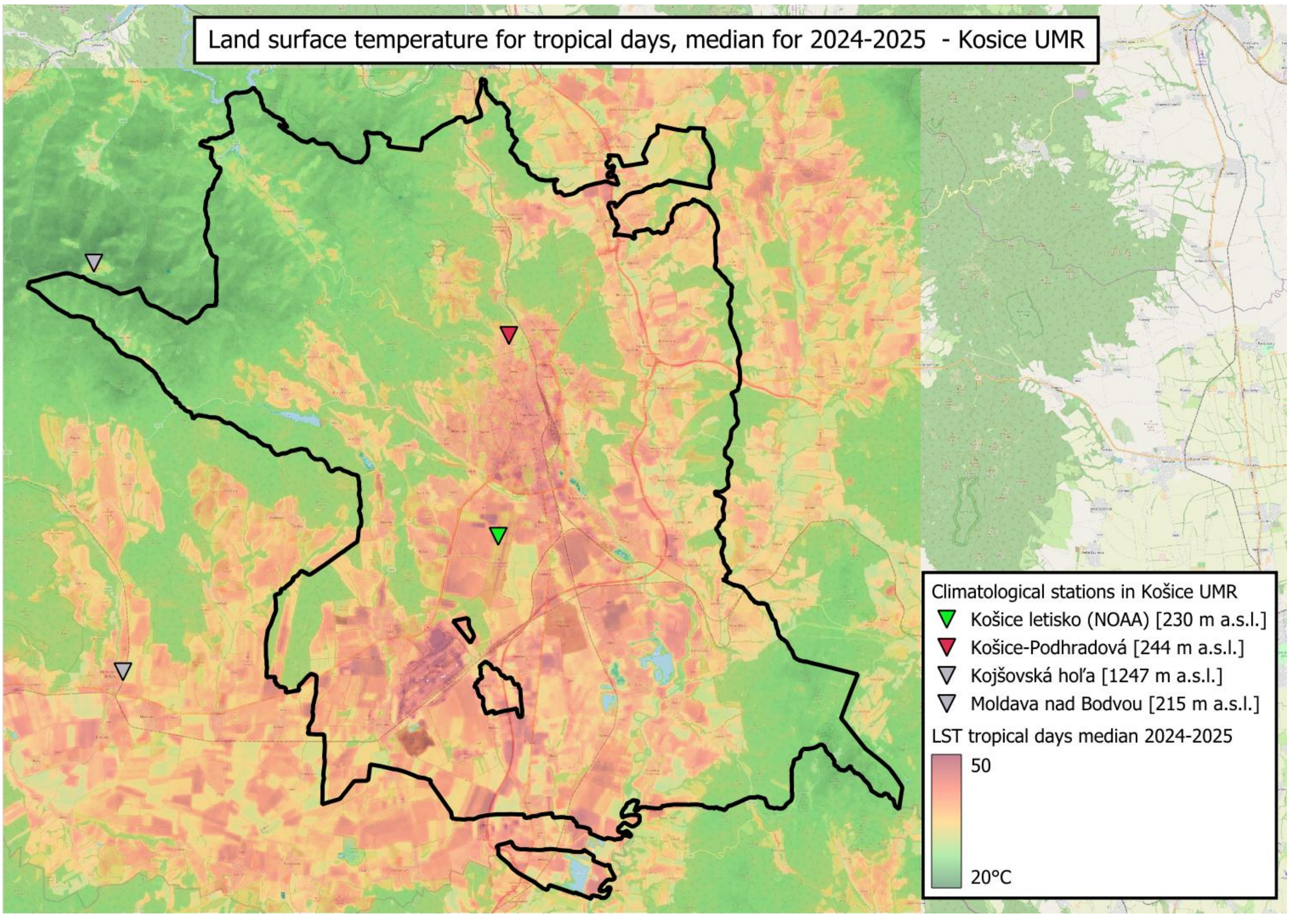


Figure 2-2 Land surface temperature for the tropical days, median from the available pictures for the summer months 2024-2025 with the nearest climatological stations in KE UMR.

The LST images selected based on measured air temperature were then used to run the CLIMAAX heatwave risk workflow at the local level. The results demonstrate how important the careful selection of LST imagery is. When we compared the results for summer 2024–2025 (median LST from tropical days with air temperature above 30 °C) with the first-phase results (median LST from all available summer images for 2013–2024), the second-phase maps more clearly highlighted the most overheated areas during the last two summers and better reflected recent land-use changes. In contrast, the first-phase results provide an overview for a longer reference period. Since Košice is a relatively small city in the European context and its urban area is not highly diverse, a five-class classification was selected because a 5 × 5 matrix was applied in the subsequent step, and five classes were sufficient for interpreting the results.

The phase 2 results will also be selected as the main output of the heatwave hazard workflow, as they better capture differences in urban areas that are most prone to heat islands. These results also better represent LST behavior during tropical days, which poses the greatest danger to vulnerable population groups. The comparison of the original and adjusted methods by KE UMR are displayed in Figure 2-3.

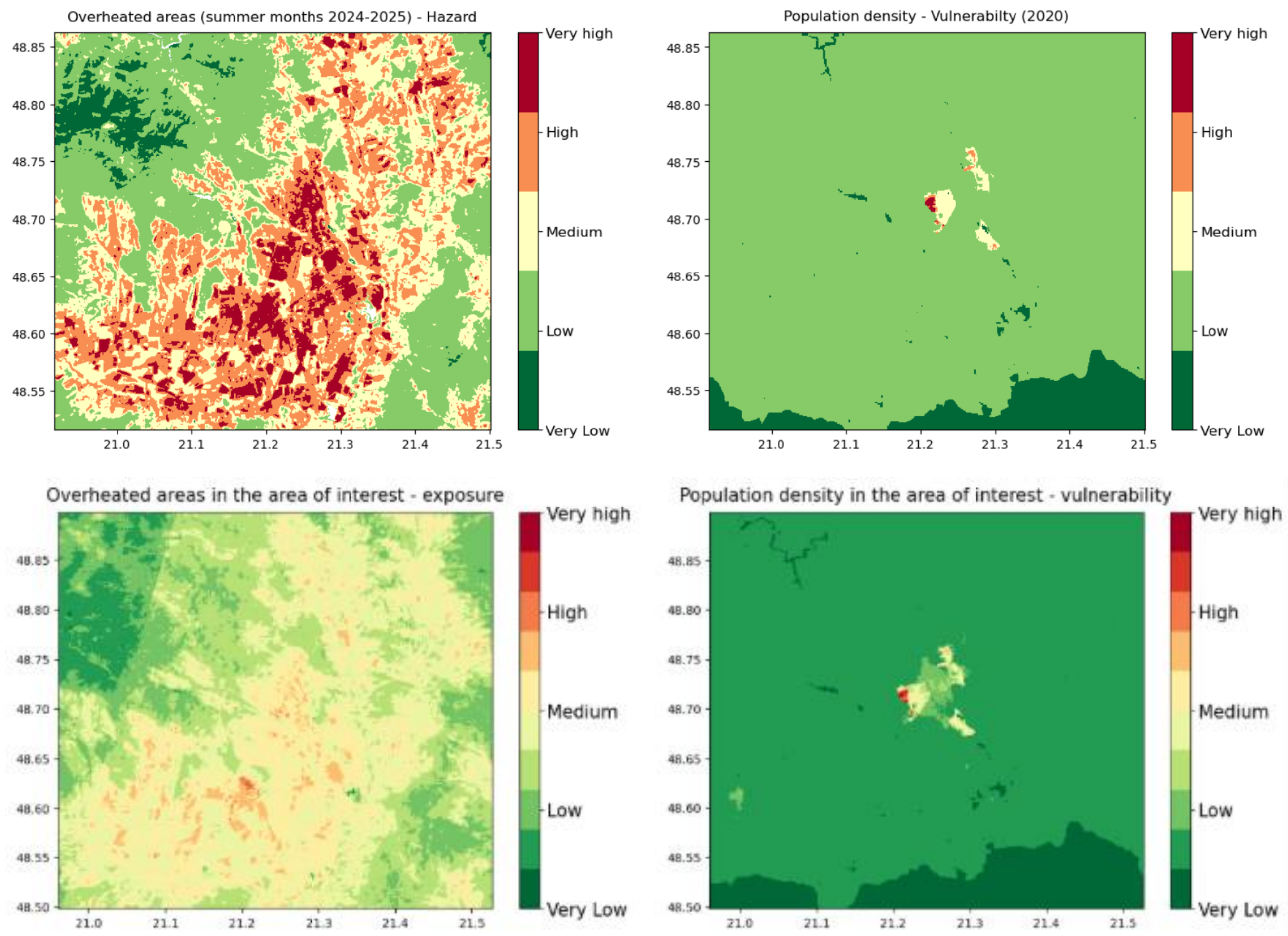


Figure 2-3 Phase 2: Overheated areas for summer months (tropical days) 2024-2025 (left-top) and Worldpop vulnerable population density 2020 (right-top) 5 class division, and Phase 1: Overheated areas for summer months (all available days) 2013 - 2024 (left-bottom) and Worldpop vulnerable population density 2020 (right-bottom) 10 class division the results of the CLIMAAX heatwave risk workflow for local level.

2.3.1.2. Risk assessment

The risk assessment provides two main results. The first is derived from the combination of heat exposure and the capacity of selected critical sites/buildings and is referred to as the **Heatwave risk level for critical buildings (heat exposure + capacity)**. The second follows the original CLIMAAX heatwave workflow and is based on the combination of heat exposure and the spatial distribution of the vulnerable population from [WorldPop](#) (2020), called **Heat risk level to vulnerable population**.

The critical places/buildings were selected based on their known potential for a high concentration of vulnerable population groups, such as older people, children, patients, and people with disabilities. In the Košice UMR, these include hospitals, kindergartens, social services buildings, and Roma segregated settlements. High heat exposure in these locations can negatively affect these sensitive groups, who are often in poorer health conditions. The results of the heat exposure for the selected places inside the KE UMR for long term 2013-2024 (all available summer days) and short term 2024-2025 (tropical days) are displayed in Figures 2-4 and 2-5.

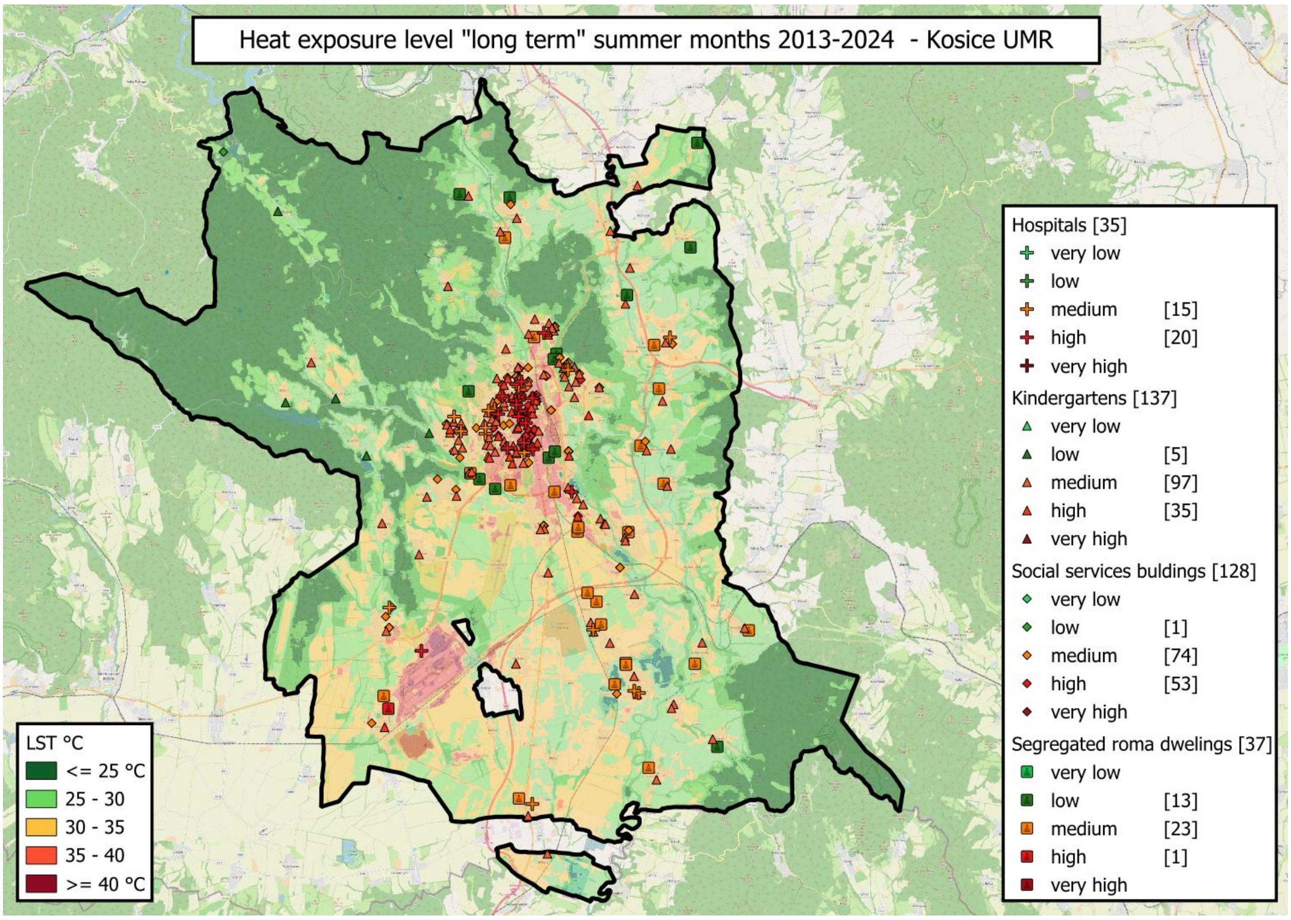


Figure 2-4 The longer-term heat exposure level based on the combination of the LST median for 2013-2024 summer months for selected critical places/buildings with the high concentration of vulnerable people.

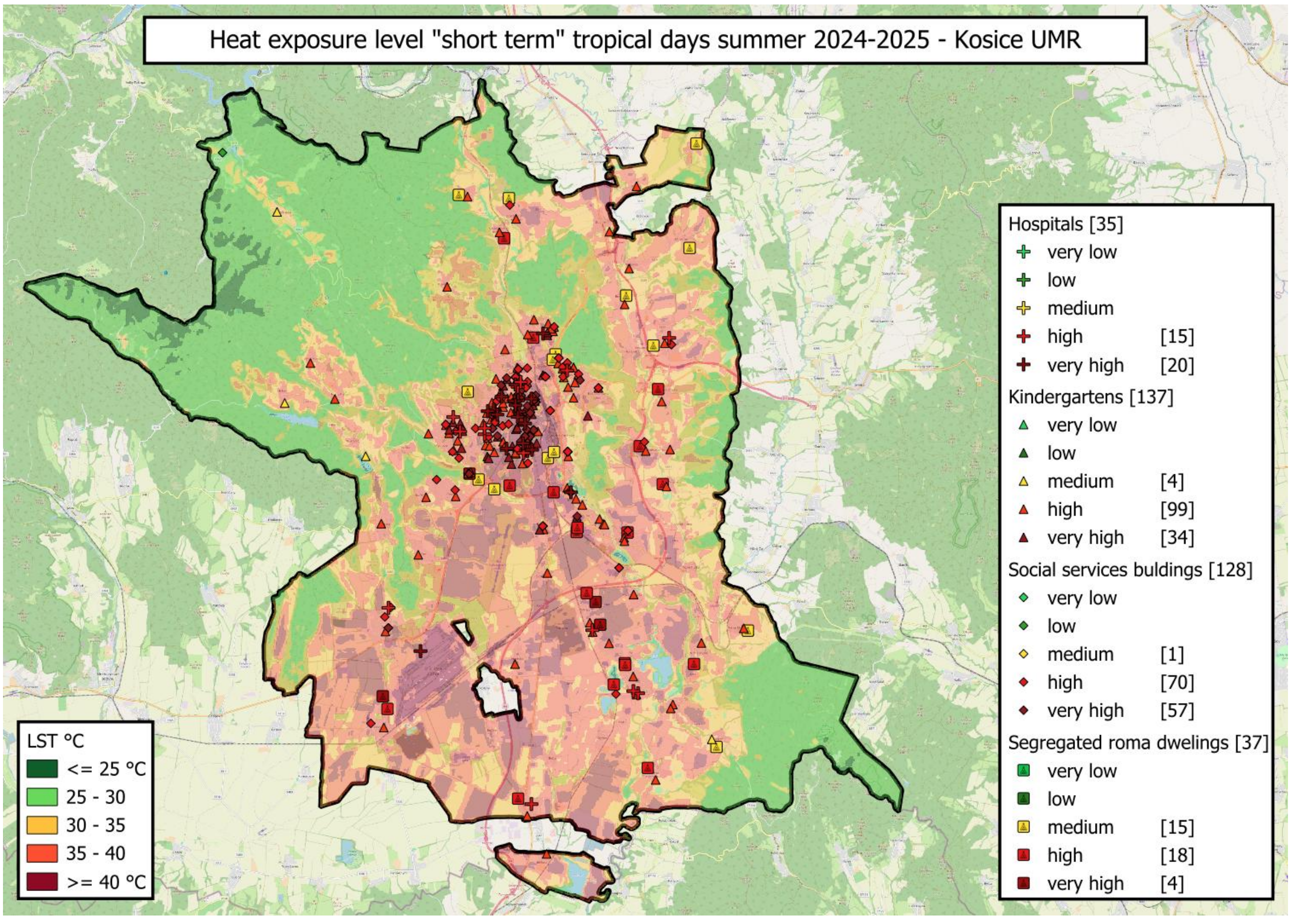


Figure 2-5 The shorter-term tropical days heat exposure level based on the combination of LST median for summer months 2024-2025 for selected critical places/buildings with the high concentration of vulnerable people.

Table 2-3 Heat exposure to vulnerable places

Heat exposure for critical buildings (summer 2024-2025)			
Vulnerabilty	***Number of exposed areas (high)***	***Number of exposed areas (very high)***	***Total number***
Kindergartens by capacity	99	**34**	137
Roma settlements by capacity	18	**4**	37
Social services by capacity	70	**57**	128
Hospitals by capacity	15	**20**	35

Table 2.3 results provide information about the selected critical places/buildings which are in the area with the high or very high heat exposure level.

Heatwave risk level for critical buildings (heat exposures + capacity):

The heatwave risk level for critical buildings brings also information about the capacity of the building which provides the number of potentially exposed people to extreme heat per each place. Result (figure 2-6) is then based on the combination of heat exposure (classed from 1-5) with the capacity of the buildings (classed from 1- 5). These steps show the level of prioritizing and urgency for applying the mitigation measures. These identified buildings or places will be prioritized for the inspection of the resilience of the building's conditions against the extreme heat. The total number of exposed buildings with high and very high heat risks are registered in table 2-4.

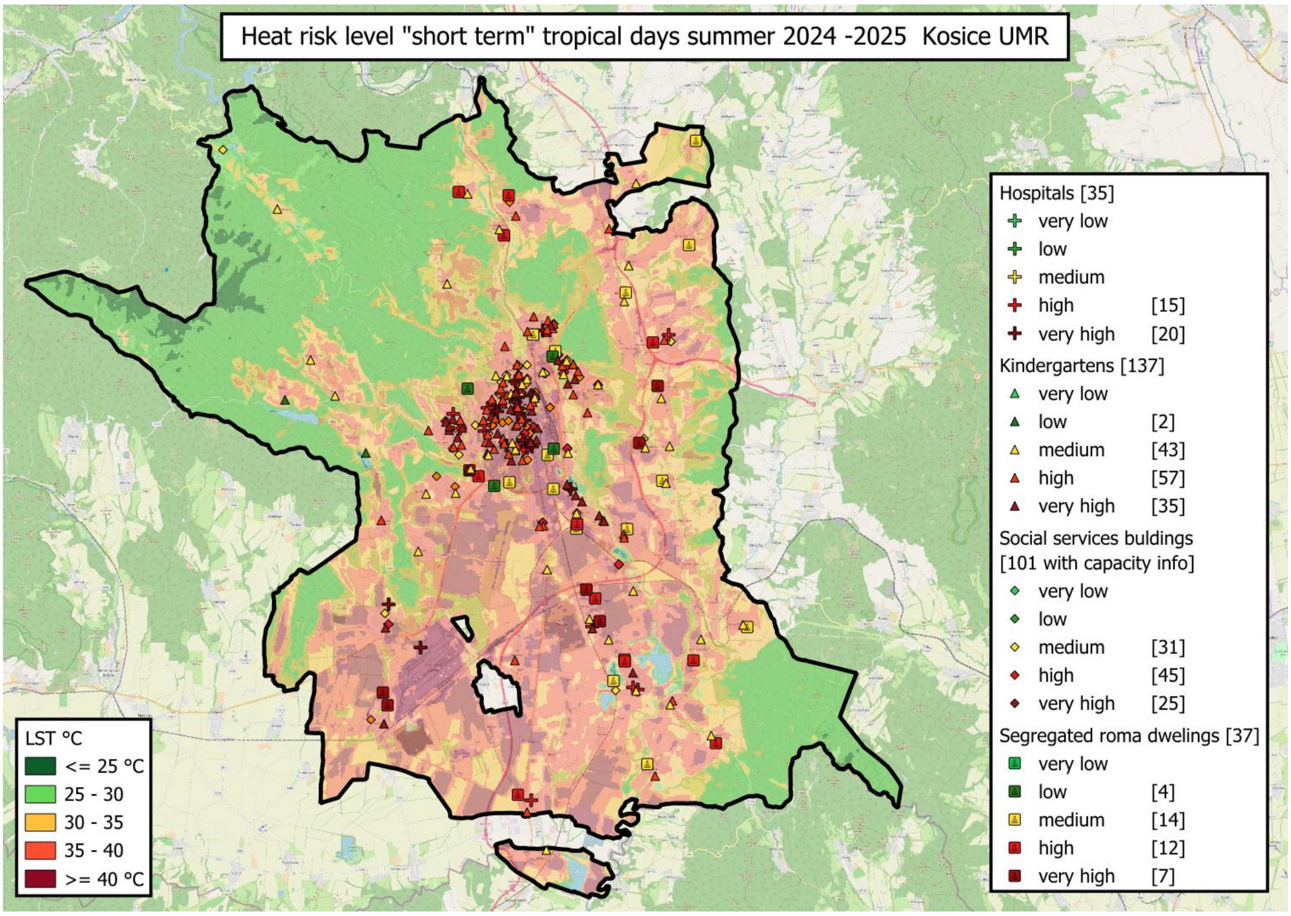


Figure 2-6 Heat risk level, (heat exposure + capacity) "short term" for tropical days from summer months 2024-2025 for selected critical places/buildings with the high concentration of vulnerable people

Table 2-4 Heat risk level for selected critical places/buildings with the high concentration of vulnerable people

Heat risk level for critical buildings (heat exposure + capacity)			
Exposure	***Number of high risk areas***	***Number of very high risk areas***	***Total number***
Kindergartens	57	**35**	137
Roma settlements	12	**7**	37
Social services	45	**25**	101
Hospitals	15	**20**	35

Heat risk to vulnerable population (CLIMAAX):

The final output of the CLIMAAX heatwave risk assessment workflow at the local level is a map of heat risk for the vulnerable population in the Košice UMR. In this assessment, vulnerable population data from WorldPop were combined with mapped overheated areas derived from the Phase 2 selection of LST imagery for tropical days. Based on these results, KVP, Ťahanovce, Luník IX, and the neighborhoods along Važecká and Galaktická streets were identified as areas most prone to overheating (Figure 2-7 and 2-8). These settlements are characterized by high building density and, based on the project results, will be further investigated to identify and prioritise appropriate mitigation measures.

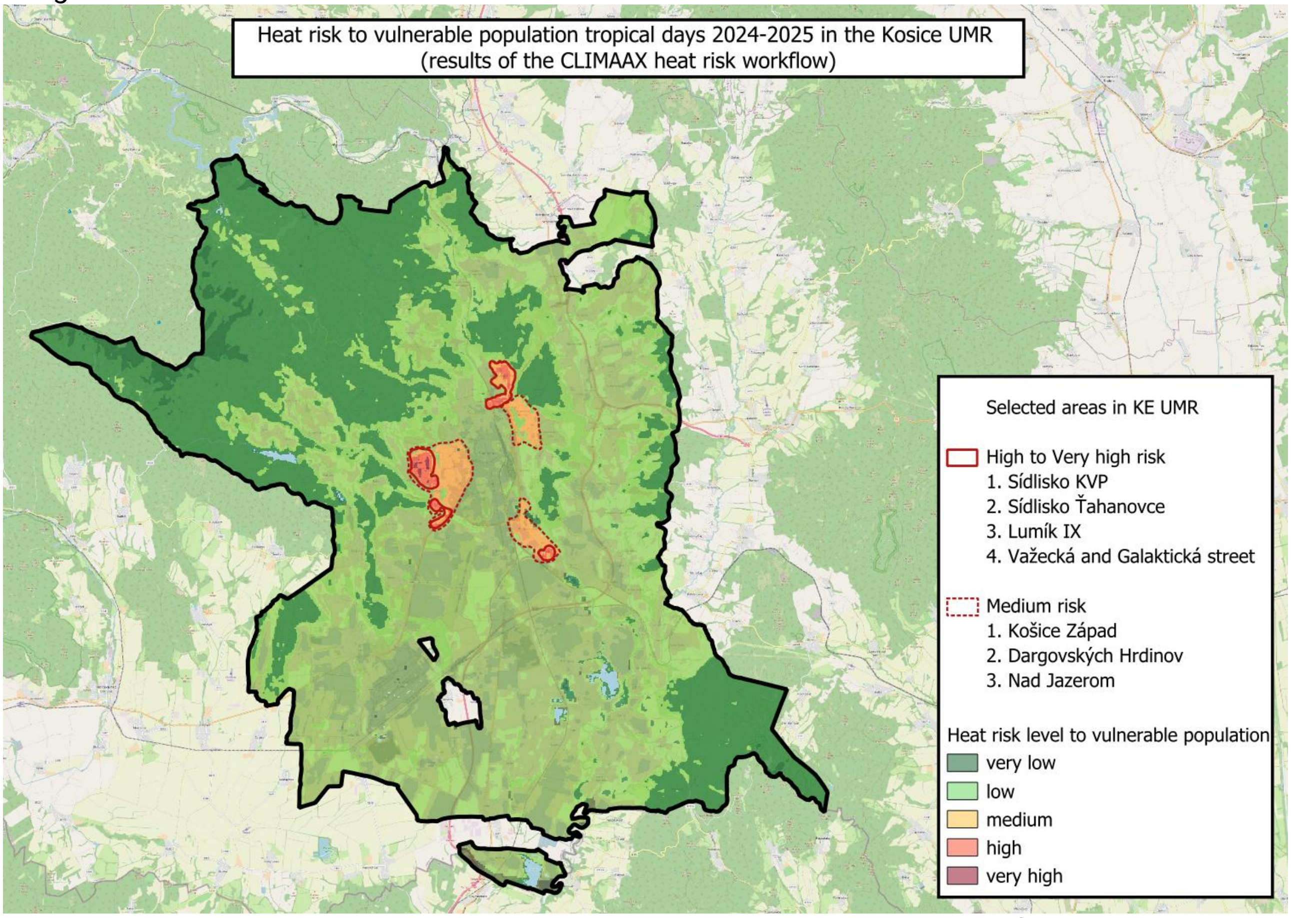


Figure 2-7 Heat risk level to vulnerable population in the Kosice UMR, based on the combination of the heat exposure level for summer 2024-2025 and distribution of the vulnerable population from Worldpop database.

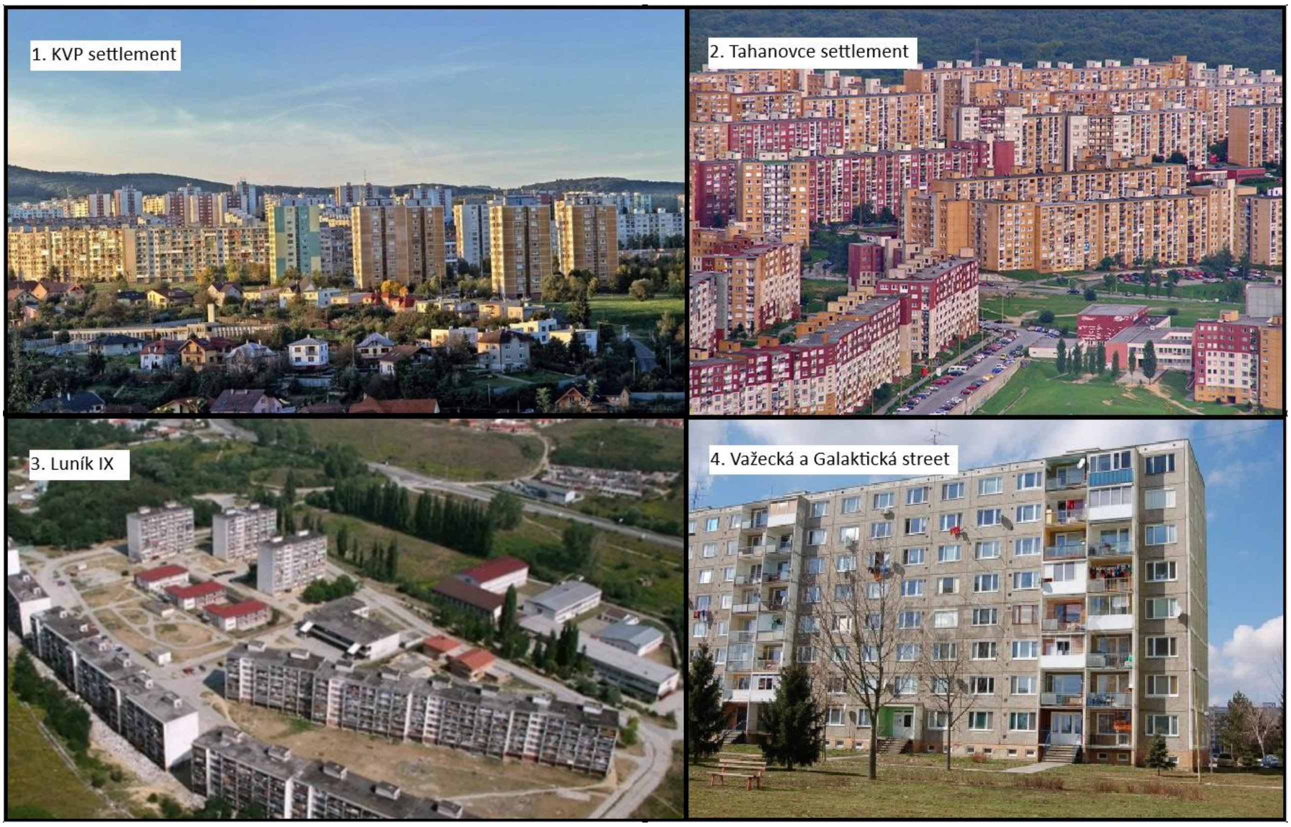


Figure 2-8 The photos of the 4 selected settlements from Kosice UMR for better visual imagination of these places and their typical buildings.

For the selected settlements, it is crucial to keep vegetated cool-down areas in good condition during the hot summer months. For this purpose, the Copernicus Browser NDVI monitoring service was selected to assess vegetation conditions during the summer in the selected green spaces, which can serve as cool-down places for citizens. This tool will also be used to monitor newly created green spaces in the future. Several green spots within the identified areas were analyzed using the Copernicus browser NDVI tool. The results showed that most of the green areas remained in good condition (maintaining high NDVI values) during the summer of 2025 (Figure 2-9). The most significant decrease in NDVI was observed in the KVP settlement, in the park at the crossroads of Moskovská and Klimkovičova streets.

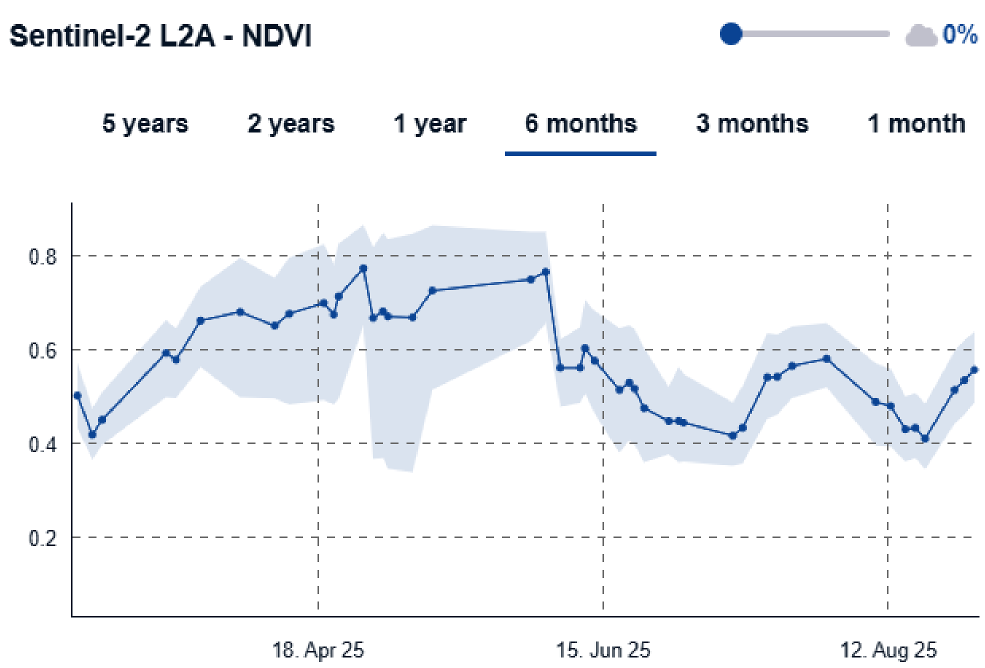


Figure 2-9 The Sentinel- L2A NDVI from [Copernicus browser] NDVI tool KVP setlement Moskovska – Klimkovicova

This workflow was adjusted to support a sustainable climate risk assessment (CRA) for the Košice UMR. The hazard assessment focuses on heat occurrence scenarios based on EuroHEAT (CDS, 2019b) data and selected heat indices provided by SHMÚ. The EuroHEAT and SHMU climate scenarios both predicted a significant increase in the occurrence of the heat in the future. It is also important to note that SHMU climate scenarios projected almost 40% higher heat days occurrence in 2021-2050.

The risk assessment heatwave workflow provides a clear overview of urban heat islands during periods of tropical days. First, Land Surface Temperature (LST) imagery from RSLab (Parastatidis, et al., 2017) was selected and validated using purchased SHMÚ observations. Second, as part of the sustainability improvement, SHMÚ data were tested against freely available NOAA data, with positive results. This comparison showed that NOAA data can be used as an alternative to the paid SHMÚ dataset. The threshold for selecting LST scenes was based on tropical days defined by SHMÚ (maximum air temperature ≥ 30 °C).

In the second step, the workflow demonstrates how selected critical locations can be combined with maps of overheated areas to derive exposure- and risk-related outputs. Finally, it shows how to identify the most critical hotspots by combining overheated areas with either the spatial distribution of selected critical buildings or the distribution of vulnerable population groups across the Košice UMR.

The Košice UMR approach produces a heat risk level map for critical buildings, providing an overview of sites suitable for monitoring and for prioritising adaptation measures. In contrast, the CLIMAAX approach generates a heat risk map for the vulnerable population, which identified four priority hotspots: KVP, Ťahanovce, Luník IX, and the areas along Važecká and Galaktická streets.

The final additional part of the workflow focused on vegetation health, since the vegetation is used as a most common weapon against urban heat. This part of the results presented how to estimate the vegetation's health during the summer months with the help of the Copernicus browser NDVI tool. On Kosice city park.

2.3.2. Hazard #2 Extreme rainfall - finetuning to local context

Table 2-5 Data overview workflow #2

Hazard data	*Vulnerability data*	*Exposure data*	*Impact metrics/Risk output*
3h precipitation flux **from** Euro-Cordex, (CDS, 2019a)	Number of affected people, type of damages [hazard impact database] [RENEWED]	Damaged or flooded areas specified in the hazard impact database. [RENEWED]	Hazard impact database (impact low-high) [RENEWED]
Projections of yearly average of heavy precipitation days >40mm/24h NEW, SHMU, (SHMU, 2025)		Exposed population, damage to buildings, disruption of transport (exposed roads, crossroads, transport system) [hazard impact database] [RENEWED]	DHI flood analysis in Kosice city. [DHI]
Measured extreme rainfall intensities mm/24h for 3 stations in the KE UMR [NEW, SHMU]			

2.3.2.1. Hazard assessment

The main goal of the extreme rainfall hazard assessment was to estimate rainfall intensities for the current and future climate (2021–2050). The intensities for recorded extreme rainfall events were based on observations from measurement stations within and around the KE UMR. Future rainfall intensities were estimated using EURO-CORDEX data. The results provide information on measured extreme rainfall events, the magnitude of potential future change for intensities and frequency and map (hazard impact database) of the past extreme rainfall events.

For the extreme rainfall hazard assessment, the two best performing combinations of the EuroCordex (CDS, 2019a) GCM and RCM were selected based on the CLIMAAX bias-uncertainty tool:

- **Precipitation:** GCM: ICHEC-EC-EARTH, RCM: KNMI-RACMO22E, Member: r12i1p1 (0.76 %)
- **Precipitation:** GCM: MOHC-HADGEM2-ES, RCM: KNMI-RACMO22E, Member: r1i1p1 (-1.3 %)

The focus was aimed at the historical period and projected period 2021-2050. Table 2.6 compares the return period and intensities for these selected GCM and RCM combinations. From the results, it's obvious that the ICHEC-KMNI combination predicts slightly milder future intensities than MOHC-

KMNI. The important result was that both projected a huge increase in the projected intensities from 8 to 43% (depending on selected RP and intensity).

Table 2-6 Historical and projected extreme precipitation intensities based on the selected Euro-Cordex climate scenarios for Košice UMR.

	GCM: ICHEC-EC-EARTH, RCM: KNMI-RACMO22E					GCM: MOHC-HADGEM2-ES, RCM: KNMI-RACMO22E				
RP	historical 1976-2005	rcp 4.5, 2021-50		rcp 8.5, 2021-50		historical 1976-2005	rcp 4.5, 2021-50		rcp 8.5, 2021-50	
	mm/ 24h	mm/ 24h	Rel. change	mm/ 24h	Rel. change	1976-2005	mm/ 24h	Rel. change	mm/ 24h	Rel. change
2	28.9	31.2	8.0	31.5	9.1	28.7	35.4	23.3	35.9	25.1
5	36.3	39.7	9.4	41.6	14.6	37.7	45.1	19.6	48.4	28.4
10	42.3	46.5	9.9	50.1	18.4	45.2	52.9	17.0	59.0	30.5
25	51.3	56.9	10.9	63.4	23.6	56.7	64.7	14.1	75.8	33.7
50	59.3	66.1	11.5	75.6	27.5	67.3	75.3	11.9	91.3	35.7
100	68.4	76.7	12.1	90.0	31.6	79.7	87.4	9.7	109.9	37.9
200	79.0	88.9	12.5	107.3	35.8	94.3	101.5	7.6	132.1	40.1
500	95.5	108.1	13.2	135.3	41.7	117.7	123.6	5.0	168.5	43.2

The projected intensities and RP were displayed also in the graph in figure 2-10 (for better readability only to 100yRP). This graphical form better displays the differences between the selected models and can also provide information about potential uncertainties which can come from the wrong selected models. The biggest differences were between the projected RCP 8.5 scenarios. For better visualization of the broader context of extreme rainfall, a map of the whole of Slovakia is presented in figure 2–1. The map shows that the Košice UMR is one of the regions most threatened by extreme rainfall in Slovakia.

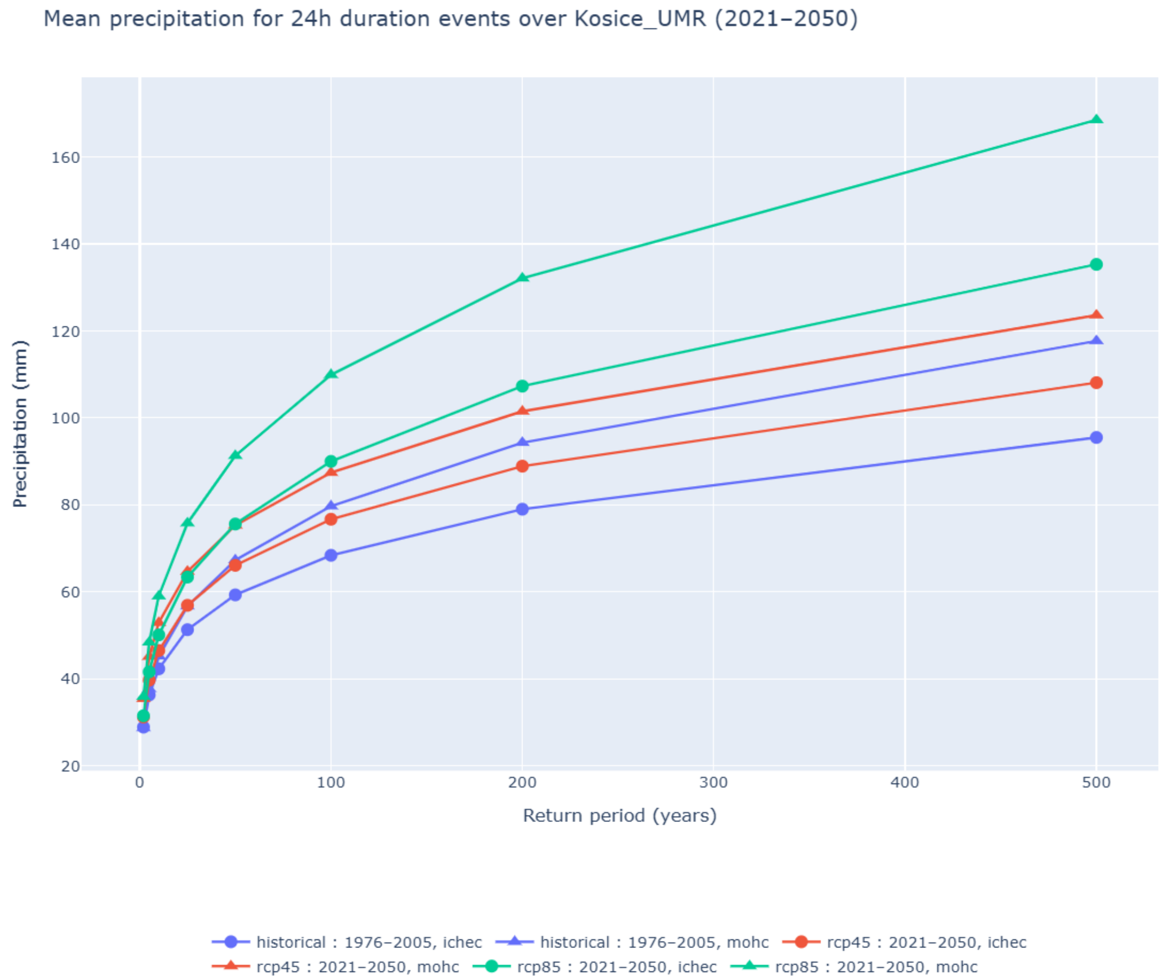


Figure 2-10 Historical and projected extreme precipitation intensities and RP for KE UMR based on the selected GCM and RCM combinations. The graph was clipped to RP 100 because of the better readability (you can find the full graph in the attachments)

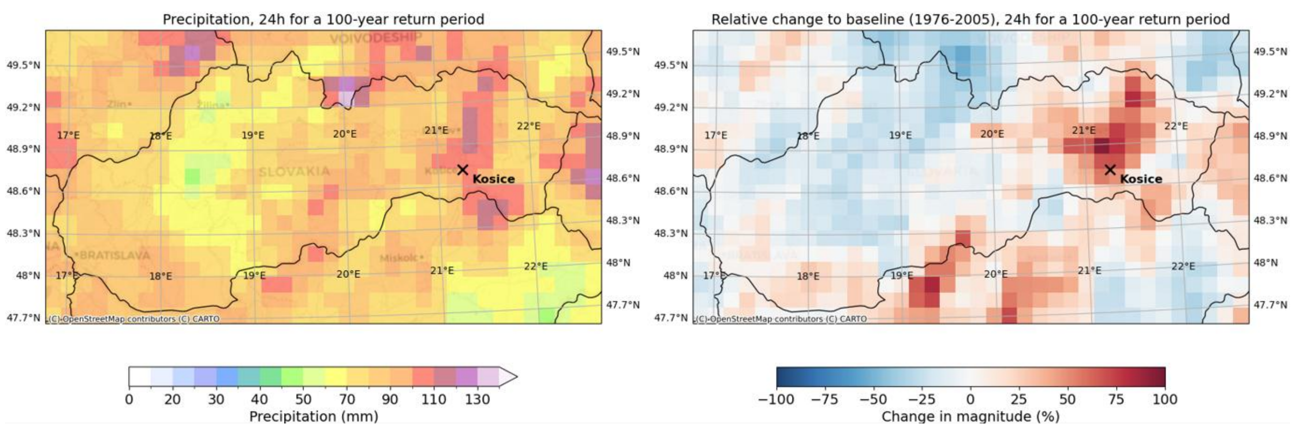


Figure 2-11 The 24 hour precipitation for 100year RP (left), and relative change to baseline (1976-2005) for the Slovakia GCM: ICHEC-EC-EARTH, RCM: KNMI-RACMO22E.

The next step was a comparison with SHMÚ climate scenarios (SHMU, 2025). However, the freely available SHMÚ scenario outputs do not provide exact precipitation intensities for the selected return periods (RPs). Instead, SHMÚ provides projections of the occurrence of heavy rainfall events

(>40 mm/24 h) for 2021–2050 and 2071–2100 under RCP 4.5 and RCP 8.5 (figure 2-12). However, these results were provided by SHMU only as PDF outputs and not as georeferenced map layers, so the comparison could be performed only visually.

The important information from this was that SHMÚ identifies 40 mm/24 h as a critical threshold for urban infrastructure across Slovakia. The main conclusion from the SHMÚ results is that extreme precipitation events are projected to increase. The 40 mm/24 h threshold was also tested using the hazard impact database.

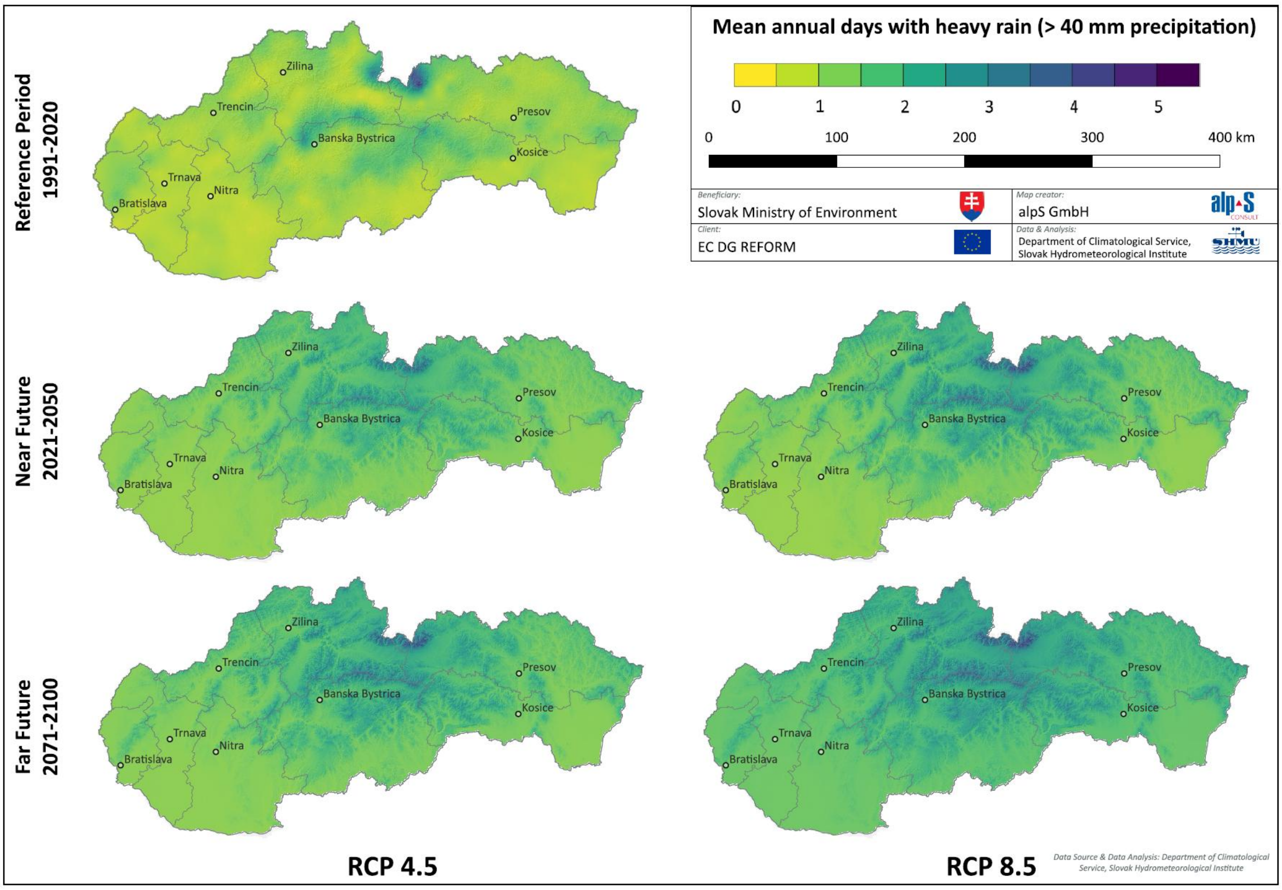


Figure 2-12 Mean annual days with heavy rain in Slovakia (SHMU, 2025)

An important part of the hazard assessment was collecting recorded rainfall accumulations for extreme precipitation events in the Košice UMR to support the hazard impact database. In Phase 1 of the project, were identified only seven dates with reported extreme precipitation within or near the Košice UMR. Phase 2 required a more comprehensive approach, using purchased SHMÚ measurements of daily rainfall totals (mm/24 h) from three stations within the Košice UMR. These observations were complemented with data from the freely available NOAA station at Košice Airport.

Together, these datasets provided measured precipitation intensities that helped to identify extreme rainfall days and to assess the variability of rainfall intensity between individual events. The differences among station records highlight the importance of a dense monitoring network. In table 2-7, the highest measured intensity for each extreme rainfall event is highlighted. In total, 19 extreme precipitation events were collected over the past 27 years. These data were used to define thresholds for three impact classes based on the observed damage, threats, and disruptions caused by the events.

In total, for 99 days were recorded where the daily measured rainfall exceeded 30 mm/24 h. Based on the last 27 years, the ratio of events above 30 mm/24 h (99 events) to events with documented impacts (19 impact events) suggests an approximate 20% likelihood that a 30 mm/24 h rainfall event will cause negative impacts in the Košice UMR.

In Table 2-7 the comparison of the return periods between two selected Euro-Cordex GCM and RCM combinations are significant differences. The return periods are similar for the low RP numbers but as RP number rises to highest numbers the changes rise more. If the focus will be on 3 selected Extreme precipitation thresholds': for 30mm (same 2y RP), 45mm (3 years/30% difference), 70mm (44years/77% difference). It is important to note that these RP were calculated for the 1976-2005 return period, while the observed intensities were from the years 1998-2024. Based on the recorded rainfall intensities the 30mm was recorded 99 times, the 45mm/27 times, the 70mm/1time in the observed period 1998-2024. The most occurrence of extreme rainfall over 30mm/24h was measured in 2010 (10 times) and 2016 (9 times).

The results also indicate that the NOAA station alone is not sufficient for detecting future extreme rainfall events, unlike the situation for heatwaves.

*Table 2-7 Recorded extreme rainfall intensities in the Košice UMR, with return periods assessed using EURO-CORDEX data. The value in the second row under the **24-hour intensity** indicates the associated **accumulated multi-day rainfall**, if there was any additional rainfall (e.g., **166 6d** means a recorded total of **166 mm over 6 days**).*

Date	Online sources mm/24h mm/days	Bankov mm/24h mm/days	Mala Ida mm/24h mm/days	Vysny Caj mm/24h mm/days	KE letisko (NOAA) mm/24h mm/days	RP ichec (1976-2005)	RP mohc (1976-2005)	Impact severity scale
7/20/1998	100	(NA)	(NA)	(NA)	(NA)	500	275	High impact (3)
8/19/2003	NA	69	33	18	37	100	54	Medium impact (2)
5/6/2010	50	50 166 6d	38 119 6d	36 111 6d	32 74 6d	25	15	Medium impact (2)
5/6/2013	(NA)	19 33 5d	14 29 5d	45 62 5d	26 43 5d	12	10	Medium impact (2)
5/27/2014	(NA)	17 27 5d	19 24 5d	36 38 5d	38 41 5d	6	5	Low impact (1)
7/8/2015	(NA)	66 71 2d	28 40 2d	24 29 2d	26 31 2d	80	45	Medium impact (2)
8/21/2016	(NA)	62	36	40	32	59	35	Medium impact (2)
6/13/2018	(NA)	68	25	13	38	95	50	Medium impact (2)
9/3/2018	(NA)	18	40	19	19	8	6	Low impact (1)
10/6/2020	30	16.5 44 (5d)	19.6 35 (5d)	23.2 48 (5d)	22.6 34 5d	2	2	Low impact (1)
10/13/2020	30	39 105 5d	27 80 5d	24 67 5d	28 77 5d	7	5	Low impact (1)
5/18/2021	34 67 5d	32 71 5d	40 71 5d	37 58 5d	34 66 5d	8	6	Low impact (1)
8/16/2022	(NA)	34	22	13	24	4	3	Low impact (1)

5/11/2023	28 44 4d	41 58 5d	36 56 5d	24 37 5d	27 42 5d	9	7	Low impact (1)
5/18/2023	25 52 / 5d	35 71 5d	41 80 5d	17 40 5d	25 51 5d	9	7	Low impact (1)
6/27/2023	(NA)	3	21	2	10	1	1	Low impact (1)
7/20/2023	(NA)	11 34 3d	25 56 3d	20 30 3d	28 76 5d	2	1	Low impact (1)
4/6/2024	(NA)	23 106 8d	25 81 8d	35 102 8d	58 146 8d	45	27	Medium impact (2)
6/13/2024	(NA)	30	23	16	12	2	2	Low impact (1)

Based on the measured rainfall intensities, thresholds for the impact classes were estimated. As shown in Table 2-7, daily rainfall totals above 30 mm/24h can cause problems for local infrastructure (eight registered low-impact events, with a mean of 35 mm/24 h). However, impacts become more severe when daily totals exceed 45 mm/24h (seven registered medium-impact events, with a mean of 60 mm/24 h).

Defining the high-impact threshold was more challenging because only one high-impact event (100 mm/24 h) was recorded over the last 27 years. Therefore, the high-impact threshold was set above the upper bound of the medium class (which reached 69 mm/24 h) table 2-8.

Table 2-8 Thresholds for the low, meduim and high impact classess estimated by the hazard impact database.

Location	Low impact		Medium impact		High impact	
	Impact	Threshold	Impact	Threshold	Impact	Threshold
Košice UMR level	Small and isolated flooding of lands and flood prone areas	**30mm/24h**	Localized flooding of lands and roads causing possible danger to life due to fast flowing water and overtopping. Disruption of travel time is expected	**45mm/24h**	Widespread flooding of lands and roads causing danger to life due to fast flowing water and overtopping. Evacuations and rescue actions may be required	**70mm/24h**

2.3.2.2. Risk assessment

The risk assessment was based on the hazard impact database. The main goal was to collect all available records of extreme rainfall impacts within the KE UMR and assign rainfall intensities to them. This provides a clear picture of how severe and how frequent extreme rainfall events have been. The next important step was to use the Extreme Rainfall Risk Assessment workflow to estimate how climate change may affect rainfall intensities and event frequency.

Overall, the hazard impact database describes 19 events with reported max daily rainfall/intensity of roughly 21–100 mm/24h. Most cases are local flash floods / pluvial flooding (runoff from slopes + small streams), often combined with storm impacts (fallen trees, lightning). A smaller number are river-flood–type impacts linked to the Hornád–Torysa system (e.g., 2010), where consequences are broader and longer lasting.

Severity distribution (Impact severity scale):

- High impact (3): 1 event
  - 20.07.1998 (100 mm) – catastrophic flash flooding in eastern Slovakia (incl. Jarovnice area; major regional consequences, casualties, extensive damage).
- Medium impact (2): 7 events
  - 2003, 2010, 2013, 2015, 2016, 2018 (June), 2024 (April). Typical pattern: multiple flooded houses/basements, active emergency response, local road disruptions; in one case (2010) also evacuations and service disruptions.
- Low impact (1): 11 events
  - Mostly localized yard/basement flooding, short-term road issues, firefighter pumping.
  - Warning-only / minimal documented impacts appear in 2022, 27.06.2023, 13.06.2024 (alerts issued but limited/no described damage).

Main impact types:

- People and safety
  - Most events report no fatalities and no major injuries in the Košice-area records.
  - Evacuations / large, affected population appear mainly in major basin-wide flooding (2010).
  - Recurrent risks: rapid water flow in streets/low-lying areas, contaminated wells, storm hazards (trees, lightning).
- Buildings and property
  - Flooded basements and ground floors, inundated yards/gardens
  - Damage to household property, mud/sediment deposition
  - Occasional structural damage (e.g., waterlogged/damaged structure in Šaca)
  - Lightning-related damage (substation/house incidents during storms)
- Transport and infrastructure

  Typical disruptions are short and local, but frequent:
  - Flooded streets/underpasses, blocked road sections by water/mud
  - Fallen trees and debris on roads (multiple years)
  - Some events include key road impacts (e.g., I/50 segment affected) and bridge/road damage in the most severe regional cases.
- Critical services and cascading effects

  Examples in the table include:
  - Temporary electricity disruptions (notably in 2010)
  - Water supply issues / well contamination (2014 case)

  - Need for repeated drain/culvert cleaning (e.g., Myslava stream / small bridge bottleneck)
- Spatial hotspots that repeat in the records
  - Košice city districts near the Hornád river (e.g., Krásna, Džungľa, Vyšné Opátske, Šaca/Poľov context)
  - Košice-okolie municipalities with steep runoff / small streams and culvert constraints: Malá Ida, Myslava, Nižný Čaj, Družstevná pri Hornáde, Bukovec, plus places downstream/along Hornád–Torysa (e.g., Sady nad Torysou / Košické Olšany context in 2010 reporting)
- Key takeaways for the report

The database indicates that medium-to-high impacts are not only a function of rainfall total, but also:

  - local drainage capacity (culverts/bridges),
  - terrain/runoff connectivity,
  - proximity to small streams and urban underpasses,
  - and (for major floods) basin-scale hydrology and reservoir/river conditions.

The dominant risk mechanism for Košice UMR in the event descriptions is short-duration intense rainfall = rapid runoff + local stream overflow, causing repeated property and transport disruption, while major basin floods drive the biggest multi-sector consequences. All extreme rainfall events were displayed on the map to better illustrate their spatial distribution. The nearest high-impact event was recorded 22 km from the KE UMR border, but the hazard impact database also includes these nearby events. An example from the hazard impact database is shown in table 2-9.

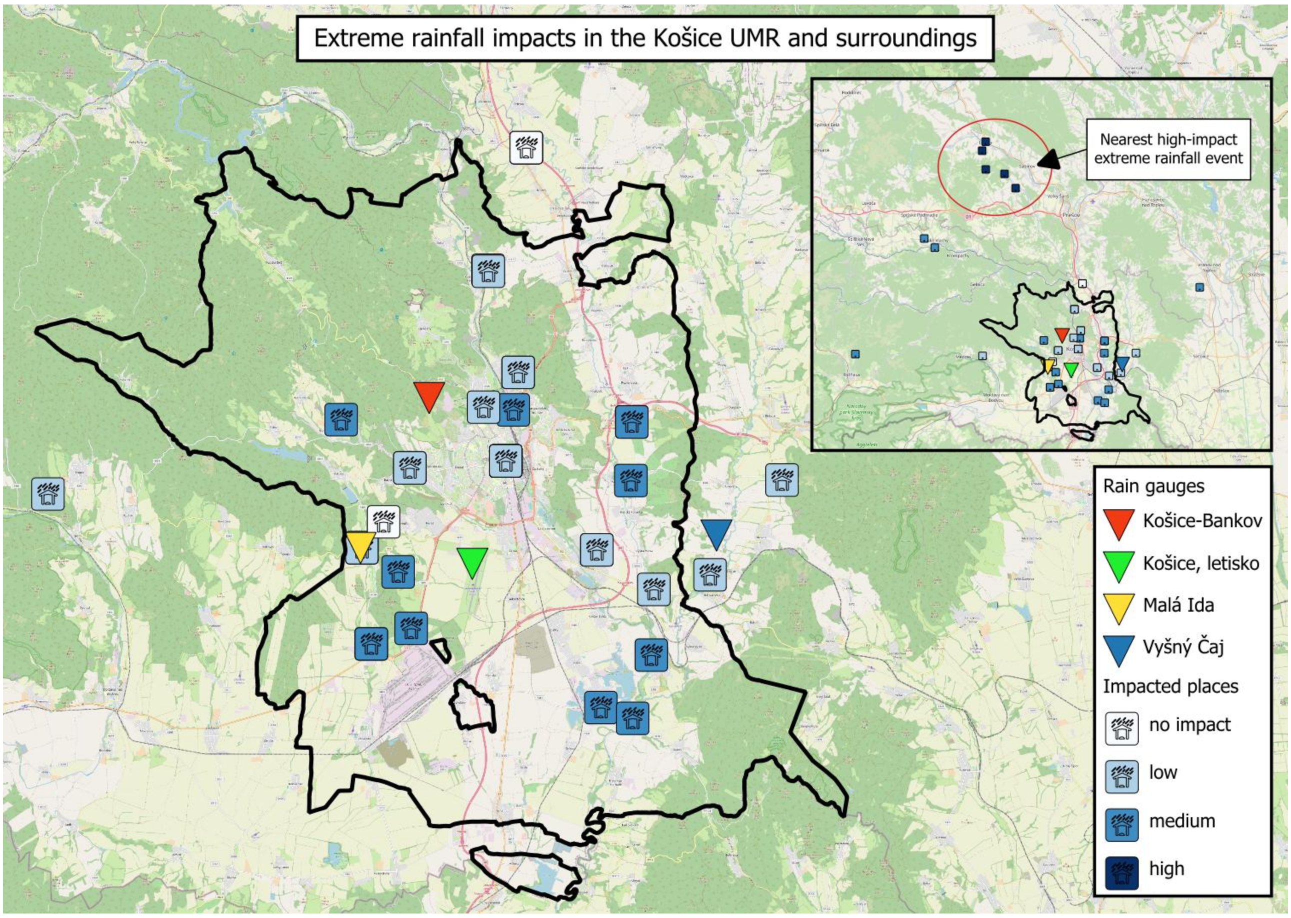


Figure 2-13 Extreme rainfall events from hazard impact database with the impact level, and rainfall gauges

Table 2-9 Example from the hazard impact database (the whole database available on Zenodo – Hazard impact database)

Date	max intensity	General description	Risk to people	Damage to buildings	Disruption of transport	Others or Comments	Impact severity scale
7/20/1998	**100**	Most severe flash-flooding occurred in the Malá Svinka catchment, especially in the municipalities Renčišov, Uzovské Pekľany and Jarovnice; further major impacts were reported in the Dubovický creek catchment (Dubovica, Lipany).	2471 Affected population, 10 people evacuated only 1 injured Impacts concentrated in settlements along Malá Svinka (Renčišov–Uzovské Pekľany–Jarovnice valley) and also Dubovica/Lipany downstream on Dubovický creek.	575 overflow houses, 476 overflow sources of drinking water In Jarovnice, the Roma settlement located in the inundation area was completely destroyed (major housing loss).	22.8 km damaged roads, 32 damaged bridges	The floods also caused extensive property damage, with estimates reaching up to $25 million at the time. In the village of Jarovnice, located only 40 km from Košice, 50 people were killed by the flood. Event affected dozens of municipalities in eastern Slovakia (Šarišská vrchovina / wider Prešov–Košice region); key named locations repeatedly cited in technical summaries: Jarovnice, Renčišov, Uzovské Pekľany, Dubovica, Lipany.	High impact (3)
8/19/2003	**69**	19.08.2003 (69.1 mm/24h) – Severe storm and overflow of local streams in Nižný Klatov (Košice-okolie), causing local flooding. (Ministerstvo životného prostredia)	Elevated risk from rapidly rising water in the village; the official flood report notes that 2003 floods did not require evacuations and had no fatalities/serious injuries. (Ministerstvo životného prostredia)	Flooding of gardens and basement spaces; erosion/sediment issues and undermining of bank reinforcement reported. (Ministerstvo životného prostredia)	State road through the village flooded. (Ministerstvo životného prostredia)	Event documented in an official flood report for 2003; flooding was linked to a strong storm and overflow of multiple local streams. (Ministerstvo životného prostredia)	Medium impact (2)
5/6/2010	**50**	Excessive flooding caused by heavy rainfall; Hornád flood wave passed through Košice and then threatened settlements downstream, incl. Ždaňa and Čaňa (below the confluence with Torysa).	~1500 people were evacuated/affected in Košice, especially from Ťahanovce, Sever (Pri hati), Džungľa, and Krásna nad Hornádom; flooding also threatened residents in villages along Hornád/Torysa (e.g., Sady nad Torysou, Košické Olšany).	Multiple houses were damaged; Sady nad Torysou: water flooded ~40 houses (some up to roofs) and ~70 people had to leave; Košické Olšany: flooded mainly the local Roma settlement (evacuated to cultural house); in Košice, the most affected city parts included Džungľa, Vyšné Opátske, Krásna nad Hornádom and Šaca.	Flooded roads and crossroads; flood protection works were concentrated at Ťahanovský bridge (locality Súdky) and at Mlynský náhon (breach/overflow risk near the railway switch), indicating local disruption and emergency protection of key urban crossings.	25 million euro aid package for the hardest hit regions in eastern Slovakia. Flood risk moved from Košice downstream; tens of thousands in Košice were temporarily without electricity; in Košice, evacuees were transported to schools (Ťahanovce / Dargovských hrdinov). Hornád continued to threaten villages below Ružín reservoir and around Košice (e.g., Nižná Myšľa; Hornád falling at Kysak).	Medium impact (2)

Potential influence of climate change on the hazard and connected impacts:

Since the recorded extreme rainfall events in the KE UMR were generally not extremely dangerous (except for one) and usually did not pose a deadly threat to citizens or cause severe damage to infrastructure, the key point is the potential influence of climate change, which may bring extreme rainfall events with higher impacts.

The CLIMAAX extreme rainfall analysis produced key results indicating substantial changes in rainfall intensities and/or return periods for the simulated period 2021–2050. The projected shifts in intensity and return period imply a more frequent occurrence of higher-impact events. The results are summarized in table 2-10 below. Both model chains indicate a marked increase in intensities and a corresponding shortening of return periods. The MOHC–KNMI combination projects the strongest change; however, when compared with the observed intensities reported in the hazard impact database, this projection appears more consistent with the measured evidence.

Table 2-10 The intensity and return period change for selected GCM and RCM combinations.

GCM:ichec-ec-earth; RCM:knmi-racmo22e						*GCM:mohc-hadgem2-es; RCM: knmi-racmo22e*					
RCP	1976-2005		2021-2050			RCP	1976-2005		2021-2050		
	intensity	RP	intensity	intensity change	RP		intensity	RP	intensity	intensity change	RP
4.5	30	2	33	10%	2	4.5	30	2	39	30%	2
	40	8	44	10%	6		40	6	52	29%	3
	45	13	50	10%	9		45	10	58	29%	4
	70	100	77	10%	64		70	57	90	28%	20
8.5	30	2	33	9%	2	8.5	30	2	41	35%	2
	40	8	48	20%	5		40	6	57	43%	3
	45	13	56	24%	7		45	10	66	46%	3
	70	100	98	40%	30		70	57	111	58%	12

2.3.3. Hazard #3 Wildfires (additional)

Table 2-11 Hazard #3 Wildfires dataset table

Hazard data	*Vulnerability data*	*Exposure data*	*Impact metrics/Risk output*
Wildfire hazard based on: EuroCordex **ECLIPS 2-0** (Chakraborty, 2020) climate scenario data. CLMcom-CLM4-8-17 driven by CNRM-CM5 (CLMcom_CCLM)	Critical building with the problem of the evacuations (KE UMR)	Critical buildings exposed to wildfires (KE UMR)	Wildfire risk to building with the higher concentration of the people with difficulty of the evacuation based on the
		Land use Corine landcover 2018 (100x100m)	
		Digital Elevation Model 100x100m	
		Registered wildfire events (Ministry of interior Slovakia, CLIMAAX SK,)	

2.3.3.1.Hazard assessment

The hazard assessment was based on the CLIMAAX hazard assessment machine learning workflow. This workflow provides two climate scenarios data options, the ECLIPS 2-0 datasets (Chakraborty, 2020) and CHELSA. The ECLIPS 2-0 datasets were selected, since these data are based on the EuroCordex bias-corrected data. For this workflow the selection of the GCM RCM combination was crucial, the selection was made based on the CLIMAAX bias-uncertainty tool, based on this the best overall matching RCM=CLMcom-CLM4-8-17 driven by GCM=CNRM-CM5 (CLMcom_CCLM) T= -0.37, P= 5.05%, was selected (table 2-12).

Table 2-12 GCM – RCM EuroCordex models selection based on the (CLIMAAX bias comparison)

RCM (driven configuration)	*Driving GCM*	*Short name*	*T bias (°C)*	*P bias (%)*
CLMcom-CLM4-8-17	**CNRM-CM5**	**CLMcom_CCLM**	**-0.37**	**5.05**
CLMcom-CLM4-8-17	MPI-ESM-LR	CLMcom_CLM	-0.09	25.35
DMI-HIRHAM5	EC-EARTH	DMI_HIRAM	-1.16	22.09
KNMI-RACMO22E	HadGEM2-ES	KNMI_RAMCO	-1.75	1.30
MPI-CSC-REMO2009	MPI-ESM-LR	MPI_CSC_REMO2009	1.18	1.01

Another important input was the map of the past recorded wildfires. Since the EFFIS database did not recorded any past wildfire in the area of KE UMR, this layer was prepared with the cooperation with ministry of interior of Slovakia, where totally 119 registred wildfires with total burned area of (1 027 966m^2) and estimated demages and estimated demages in EUR 2015-2024 (65 000EUR) was recorded in the past 10 years. This local input significantly changes the output map of the wildfire hazard workflow, against the non-registered map based on EFFIS. The data gathering of the recorded past wildfire events was initiated within the CLIMAAX SK initiative, which helps to gather data without charge from the Slovakian Ministry of interior. Based on the results of the wildfire hazard there is a projected 72km^2 increase of the high wildfire hazard, which is 25% increase (RCP4.5 and 8.5 has simmilar results). For the wildfire exposure the distribution of the critical infrastructure buildings was selected and overlaid with wildfire hazard map. From the figure 2-14 it is obvious that multiple critical buildings are in medium and high danger areas.

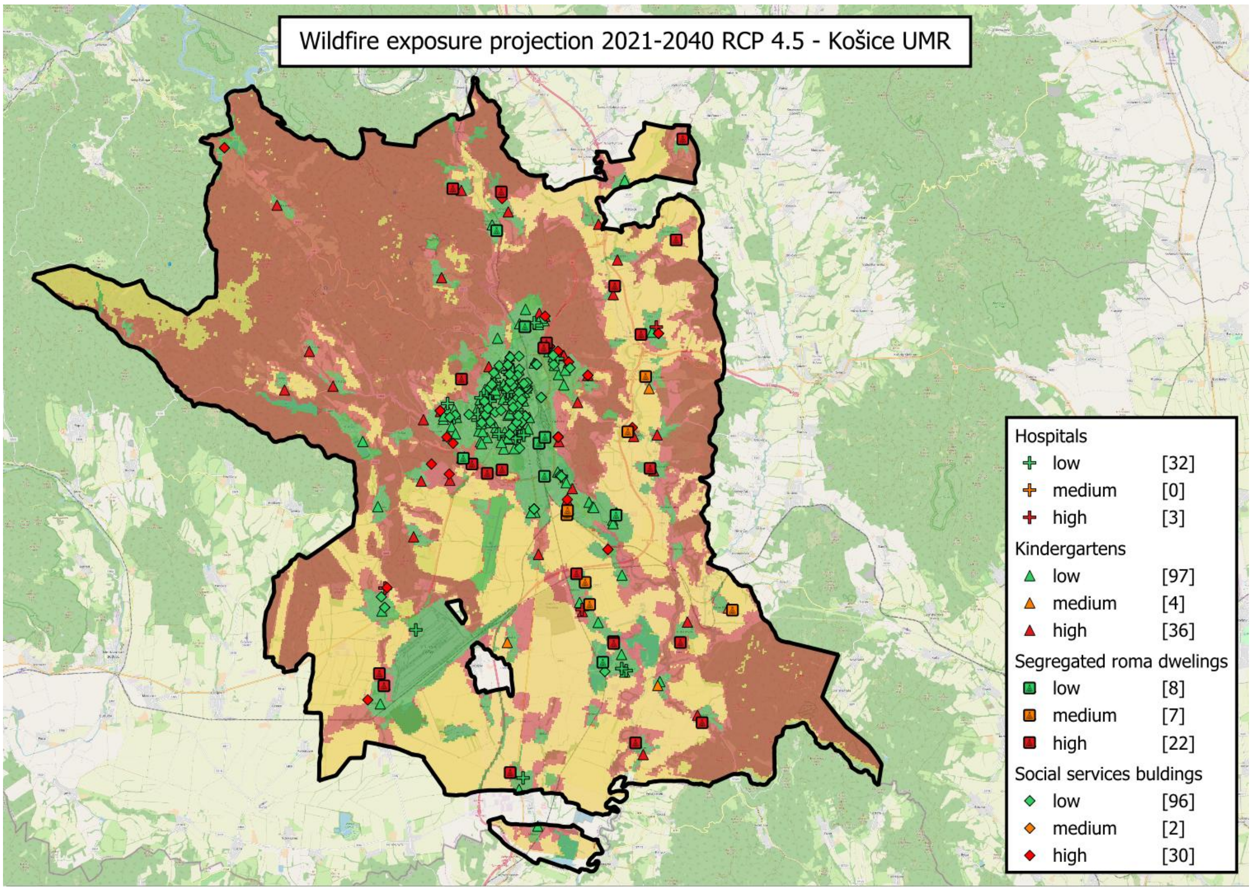


Figure 2-14 Wildfire exposure of the critical buildings, RCP 4.5, 2021-2050, *GCM=CNRM-CM5, RCM=CLMcom-CLM4-8-17.*

2.3.3.2.Risk assessment

This step of the workflow assesses not only the wildfire exposure of each critical building, but also its capacity, which provides an estimate of the potential number of people who may require evacuation in the event of a wildfire. Evacuation from some facilities may be particularly challenging because occupants can have limited mobility or other physical and psychological constraints. By combining building exposure with capacity, we produced wildfire risk index maps for the Košice UMR. This approach helps identify and prioritize the most critical buildings for preparedness and response planning.

Although the projected climate change may increase wildfire exposure in some parts of the study area, the projected increases are not concentrated in locations with the highest density of critical buildings. Because the exposure class of these buildings does not differ substantially between the historical period and the future scenarios, we present the risk map for the RCP4.5 scenario for the 2021–2050 period.

Wildfire risk index - evacuation burden proxied by building capacity (Figure 2-15) for critical buildings in the Košice UMR for the RCP4.5 scenario (2021–2050). The index combines wildfire exposure (classes 1–3) with building capacity (q3; classes 1–3) to indicate relative risk and the potential number of people requiring evacuation. For the analysis's buildings, exposure classes show only minor differences across scenarios; therefore, RCP4.5 is presented as a representative future case.

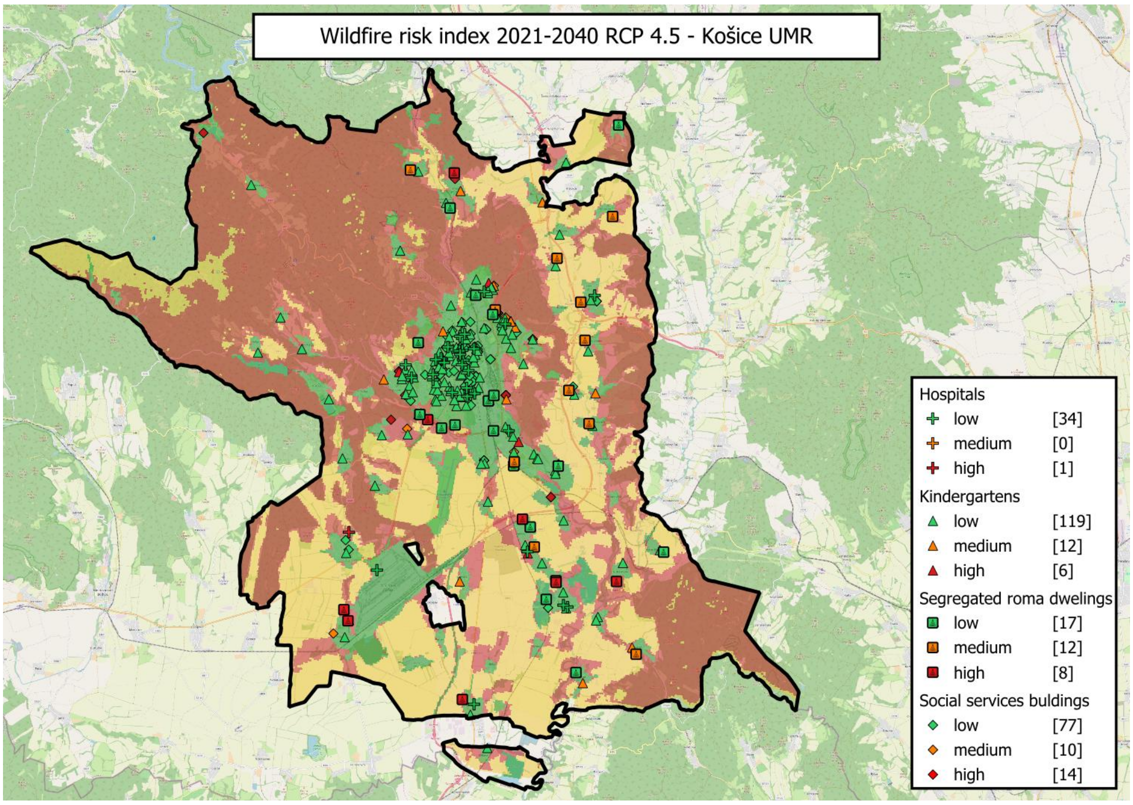


Figure 2-16 Wildfire risk index (evacuation burden *proxied* by building capacity) RCP 4.5, 2021-2050

This approach helps identify the most critical buildings in terms of potential wildfire danger and evacuation burden. In this assessment, the evacuation burden is represented by building capacity (q3), which serves as a proxy for the potential number of people who may require evacuation or assistance during a wildfire event. By combining wildfire exposure with capacity, the resulting risk index highlight's locations where wildfire impacts could affect the largest number of people

The identified most critical places by evacuation burden proxied by building capacity (figure 2-15):

- Hospitals: Nemocnica Agel Košice Šaca.
- Kindergartens: Havanská 26, Sv. Bernadety, Hemerkova, Hrebendova, Jenisejská, Valaliky
- Segregated Roma dwellings: Varovecká, Mašličkovo, Záhradky, Nižná Myšľa, Svornosti, Nová Osada, Stará Osada, Seňa
- Social services: community center Družstevná pri Hornáde, psychosocial centre Adlerova 4., Crisis center for mothers with children Poľná 1. street, Droka, Connected school for physically handicapped children, daily center for elderly people, Lunik IX community center, community center for elderly people Bethesda, Oasis of Hope for new life. Some of the centers consist of multiple departments but the name of the institution is same.

Because many wildfires are human caused, a key objective is to strengthen prevention through targeted public awareness and education on wildfire risk, consequences, and safe behavior (e.g., avoiding open fires and improper waste burning, and reporting smoke early). Outreach activities should be prioritized in the areas identified as having the highest combined exposure–capacity risk, particularly around facilities with high occupancy or vulnerable users.

2.3.4. Hazard #4 Agricultural droughts (additional)

Table 2-13 Agricultural droughts datasets

Hazard data	*Vulnerability data*	*Exposure data*	*Impact metrics/Risk output*
Yield reduction based on Euro Cordex climate indices data 2021-2050 GCM: NCC_NORESM1_M RCM: GERIC_REMO2015 (CDS)	Irrigation availability **(CLIMAAX)**	Crop specific information **(CLIMAAX)**	Revenue loss **(CLIMAAX)**
		List of most strategic crops for KE UMR **(KE UMR, infoma.sk)**	

2.3.4.1. Hazard assessment

The hazard assessment follows the CLIMAAX agricultural drought workflow. A key step was selecting the most strategic crops for the Košice UMR and the most suitable GCM–RCM combination for EURO-CORDEX climate indices data. The strategic crops were identified using the database of Slovak food producers (Infoma.sk). The model selection was based on the CLIMAAX bias-uncertainty tool. Because agricultural drought assessment depends on both temperature and precipitation, the NCC_NORESM1_M–GERIC_REMO2015 combination was selected, as it shows the best overall agreement with the reference period according to table 2-14.

Table 2-14 The selection of the best GCM-RCM combination based on CLIMAAX bias-uncertainty tool.

Global Climate Model (GCM)	*Regional Climate Model (RCM)*	*T bias (°C)*	*P bias (%)*
NCC_NORESM1_M	**GERIC_REMO2015**	**1.24**	**8.50**
MPI_M_MPI_ESM_LR	SMHI_RCA4	0.05	30.52
CNRM_CERFACS_CM5	KNMI_RACMO22E	-2.67	2.65
CNRM_CERFACS_CM5	CNRM_ALADIN63	-1.04	22.73
NCC_NORESM1_M	SMHI_RCA4	-0.19	14.66

The main goal of the agricultural drought hazard assessment was the prediction of potential yield loss. This analysis was performed for the 4 selected crops (maize, wheat, rapeseed and barley)

2.3.4.2. Risk assessment

The agricultural drought risk assessment provides projections of potential average annual economic losses for non-irrigated fields under climate change conditions in 2021–2050, relative to fully irrigated conditions (i.e., the losses that could be avoided through irrigation). The potential losses are presented in table 2-15. The largest projected losses are for wheat, reaching up to €6,400 per growing season per 1 km² under RCP4.5. While these losses may be modest for smaller areas, they can become substantial for larger fields.

Table 2-15 Agricultural yield and revenue loss, RCP 4.5 for 2021-2050 (NCC_GERI)

Agricultural yield and revenue loss RCP 4.5 for 2021-2050 (NCC_GERI) KE UMR			
Crop	Projected yield loss RCP 4.5 [%]	Projected revenue loss up to € [average per growing season/12x12km]	Projected revenue loss up to € [average per growing season/1x1km]
Maiz	43	187 000	1 300
Wheat	35	917 000	6 400
Rapeseed	35	109 000	750
Barley	29	99 000	690

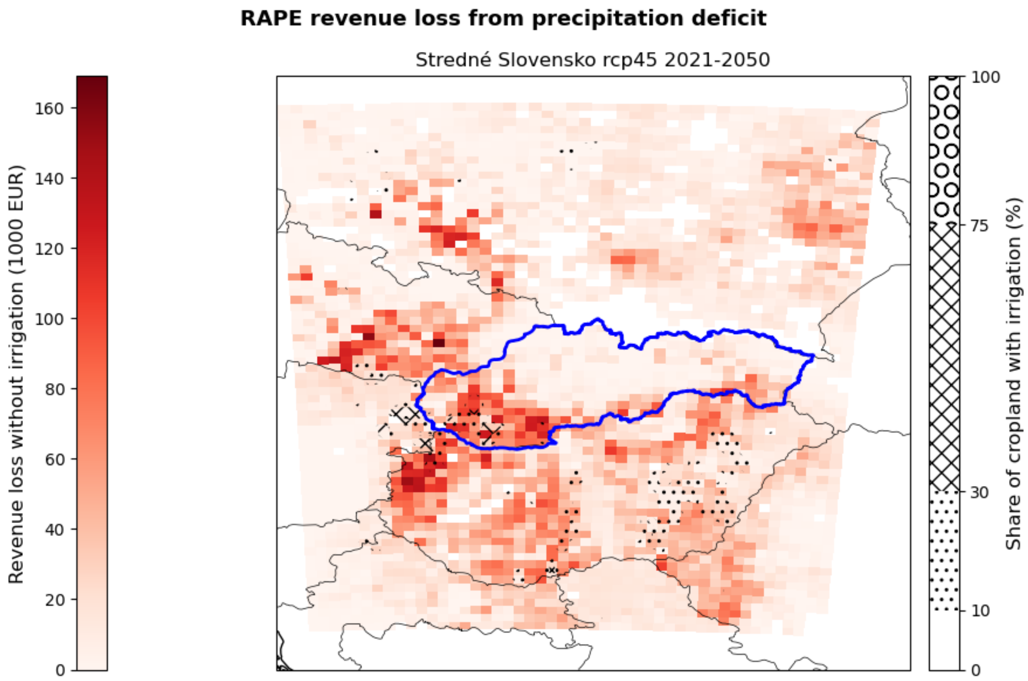


Figure 2-17 Rapeseed revenue loss from the precipitation deficit for the area of Slovakia.

2.3.5. Additional assessments based on local models and data

In this part, the KE UMR SCOPE team proposes additional assessments that can help to follow up on, supplement, or extend the selected CLIMAAX workflows. These tools provide next steps for the CLIMAAX workflows, supporting targeted emergency response, improved localization of impacts, and potential solutions to climate-related problems. The selected additional assessments/tools include:

1. KE UMR Flood analysis from DHI Slovakia (connection to extreme rainfall)
2. Questionnaire for KE UMR municipalities (hazard feel mapping)
3. Seed4forest (connection to heatwaves and wildfires)
4. Intersucho (connection to agricultural drought)

The flood analysis prepared by DHI usefully complements the CLIMAAX extreme precipitation workflow. The analysis was developed for the Košice UMR and identifies areas most prone to flooding triggered by intense rainfall. A high-resolution DEM (1 × 1 m), combined with land-use data and other runoff-controlling characteristics, was used to estimate potential flood depths associated with an extreme rainfall event of 30 mm in 60 minutes. The DHI analysis highlights the locations likely to experience the most severe impacts during extreme precipitation events, while the CLIMAAX extreme rainfall workflow provides information on potential climate-change-driven shifts in magnitude and frequency (i.e., the urgency). Together, these results provide a strong basis for targeted planning and implementation of adaptation measures. Among the most critical locations in Košice, with projected flood depths exceeding 0.5 m, are the Trauma Surgery Clinic (UPJŠ Faculty of Medicine and L. Pasteur University Hospital), Panelová Polyclinic, Kindergarten (Nemcovej 4), Košice Railway Station, the Južné nábrežie (South Embankment) settlement, the Integrated School for Pupils with Physical Disabilities (Opatovská Street), the Mašličkovo segregated Roma settlement, and the East Slovak Institute of Cardiovascular Diseases, among others. The flood hazard map is provided in the attachments.

Between the tools actively used by the Košice UMR to assess risks of greatest concern to local stakeholders is a simple but effective questionnaire administered to mayors of municipalities within the Košice UMR. The questionnaire provides an on-the-ground perspective on climate-related problems based on local experience. This input represents an important component of the climate risk assessment and was applied prior to the use of climate models and analytical tools, in order to obtain an initial overview of the key climate-related issues in the area and to help define priorities for subsequent analyses. The results of the questionnaire are presented in Section 1.1.

The Seed4Forest web application complements the CLIMAAX heatwave and drought workflows. It provides projections of tree species suitability under future climate conditions and can be used by foresters and urban planners to support the selection of appropriate tree species for city parks and other urban green spaces. The application indicates whether selected species are likely to thrive under climate change scenarios for RCP4.5 and RCP8.5. Although the tool was not fully implemented in the current phase, it will be presented to local forestry stakeholders in Phase 3 as a decision-support tool for climate-resilient planning.

The final tool is Intersucho, a drought monitoring and short-term forecasting platform operated by SHMU and supported by local data. It complements the agricultural drought workflow by providing regular information on drought conditions and related impacts on agriculture, vegetation, soil moisture, and groundwater. The platform is also designed for agricultural companies: registered users can submit observations and contribute to drought reporting, and in return receive drought forecasts from SHMU. In Phase 3, this tool will be presented to local agricultural companies as part of the stakeholder engagement and decision-support activities.

2.4. Key Risk Assessment Findings

The Key Risk Assessment step synthesizes the outputs of the hazard, exposure, and vulnerability analyses and evaluates them through the lenses of severity, urgency, and the region's capacity to respond. This step follows the CLIMAAX Key Risk Assessment protocol and is intended to be carried out in close interaction with stakeholders, experts, and priority groups using the evaluation dashboard.

2.4.1 Mode of engagement for participation

Stakeholder engagement for the risk evaluation built on the process described in Section 2.1.5. During consultations and the stakeholder survey, municipalities, regional institutions, emergency services, academic partners and operators of critical infrastructure provided feedback on the perceived severity and urgency of key hazards. Their input confirmed heatwaves and extreme rainfall as the most pressing risks, while drought and wildfires were identified as emerging concerns, especially for rural areas. Stakeholders also highlighted limited financial and technical capacity, fragmented governance, and gaps in hazard-impact data as factors that reduce regional resilience.

2.4.2 Gather output from Risk Analysis step

The risk evaluation is based on the consolidated outputs generated in the Risk Analysis step for all four assessed hazards: heatwaves, extreme rainfall, drought, and wildfires. In line with the CLIMAAX framework, the following types of outputs were used:

1. **Hazard maps** showing the spatial distribution, frequency, and intensity of each hazard under current and future climate conditions.
2. **Exposure maps** identifying population, critical infrastructure, public services, and economic assets located in areas affected by each hazard.
3. **Vulnerability indicators** derived from socio-economic data, including age structure, social disadvantage, concentration of priority groups, and the location of sensitive facilities such as hospitals, kindergartens, and elderly care institutions.
4. **Combined risk layers** that integrate hazard intensity with exposure and vulnerability to highlight areas where impacts are expected to be most significant.

These outputs provided the evidence base for assessing **severity**, **urgency**, and **resilience capacity** in the Key Risk Assessment step and directly informed the prioritization of climate risks for the Košice UMR.

2.4.3 Assess Severity

Severity was assessed using CLIMAAX criteria, evaluating impacts on health, infrastructure, ecosystems, and the economy while accounting for historical trends and future intensification.

- **Heatwaves** currently show substantial severity due to direct health impacts on vulnerable groups and the urban heat island effect. This is projected to reach critical severity as rising frequency and intensity create irreversible health risks and strain emergency services.
- **Extreme rainfall** is likewise moving from substantial to critical severity; past events have repeatedly damaged transport and drainage systems, and future increases in magnitude are expected to cause large-scale infrastructure failure and road closures.
- **Drought** currently presents moderate severity, primarily affecting rural water availability and agriculture, but is projected to become substantial as longer dry periods to diminish productivity and degrade ecosystem services.
- **Wildfires** are rated as limited to moderate currently, with high severity localized in urban forests, but rising temperatures are expected to shift this to substantial severity due to ecosystem loss and smoke-related health impacts.

Stakeholder perspectives reinforced these findings, as municipal and emergency services identified heatwaves and rainfall as the most severe current threats based on observed impacts, while rural actors emphasized the growing pressure of drought and wildfire alerts.

2.4.4 Assess Urgency

Urgency was assessed by categorizing hazards based on their timing and the necessity for intervention to minimize damage. Heatwaves and extreme rainfall are classified as requiring immediate action because their severity is projected to transition from substantial to critical soon (2021–2050). While extreme rainfall is a sudden hazard requiring rapid response, heatwaves act as both slow-onset processes and sudden extremes, both of which have the potential to persist and worsen significantly.

Drought and wildfires are currently assessed as risks requiring enhanced monitoring or moderate additional action; however, their significance for long-term planning is considerable, as delayed intervention could lead to irreversible ecosystem degradation. Stakeholder perspectives further intensify the sense of urgency: for instance, 91% of municipalities identify heatwaves as a priority risk, prompting a stronger emphasis on immediate urban cooling measures and public health protection.

2.4.5 Understand Resilience Capacity

Resilience capacity was assessed through existing management measures and identified gaps, with categories reflecting the region's ability to limit climate-related impacts.

- Physical and natural capacity (medium) is supported by green and blue infrastructure, including extensive drainage systems and urban forests, although rising temperatures threaten ecosystem resilience.
- Social and human capacity (medium) benefits from relatively high awareness and outreach activities but limited technical expertise remains a key constraint.
- Financial and policy capacity (low–medium) is shaped by a supportive policy framework, yet funding access remains insufficient for many municipalities.

Existing measures include active participation in EU funding programmes, nature-based solutions such as tree planting and rain gardens, and cooperation with universities and NGOs. Despite these efforts, overall capacity remains inadequate due to weak inter-municipal coordination, limited financing, insufficient local risk data, and maintenance constraints in drainage infrastructure. Implemented initiatives include a Sustainable Mobility Plan and emissions monitoring, while planned actions focus on geothermal integration in district heating and co-designed adaptation measures for vulnerable settlements.

2.4.6 Decide on Risk Priority

Risk priority was determined by combining future risk severity, urgency of action, and resilience capacity, using the CLIMAAX ordinal scoring system (1–5). Resilience capacity is applied on an inverse scale, where higher values indicate weaker capacity. The resulting Risk Priority Index (RPI) enables transparent ranking and comparison across hazards.

Risk Priority Index (RPI) = Severity × Urgency × Resilience Capacity

Table 2-16 CLIMAAX Risk Priority Dashboard

Climate Hazard	Severity (Future)	Urgency	Resilience Capacity*	Risk Priority Index (S×U×RC)	Priority Level
Heatwaves and Urban Heat Islands	5 (Critical)	5 (Immediate Action Needed)	3 (Medium)	**75**	**Critical Priority**
Extreme Rainfall and Flash Floods	4 (High)	4 (Urgent Action Needed)	4 (Low)	**64**	**High Priority**
Drought and Wildfires	4 (High)	3 (More Action Needed)	3 (Medium)	**36**	**Medium–Long-term Priority**

** Resilience capacity scored inversely in line with the CLIMAAX Handbook (1 = very high capacity, 5 = very low capacity).*

Heatwaves and urban heat islands are assigned as a critical priority due to their critical projected severity (5), immediate urgency (5), and only medium adaptive capacity (3). The risk is further intensified by the spatial concentration of vulnerable populations in high-exposure housing estates such as KVP, Ťahanovce, and Luník IX, where the most significant health impacts are expected. Extreme rainfall and flash floods are classified as a high priority, driven by high future severity (4) and urgent action needs (4), combined with low resilience capacity (4) linked to drainage limitations and the vulnerability of transport infrastructure. Expected increases in short-duration; high-intensity rainfall events substantially raise the likelihood of disruption and physical damage. Drought and wildfires are considered the medium to long-term priority. Although current urgency is moderate (3), the high projected future severity (4) and medium adaptive capacity (3) justify early strategic intervention. Without timely action, the region faces risks of irreversible ecosystem degradation and significant long-term agricultural and economic losses.

2.5. Monitoring and Evaluation

The second phase of the climate risk assessment strengthened our understanding of how climate hazards interact with local exposure and socio-economic vulnerability across the Functional Urban Region. We learned that heatwaves and extreme rainfall already produce significant impacts and will intensify rapidly, while drought and wildfires represent growing long-term pressures. The most significant difficulties arose from limited availability of local hazard-impact data—especially for flash floods—uneven technical capacity across municipalities, and the challenge of aligning climate projections with short-term socio-economic planning.

Stakeholders played a central role in the Monitoring and Evaluation process. Their insights validated severity, urgency, and resilience of capacity scores and helped identify local hotspots not visible in national datasets. They also provided essential feedback on operational constraints such as drainage overloads, heat-related health incidents, and drought stress in rural areas. Stakeholder feedback on the CRA was positive, highlighting the clarity of the methodology, the usefulness of the evaluation dashboard, and the value of transparent prioritization. Their involvement ensures that the CRA supports both policy relevance and institutional learning.

Learning is ensured through continuous engagement, transparent scoring, and systematic documentation of assumptions, limitations, and data needs. The iterative nature of the CRA—combining scientific evidence with local knowledge—creates a feedback loop that strengthens institutional capacity and supports long-term adaptation planning. While some new datasets became available during the process, further data is needed to improve accuracy, including detailed flood-impact records, high-resolution hydrological and soil-moisture data, long-term drought indicators, and vulnerability data for smaller municipalities. Additional staff capacity and technical expertise would further enhance future assessments.

Final outcomes will be communicated through the CLIMAAX deliverable, the evaluation dashboard, presentations to municipal and regional authorities, and public-facing summaries. Integration into strategic documents such as the Adaptation Plan, PHRSR, and SECAP will ensure that results inform policy and investment decisions. Although partial monitoring systems exist (crisis management, environmental monitoring, hydrological alerts), they are not yet fully aligned with the analyzed risks. Strengthening monitoring of heat stress, local flooding, drought indicators, and wildfire alerts will be essential for Phase 3.

Overall, the CRA process worked well in terms of stakeholder engagement, methodological clarity, and integration of scientific and local knowledge. Challenges included data gaps, uneven municipal capacity, and time constraints for deeper modelling. Resources were used efficiently, which helped maintain focus and ensure timely delivery, but limited staff time also reduced opportunities for broader engagement and more detailed validation. Despite these constraints, the CRA had a strong positive impact: it improved institutional understanding of climate risks, increased stakeholder awareness, strengthened cross-municipal cooperation, and provided a solid foundation for targeted adaptation planning and future investment.

2.6. Work plan Phase 3

Phase 3 of the project will focus on translating the key risk assessment findings into concrete and actionable climate adaptation strategies for the city of Košice and the wider urban development area. Building directly on the priority risks identified in Phase 2—heatwaves, extreme rainfall, drought and wildfires—the work will concentrate on developing measures that are feasible, locally relevant and aligned with existing planning and policy frameworks. Throughout this phase, the team will work closely with municipalities, regional authorities, emergency services and sectoral experts to co-design adaptation options that respond to the most urgent vulnerabilities, particularly in areas where resilience capacity was assessed as medium or low. The process will involve evaluating a range of potential interventions, including nature-based solutions, infrastructure upgrades, social and health-focused measures, and improvements to early-warning and crisis-management systems. The aim is to ensure that the CRA results lead to practical steps that can be implemented at the neighborhood, municipal, and regional levels.

A key part of the work will be translating the CRA findings into policy recommendations for land-use planning, civil protection, building regulations and strategic development documents. This will include preparing concise policy briefs for decisionmakers and identifying gaps in existing regulations or procedures that limit the region's ability to adapt to climate risks. Communication and engagement will also play an important role: the project team will present the CRA outcomes and propose adaptation measures to stakeholders and the public, using clear visual materials and accessible summaries to support awareness and uptake. In parallel, the team will document successful examples of adaptation practice emerging from the project, creating “CLIMAAX success stories” that can be shared and replicated in other regions.

Phase 3 will not include detailed hydrological or climate modelling, extensive new data-collection campaigns, or engineering-level feasibility studies, as these activities fall outside the scope, resources and timeline of the project. Instead, the focus will remain on applying the results already generated in the CRA, strengthening governance and planning processes, and supporting municipalities in identifying realistic next steps. By concentrating on implementation, policy relevance and practical adaptation planning, Phase 3 will ensure that the insights gained in the risk assessment are carried forward into concrete actions that improve resilience across the region.

3. Conclusions Phase 2- Climate risk assessment

Phase 2 of the CLIMAAX project significantly advanced the understanding of climate risks in Košice and the Functional Urban Region by refining hazard analyses, integrating local data, and engaging stakeholders in the interpretation of results. This phase provided a clearer and more spatially detailed picture of how climate hazards interact with exposure and vulnerability, and it established a transparent basis for prioritizing risks. The refined assessment confirmed that climate change is already shaping local conditions, particularly through intensifying heatwaves and more frequent short-duration rainfall events, and that socio-economic vulnerability strongly influences the magnitude of impacts.

The main conclusion of Phase 2 is that heatwaves and extreme rainfall represent the most urgent and consequential climate risks for the region. Both hazards show high or critical projected severity, rapid onset, and strong interactions with existing vulnerabilities. Heatwaves pose direct health risks, especially in dense housing estates with limited shading and high concentrations of vulnerable populations. Extreme rainfall and flash floods threaten transport infrastructure, drainage systems, and built-up areas, with increasing frequency and intensity expected in the coming decades. At the same time, drought and wildfires emerged as medium- to long-term risks whose impacts will intensify gradually but could become severe without early strategic intervention. These findings provide a clear direction for Phase 3, where adaptation strategies will be developed.

Phase 2 successfully addressed several methodological and practical challenges. The project team managed to integrate diverse datasets—local, national, and CLIMAAX-provided—into a coherent analytical workflow, improving the spatial resolution and accuracy of hazard maps. Stakeholder engagement was a major strength of this phase: municipalities, emergency services, and sectoral experts contributed essential local knowledge that validated the results and revealed hotspots not visible in national datasets. The use of the CLIMAAX evaluation dashboard enabled a transparent comparison of hazards across severity, urgency, and resilience capacity, supporting evidence-based prioritization.

However, several challenges could not be fully addressed within this phase. The most significant limitation remains in the lack of detailed local impact data, particularly flash floods, which restricts the ability to validate models and quantify damages. Smaller municipalities continue to face limited technical and human capacity, which affects their ability to engage deeply with the CRA process and maintain long-term monitoring systems. Phase 2 did not include advanced hydrological modelling, socio-economic scenario development, or engineering-level feasibility studies, as these activities fall outside the project's scope and resources. These gaps highlight the need for continued investment in data collection, monitoring, and capacity building.

The key findings of Phase 2 can be summarized as follows:

1. **Heatwaves and urban heat islands** are the most critical risks, with projected severity reaching the highest level and urgency requiring immediate action. Vulnerable populations in dense housing estates such as KVP, Ťahanovce, and Luník IX face disproportionate health impacts.

2. **Extreme rainfall and flash floods** represent a high priority due to increasing frequency and intensity of short-duration rainfall events, combined with drainage system limitations and the vulnerability of transport infrastructure.
3. **Droughts and wildfires** are emerging with long-term risks. Although current urgency is moderate, future severity is high, and delayed action could lead to irreversible ecosystem degradation, reduced water availability, and agricultural losses.
4. **Resilience capacity is uneven across the region**, with medium capacity in Košice but lower capacity in smaller municipalities. This disparity increases overall vulnerability and highlights the need for targeted support.
5. **Stakeholder engagement significantly improved the assessment**, revealing local hotspots, operational constraints, and community-specific vulnerabilities that were not visible in national datasets.
6. **Data gaps remain a major barrier**, particularly for flood impacts, hydrological monitoring, and socio-economic vulnerability indicators.

Overall, Phase 2 has provided a robust and actionable understanding of climate risks in the region. It clarified which hazards require immediate attention, where vulnerabilities are most concentrated, and how resilience capacity can be strengthened. The refined assessment offers a strong foundation for Phase 3, where the focus will shift from analysis to implementation. The insights gained in this phase will guide the development of adaptation strategies, policy recommendations, and practical measures that can be integrated into urban planning, civil protection, and long-term development strategies. By building on the evidence and stakeholder input gathered in Phase 2, the project is well positioned to support Košice and its surrounding municipalities in strengthening resilience and preparing for a climate-resilient future.

4. Progress evaluation

This Phase 2 deliverable provides the refined multi-risk assessment that forms the analytical basis for all activities planned in Phase 3. The outputs—high-resolution hazard analyses, prioritized risks, and identification of resilience gaps—ensure that the next phase can focus on designing concrete adaptation strategies and policy recommendations grounded in solid evidence. Two CLIMAAX workflows were successfully applied and more deeply analyzed, confirming methodological continuity and fulfilling the technical requirements for this stage.

During Phase 2, the project team conducted a targeted survey with affected municipalities, which provided valuable local insights into recent climate impacts, infrastructure vulnerabilities, and community-level concerns. Based on this survey, the team decided to add two additional risks to the assessment to better reflect local realities and ensure that the CRA captures the full spectrum of challenges faced by smaller municipalities. This strengthened the relevance and accuracy of the final risk prioritization.

The progress achieved in Phase 2 fully aligns with the project's key performance indicators. A total of 12 stakeholders were actively involved in the assessment process, and 12 communication actions were completed, including a press release on the city´s website and Facebook and Instagram posts (phase 1), a contribution to the CLIMAAX newsletter, and a presentation for secondary-school students (St. Thomas Aquinas High School in Košice). The results were also presented at the Cooperation Council, ensuring alignment with regional development priorities, and shared with stakeholders from HarmonMission, Mission CE Climate, and UNDERPIN (Climate KIC), supporting cross-project learning and broader dissemination.

The outputs of this deliverable directly guide Phase 3. The prioritized risks—heatwaves, extreme rainfall, drought, and wildfires—will serve as the foundation for selecting adaptation measures and preparing four policy notes for decision-makers. The identification of vulnerable areas and system weaknesses provides a clear roadmap for where interventions are most needed.

In summary, this deliverable completes the analytical component of the project and ensures that Phase 3 can focus on implementation, policy translation, and strategic adaptation planning. The successful fulfilment of all Phase 2 KPIs confirms that the project is on track and that the knowledge generated so far is ready to be transformed into actionable measures that strengthen climate resilience across the region. Phase 3 will also include expanded more dissemination activities, including a press release, additional social media posts, and other outreach actions aimed at informing residents about the results and increasing public awareness of climate risks and planned adaptation measures.

Table 4-1 Overview of key performance indicators

Key performance indicators	*Progress*
12 stakeholders involved in the activities of the project	done
12 communication actions taken to share results with your stakeholders	done
4 publications and dissemination actions	done
4 notes for policy makers	Phase 3
2 of workflow successfully applied on deliverable 1	done
2 of workflow successfully applied on deliverable 2	done

Table 4-2 Overview of milestones

Milestones	*Progress*
Mls 1 Stakeholder meeting in phase 1	done
Mls 2 Phase 1result presented	done
Mls 3 Stakeholder meeting and co-design in phase 2	done
Mls 4 Attend the CLIMAAX workshop held in Barcelona	done
Mls 5 Policy recommendation actions	Phase 3
Mls 6 Attend the CLIMAAX workshop held in Brussels	Phase 3

5. Supporting documentation

✓ **Main report**

Submitted 16.1.2026

✓ ***Visual outputs***

Submitted by Phase 2_results (heatwave_workflow, heavy_rainfall_workflow, wildfire_workflow, droughts_worlflow)

✓ **Communication Outputs**

Figure 5-1 18.6.2025 - meeting with mayors (stakeholders) of the functional urban area of Kosice

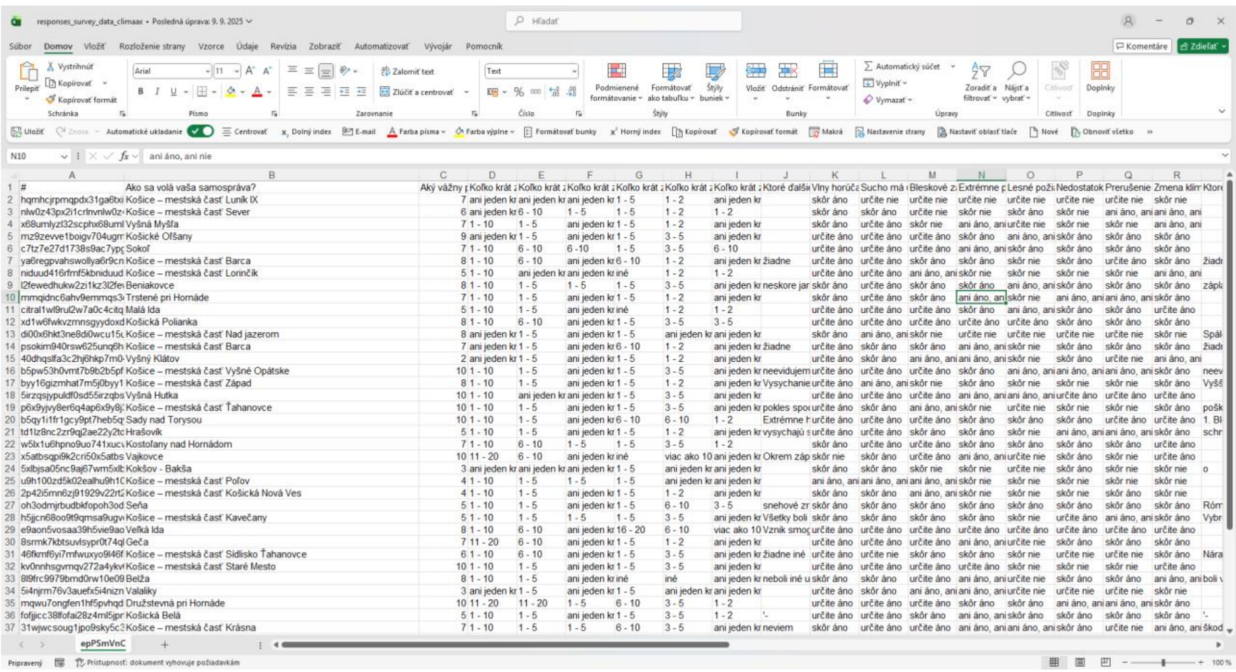


Figure 5-2 Survey CLIMAAX responses

Figure 5-3 9.9-10.9.2025 - Stakeholders meeting via Harmonmission training (Harmonmission – Interreg Danube)

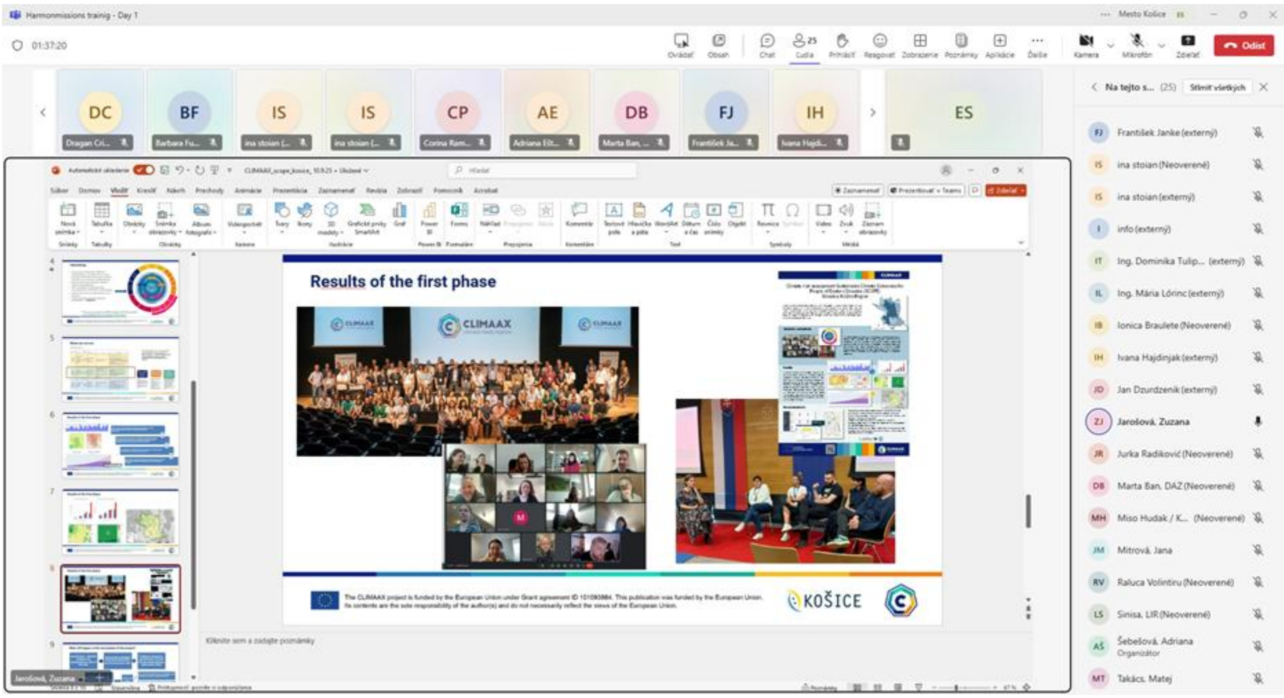


Figure 5-4 9.9-10.9.2025 - Stakeholders meeting via Harmonmission training (Harmonmission – Interreg Danube)

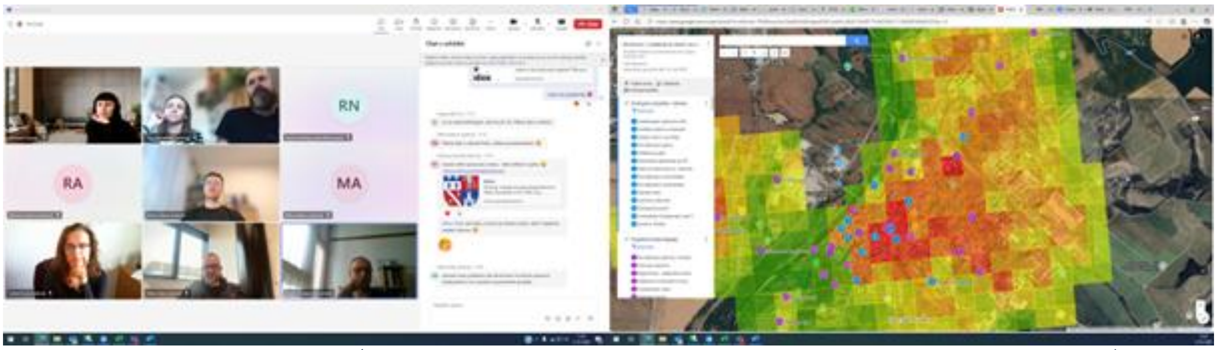
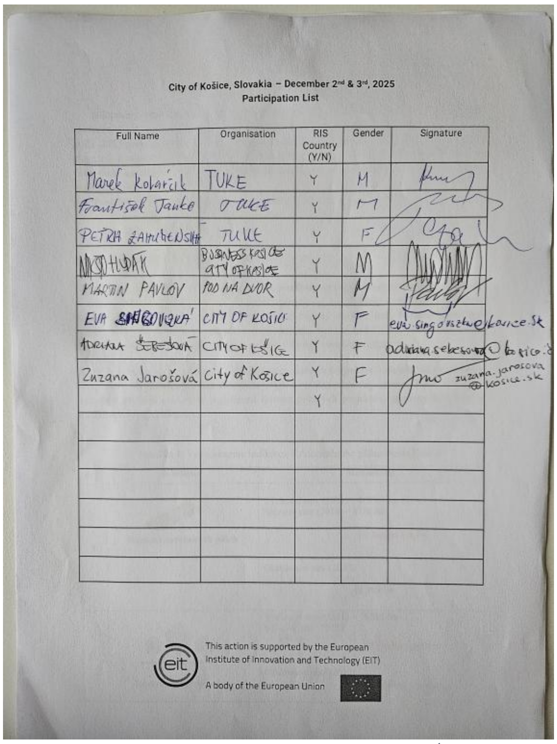


Figure 5-5 Meetings CLIMAAX SK (4.4.2025, 16.5.2025, 20.6.2025, 1.8.2025, 5.9.2025, 3.10.2025, 7.11.2025)

Figure 5-6 27.11.2025 - Presentation for secondary-school students (St. Thomas Aquinas High School in Košice)



City of Košice, Slovakia – December 2nd & 3rd, 2025
Participation List

Full Name	Organisation	RIS Country (Y/N)	Gender	Signature
Marek Kolarčik	TUKE	Y	M	[illegible]
František Janke	TUKE	Y	M	[illegible]
PETRA ZAHNHENSKÁ	TUKE	Y	F	[illegible]
MICHAL HUDÁK	BUSINESS KOŠICE CITY OF KOŠICE	Y	M	[illegible]
MARTIN PAVLOV	POD NA DVOR	Y	M	[illegible]
EVA SINGOVSZKÁ	CITY OF KOŠICE	Y	F	eva.singovszka@kosice.sk
ADRIANA ŠEBEŠOVÁ	CITY OF KOŠICE	Y	F	adriana.sebesova@kosice.sk
Zuzana Jarošová	City of Košice	Y	F	[illegible] zuzana.jarosova@kosice.sk
		Y		

This action is supported by the European Institute of Innovation and Technology (EIT)
A body of the European Union

Figure 5-7 2.12.- 3.12. 2025 – UNDERPIN (Climate KIC)- presentation of CLIMAAX results

Figure 5-8 13.1.2025 - Meeting with stakeholders via Training: Data for climate action (Climate CE Mission, Interreg Central Europe)

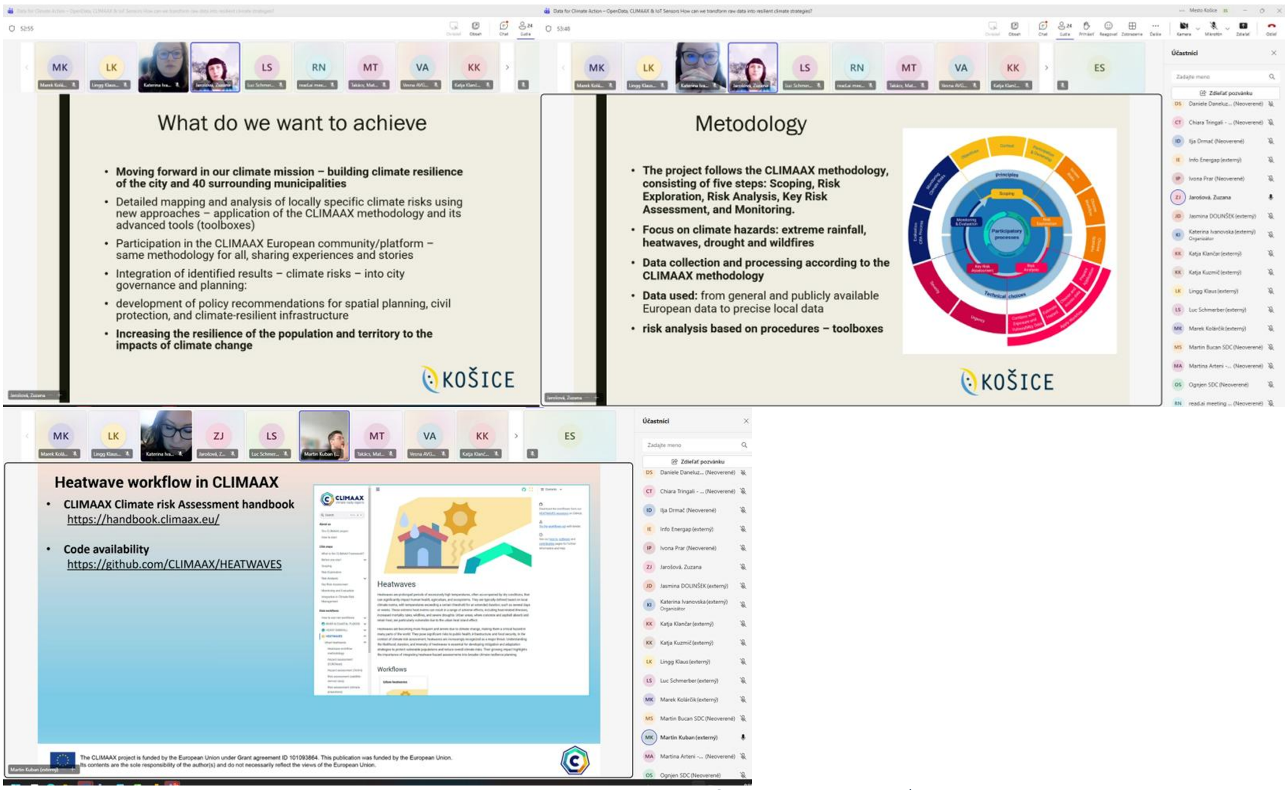


Figure 5-9 13.1.2025 - Meeting with stakeholders via Training: Data for climate action (Climate CE Mission, Interreg Central Europe)


Project promotion — Harmonmissions Newsletter

PROJECT NAME : SCOPE - Sustainable Climate Outcomes for People of Eastern Slovakia

CLIMAAX climate ready regions

Funded by the European Union

CITY OF IMPLEMENTATION Košice
TOTAL COST € 171 975
NFP AMOUNT € 171 975
OPERATIONAL PROGRAMME CLIMAAX - Horizon Europe
FUNDING RATE This project is co-financed by the European Union at 100%
RECIPIENT City of Košice
HQ of the RECIPIENT Trieda SNP 48/A, 040 11 Košice

PROJECT OBJECTIVE

CLIMAAX (CLIMAte risk and vulnerability assessment framework and toolboxX) is a four-year Horizon Europe project that will provide financial, analytical and practical support to improve regional climate and emergency risk management plans. CLIMAAX is intended to contribute to the harmonisation and consolidation of climate risk assessment practice and to leave a legacy for upcoming European initiatives.

CLIMAAX builds on existing risk assessment frameworks, methods and tools and promotes the use of datasets and service platforms for deployment at local and regional level. It will create a reliable and coordinated framework for consistent, harmonised and comparable risk assessments. The project moves existing tools and services beyond the status quo by prioritising further development of accessibility, guidance, adaptation to local conditions, interpretation and use by representative disaster risk management and civil protection authorities.

PROJECT DESCRIPTION

The main objective of the SCOPE project is a detailed mapping and analysis of climate risks specific to the city of Košice and its functional area of sustainable urban development. Using modern tools and methodologies provided by CLIMAAX, we will generate and regularly update localized climate risk data that is both accurate and actionable.

The results of the project will support the integration of climate risks into all aspects of local governance and planning. This holistic approach will ensure that climate change adaptation and risk management are not stand-alone efforts, but are integrated into the broader framework of regional development, urban planning and social welfare policies.


interreg Danube Region
HARMONMISSIONS
MISSION 4 — APRIL 2025
NEWSLETTER
Word of the editor
Dear readers,
UPCOMING EVENTS
Smart Cities Symposium Prague 2025
For more details, please visit: okce.fd.cvut.cz

Figure 5-10 Harmonmission Newsletter april 2025– project CLIMAAX (SCOPE) promotion (newsletter25)


Building Climate Resilience in the Košice Region Through Local Risk Assessment

November 14, 2025

Košice and 45 nearby municipalities assessed local climate risks under the CLIMAAX SCOPE project, revealing growing impacts and the need for coordinated adaptation actions.

As part of the CLIMAAX SCOPE project, the **City of Košice** has conducted a comprehensive **climate risk assessment** to strengthen resilience across its metropolitan area—covering 22 city districts and 40 surrounding municipalities.

Figure 5-11 CLIMAAX newsletter - Building Climate Resilience in the Košice Region Through Local Risk Assessment - Climaax (14.11.2025)

✓ **Datasets collected (Excel or CSV)**

Heatwave:

1. KE_UMR_risk_LST_2024_2025.tif

2. KE_UMR_risk_pop.tif
3. KE_UMR_possible_heat_risk_to_vulnerable_population.tif
4. scope_hospitals_heat24_25.gpkg
5. scope_social_services_buildings_jtsk_heat24_25.gpkg
6. scope_vulnerabl_roma_dwelings_heat24_25.gpkg
7. scope_vulnerabl_kindergarten_merge_jtsk_heat24_25.gpkg
8. scope_hospitals_cap_q5_risk.gpkg
9. scope_social_services_buldings_jtsk_cap_q5_risk.gpkg
10. scope_vulnerabl_roma_dwelings_cap_q5_risk.gpkg
11. scope_vulnerabl_kindergarten_merge_jtsk_heat_cap_q5_risk.gpkg

Extreme rainfall:

12. hazard_impact_database.xlsx
13. kosice_hazard_impact_points.gpkg
14. kosice_rain_gauges.gpkg
15. idf_24h_ichec-ec-earth_knmi-racmo22e_historical_1976-2005.nc
16. idf_24h_ichec-ec-earth_knmi-racmo22e_rcp45_2021-2050.nc
17. idf_24h_ichec-ec-earth_knmi-racmo22e_rcp45_2021-2050_change.nc
18. idf_24h_ichec-ec-earth_knmi-racmo22e_rcp85_2021-2050.nc
19. idf_24h_ichec-ec-earth_knmi-racmo22e_rcp85_2021-2050_change.nc
20. idf_24h_mohc-hadgem2-es_knmi-racmo22e_rcp45_2021-2050.nc
21. idf_24h_mohc-hadgem2-es_knmi-racmo22e_rcp45_2021-2050_change.nc
22. df_24h_mohc-hadgem2-es_knmi-racmo22e_rcp85_2021-2050.nc
23. idf_24h_mohc-hadgem2-es_knmi-racmo22e_rcp85_2021-2050_change.nc
24. idf_24h_mohc-hadgem2-es_knmi-racmo22e_historical_1976-2005.nc

Wildfires:

25. hazard_HIST_199110
26. hazard_RCP45_CLMcom_CCLM_202140
27. hazard_RCP85_CLMcom_CCLM_202140
28. registered_wildfire_keumr.gpkg
29. scope_hospitals_wildfire_hazard.gpkg
30. scope_social_services_buldings_jtsk_wildfire_hazard.gpkg
31. scope_vulnerabl_roma_dwelings_wildfire_hazard.gpkg
32. scope_vulnerabl_kindergarten_merge_jtsk_wildfire_hazard.gpkg
33. scope_hospitals_wildfire_hazard_123_200m_risk_q3.gpkg
34. scope_social_services_buldings_jtsk_wildfire_hazard_123_200m_risk_q3.gpkg
35. scope_vulnerabl_kindergarten_merge_jtsk_wildfire_hazard_123_200m_risk_q3.gpkg
36. scope_vulnerabl_roma_dwelings_wildfire_hazard_123_200m_risk_q3.gpkg

Agricultural Droughts:

37. SK_BARL_ncc_geri_revenue_loss_1000EUR_svk_ke_umr.tif
38. SK_MAIZ_ncc_geri_revenue_loss_1000EUR_svk_ke_umr.tif
39. SK_RAPE_ncc_geri_revenue_loss_1000EUR_svk_ke_umr.tif
40. SK_WHEA_ncc_geri_revenue_loss_1000EUR_svk_ke_umr.tif
41. SK_yield_loss_barley_rcp45_ncc_geri_2021_2050_svk_ke_umr.tif
42. SK_yield_loss_maize_rcp45_ncc_geri_2021_2050_svk_ke_umr.tif

43. SK_yield_loss_rapeseed_rcp45_ncc_geri_2021_2050_svk_ke_umr.tif
44. SK_yield_loss_wheat_rcp45_ncc_geri_2021_2050_svk_ke_umr.tif
45. Stredné Slovensko_irrigation_share_percent_svk_ke_umr.tif

6. References

Adaptačný plán mesta Košice na zmenu klímy (2022–2030) (Adaptation plan of the city of Košice for climate change (2022–2030)), https://static.kosice.sk/s/f2a7cfef764f92a7cd26ae247.

Bečić, D., and Gašparović, M.: Urban Heat Islands and Land-Use Patterns in Zagreb: A Composite Analysis Using Remote Sensing and Spatial Statistics, https://doi.org/10.3390/land14071470, 2025.

Blöschl, G., Ardoin-Bardin, S., Bonell, M., Dorninger, M., Goodrich, D., Gutknecht, D., Matamoros, D., Merz, B., Shand, P., and Szolgay, J.: At what scales do climate variability and land cover change impact on flooding and low flows?, Hydrological Processes, 21(9), 1241–1247, 2007.

Buzási, A.: Comparative assessment of heatwave vulnerability factors for the districts of BUMRpest, Hungary, https://doi.org/10.1016/j.uclim.2022.101127, 2022.

CDS (2019)a: CORDEX regional climate model data on single levels, Copernicus Climate Change Service (C3S) Climate Data Store (CDS), https://doi.org/10.24381/cds.bc91edc3, 2019. Accessed (14.1.2026).

CDS (2019)b: Heat waves and cold spells in Europe derived from climate projections, Copernicus Climate Change Service (C3S) Climate Data Store (CDS), https://doi.org/10.24381/cds.9e7ca677, 2019. Accessed (14.1.2026).

Cheval, S., Dumitrescu, A., Amihăesei, V., Irașoc, A., Paraschiv, M.-G., and Ghent, D.: A country scale assessment of the heat hazard-risk in urban areas, https://doi.org/10.1016/j.buildenv.2022.109892, 2023.

Chakraborty, D., Dobor, L., Zolles, A., Hlásny, T., and Schueler, S.: High-resolution gridded climate data for Europe based on bias-corrected EURO-CORDEX: the ECLIPS-2.0 dataset (v1), doi:10.5281/zenodo.3952159, 2020, Zenodo.

CLIMAAX Handbook (Bias Uncertainty Tool), 2025: Bias uncertainty tool dashboard (SK04), https://handbook.climaax.eu/dashboards/bias-uncertainty/#SK04, 2025. Available (14.1.2026).

Copernicus Browser, 2026: Copernicus Browser NDVI tool (Copernicus Data Space Ecosystem), https://browser.dataspace.copernicus.eu/?zoom=15&lat=49.19842&lng=18.72718&themeId=DEFAULT-THEME&visualizationUrl=U2FsdGVkX19DaPrOu6SHOmE3pc13bKCF80j3YPiG1ZT8s5olOsTKtB%2FA%2B3qd3ifaqYz3n%2FLmEleppejrwom79yBDIuNvj6uPxQgJCL7E2ukA5HDPF3Pkv%2B3A%2BE2kSedF&datasetId=S2_L2A_CDAS&fromTime=2019-08-31T00%3A00%3A00.000Z&toTime=2019-08-31T23%3A59%3A59.999Z&layerId=1_TRUE_COLOR&demSource3D=%22MAPZEN%22&cloudCoverage=30&dateMode=SINGLE, 2026. Available (14.1.2026).

CORINE Land Cover, 2018: CORINE Land Cover (CLC) 2018, https://land.copernicus.eu/en/products/corine-land-cover, 2018. Available (14.1.2026).

EFFIS, n.d.: Current situation viewer, https://forest-fire.emergency.copernicus.eu/apps/effis_current_situation/, n.d. Available (14.1.2026).

Farkas, R., Csizovszky, A., Beszedics-Jäger, B. S., and Buzási, A.: Heatwave vulnerability and climate policy assessment in Central Europe: A comparative study of Hungarian and Slovak cities, https://doi.org/10.1016/j.uclim.2024.102073, 2024.

Geletič, J., Lehnert, M., and Dobrovolný, P.: Land Surface Temperature differences within Local Climate Zones, based on two Central European cities, https://doi.org/10.3390/rs8100788, 2016.

Infoma, 2024: Agriculture and food (report), https://www.infoma.sk/dokumenty/polnohospodarstvo-potravinarstvo-2024.pdf, 2024. Available (14.1.2026).

Intersucho, n.d.: Drought monitoring web application, https://www.intersucho.sk/sk/, n.d. Available (14.1.2026).

Košice Online, 2024: Information about collapses from heat, https://www.kosiceonline.sk/vyse-sto-kosicanov-skolabovalo-z-tepla#:~:text=Vysok%C3%A9%20teploty%20nad%2030%20stup%C5%88ov%20pretrv%C3%A1vaj%C3%BA%20nieko%C4%BEko,predstavuje%20okrem%20in%C3%A9ho%20aj%20z%C3%A1%C5%A5a%C5%BE%20na%20organizmus., 2024. Available (14.1.2026).

Květoňová, V., Pánek, J., Geletič, J., Šimáček, P., and Lehnert, M.: Where is the heat threat in a city? Different perspectives on people-oriented and remote sensing methods: The case of Prague, https://doi.org/10.1016/j.heliyon.2024.e36101, 2024.

Lehnert, M., Jirmus, R., Květoňová, V., Geletič, J., Jurek, M., Středová, H., and Frajer, J.: Overheated children's playgrounds in Central European cities: The effects of surfaces and shading on thermal exposure during hot summer days, https://doi.org/10.1016/j.uclim.2024.101873, 2024.

NOAA (NCEI), n.d.: Daily observation data (maps), https://www.ncei.noaa.gov/maps/daily/, n.d. Available (14.1.2026).

Parastatidis, D., Mitraka, Z., Chrysoulakis, N., and Abrams, M.: Online Global Land Surface Temperature Estimation from Landsat, Remote Sensing, 9, 1208, https://doi.org/10.3390/rs9121208, 2017.

Program hospodárskeho rozvoja a sociálneho rozvoja mesta Košice a jeho funkčnej oblasti 2022–2027 (Program of economic and social development of the city of Košice and its functional area 2022–2027), https://static.kosice.sk/files/manual/phsr/PHRSR_mesta_Kosice_a_jeho_funkcnej_oblasti_2022-2027.pdf.

Seed4Forest, n.d.: Influence of climate change on trees (web application), https://seed4forest.vercel.app/, n.d. Available (14.1.2026).

SHMÚ, 2015: Tropical days, https://www.shmu.sk/sk/?page=2049&id=612, 2015.

SHMÚ, 2025: Future climate scenarios from SHMÚ, https://www.klima-adapt.sk/scenare-buducej-klimy, 2025. Available (14.1.2026).

Slovak statistical portal, 2025: Košický kraj – characteristic of the region, https://slovak.statistics.sk/wps/portal/ext/themes/regional/kosicky%20kraj/about/%21ut/p/z1/jZHBDoIwEEQ_aQcoUI4VtdQQhNaK9mI4GINR8GD8fo2JFxMre9vkzctuhhztyA3doz91934cu *str37vk0KSKz2aBAI9TQFXGAlsDs06o_QIqvYDaiFrqFQvAYnJT8rkUBUtLgJcyhhKF1VkTRRDRtDx-jMC0vAdwfn1L7o34PvjncN4jZfAHwMewNHUoMibzuV4vXy3kITdlEgIBVcV4PZI5DnS7Wmt36NWZiSf23si3/dz/d5/L2dJQSEvUUt3QS80TmxFL1o2X1ZMUDhCQjFBMEc3VDEwSU5OU1VWOFEzTUgx/, 2025. Available (14.1.2026).*

Teraz.sk, 2025: Information about collapses from heat, https://www.teraz.sk/import/kolapsy-z-tepla-za-poslednych-pat-dn/900301-clanok.html, 2025. Available (14.1.2026).

Veitengruber, A.: D.1.2.1: Analysis of the Areas (READY4Heat project deliverable), https://www.interreg-central.eu/wp-content/uploads/2023/11/CE0100067-Ready4Heat-D.1.2.1-Analise-of-the-areas.pdf, 2023.

WorldPop, 2020: Vulnerable population density data, https://data.humdata.org/organization/worldpop, 2020. Available (14.1.2026).