CLIMAAX
climate ready regions

Deliverable Phase 1 – Climate risk assessment

Updating Västernorrland's Climate Risk and vulnerability Assessment using the CLIMAAX methodology

UVCRA

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

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Document Information

Deliverable Title	Phase 1 – Climate risk assessment
Brief Description	During Phase 1 CABV successfully tested and applied the CLIMAAX methodology for 2 workflows – heavy snowfall & blizzards, and heavy rainfall. Preliminary hazard and risks maps were produced and discussed during the workshop together with internal county experts. The outputs of this Phase 1 will be used during the Phases 2 and 3. Phase 1 outputs (initial risk evaluation, project stakeholder network development, data collection and methodological gap evaluation) will serve as a foundational basis for the CRA work during Phases 2 and 3 that will focus on more detailed analysis and active cooperation with external stakeholders.
Project name	**Updating Västernorrland's Climate Risk and vulnerability Assessment using the CLIMAAX methodology**
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5.0	…		Final version to be submitted

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Abbreviations and acronyms

Abbreviation / acronym	Description
CABV	The County administrative Board of Västernorrland
CRA	Climate Risk Assessment
GIS	Geographic Information System
MSB	Swedish Civil Contingencies Agency
SGI	Swedish Geotechnical Institute
SMHI	Swedish Meteorological and Hydrological Institute

Executive summary

Västernorrland County is located in eastern Central Norrland. Its landscape is hilly, with high mountains and deep river valleys. This landscape has been influenced by post-glacial rebound, a process that has been ongoing since the Ice Age and continues today. The land rises by approximately 8 mm each year. Västernorrland County is one of the most forested areas in Sweden, with 74% of its total area covered by forests, 3% by agricultural land, and 2% by developed land.

The CLIMAAX project is expected to raise awareness and promote knowledge of climate adaptation work and the impact of climate change in the county among local stakeholders. The project provides an opportunity to update *the 2018 Climate Risk and Vulnerability Analysis in Västernorrland County* and its accompanying *Action Plan.*

Prior to the CLIMAAX project, climate hazards, impacts, and risks were assessed in our region through national coordination efforts, as well as through the implementation of the Regional Action Plan for Climate Adaptation in Västernorrland County (2018) and its follow-up report (2018–2022). Additionally, the Swedish Meteorological and Hydrological Institute (SMHI) provides Swedish regions and municipalities with long-term climate data, scenario modelling, and tools which helps assess risks.

During Phase 1, the County Administrative Board of Västernorrland (CABV) identified internal roles, responsibilities, and areas of cooperation within the institution. **An inter-disciplinary project team was formed**, comprising experts from various units, including the Civil Protection and Emergency Preparedness Unit and the Community Planning Unit, bringing together diverse competencies and a shared understanding. On May 27, 2025, **an internal workshop** was held to discuss the initial CLIMAAX project analysis and explore possibilities for using and further developing the results.

The severity and urgency of the risks in our region became particularly evident during the deliverable writing period. On September 6, 2025, heavy rain severely affected the Västernorrland region. The rain caused severe damage to infrastructure – approximately 40 roads and railway were affected. Passenger train traffic was suspended northward from Sundsvall. Water levels became extremely high in many waterways and numerous property owners experienced flooded basements and other water damage. The CABV activated its emergency response team to manage the situation.

The primary activity in Phase 1 was the application of the CLIMAAX methodology and tools to address the region's specific climate hazards, namely **heavy rainfall and blizzards.** The workflows were implemented for both hazards; however, limitations arose due to the low resolution of available hazard maps. Nevertheless, the use of CLIMAAX tools established a foundation for subsequent project phases, during which national, regional, and local data will be analyzed and utilized.

The CLIMAAX analysis confirmed the regional climate trend reported by earlier studies, concluding that the future climate is expected to be warmer and wetter in our region, characterized by **decreased snowfall and increased rainfall.** The county-based scenarios for Västernorrland with regards to heavy rainfall shows a general increase of about 20% rain in both RCP-scenarios (RCP 4.5 and RCP 8.5). The geographic distribution of maximum daily precipitation showed a concentration in coastal areas. These results provide a valuable foundation for strategic-level planning and will be supplemented by localized analyses in phases 2 and 3 that account for our region's specific geography and unique conditions.

1 Introduction

1.1 Background

Västernorrland County is located in the eastern part of Central Norrland and consists of seven municipalities. Ånge and Sollefteå are inland municipalities, while Sundsvall, Timrå, Härnösand, Kramfors, and Örnsköldsvik have both coastal and inland areas. The county has approximately 244,000 inhabitants spread over an area of 21,548 square kilometres. While the larger Sami population is concentrated further north in Swedish Lapland, Västernorrland retains a significant Sami community that identifies strongly with their heritage.

The landscape is hilly, with high mountains and deep river valleys. The county's largest rivers are the Ångermanälven, Indalsälven, and Ljungan. In addition, there are many smaller rivers and streams. Many of these waterways are regulated, and the hydropower produced in the county accounts for 9% of Sweden's total electricity production.

The landscape is influenced by post-glacial rebound, which has been ongoing since the Ice Age—and continues today. The land rises by about 8 mm per year. In most parts of the county, the topsoil consists of moraine. The moraine and eskers are partially covered by younger fine sediments.

The county is one of the most forest-rich in the country, with 74% of the total area covered by forest land, 3% by agricultural land, and 2% by developed land. The local economy has evolved from the county's natural resources in the form of forests and energy. The foundational industries (forestry, pulp/paper, and hydropower) remain strong, alongside a well-developed technology and environmental technology sector.

1.2 Main objectives of the project

Project Specific Objectives:

- Develop a *Climate Risk and Vulnerability Assessment* using the CLIMAAX methodology, with a focus on two key hazard profiles: **heavy snowfall & blizzards, and extreme precipitation**.
- Integrate the assessment results into internal planning and decision-making processes at Länsstyrelsen Västernorrland, serving as a guiding document for future work.
- Disseminate updated knowledge and materials derived from the project to support urban planning and decision-making at the municipal level, as well as within civil society, including Sámi villages and local organizations.

The project is expected to bring increased attention and knowledge to the work on climate adaptation and the impact of climate change in the county among local stakeholders. It provides an opportunity to update the *Climate Risk and Vulnerability Analysis,* along with the accompanying *Action Plan*, which was developed in 2018. This will offer guidance to the county's municipalities, authorities, and citizens on how the region may be affected by a changing climate, and what measures we can take today to address these changes.

Throughout the project's implementation, we will engage in various communication efforts with our stakeholders, for example in the forms of workshops and meetings. This will give us opportunities to discuss the effects of the climate change on the regional level as well as explore the actions to reduce those vulnerabilities.

The project also enables us to exchange experiences with other regions in Europe undertaking similar work, allowing us to learn from them and share our own insights from the efforts being carried out in our region.

By using the handbook's working method, we will ensure that our region, and other participating regions, conduct these analyses in the same way. This allows us to make sure that Europe's regions carry out this work according to a unified approach. It also gives us the opportunity to propose the method improvements and test the available factual data.

1.3 Project team

During Phase 1, an external consultant company carried out the CLIMAAX analysis. The team consisted of two professionals specializing in environmental science, extreme precipitation management, and community planning.

The project team at the County Administrative Board of Västernorrland has consisted of:

- Unit Manager Viveka Sjödin, Community Planning
- Unit Manager Tobias Lindenkäll, Civil Protection and Emergency Preparedness
- Felicia Edholm, Emergency Preparedness Officer

The project manager, Asta Gulijeva, has been recruited and began her employment on August 13, 2025. The project manager will compile the first CLIMAAX deliverable and will actively contribute to Phases 2 and 3.

The project team will also be expanded to include experts in GIS and financial reporting.

1.4 Outline of the document's structure

This document is following the already defined CLIMAAX template structure.

2 Climate risk assessment – phase 1

2.1 Scoping

2.1.1 Objectives

Sweden is divided into 21 counties, each overseen by a County Administrative Board (Länsstyrelsen). These boards are responsible for ensuring that national objectives are implemented at the regional level, while also considering local conditions and needs. The County Administrative Board operates from a comprehensive governmental perspective, coordinating societal interests and the efforts of national agencies. It also monitors regional development and informs the government about the county's needs.

For the past decade, in response to a government mandate, **the County Administrative Board of Västernorrland** has worked to enhance understanding of how climate change may impact our county. Throughout this period, awareness has steadily increased, and we have actively shared insights with municipalities, public agencies, and other regional stakeholders. However, due to insufficient funding, this work has not continued over the past year.

Our aim with the updated Climate Risk and Vulnerability Assessment (CRA) is to bring back attention on climate-related risks within our own organization. We would like to ensure that the impacts of climate change are systematically integrated into our work, including the guidance and policy documents we oversee across various sectors. This initiative will also help raise awareness among municipalities, which must account for climate risks in areas such as spatial planning, long-term strategies for drinking water supply, and efforts to strengthen crisis preparedness among public authorities and the wider community.

At the national level, the legislation now includes more requirements to consider the impacts of climate change (for example, within municipal land and water use planning). A regional **CRA will be a valuable support tool for municipalities as they develop new comprehensive plans.** National agencies have also worked to produce knowledge platforms and guidance documents on climate adaptation for various sectors, and we can help disseminate that knowledge within our county.

The CRA, along with its associated action plan, will improve the capacity of **regional authorities and the public to understand the increasing risks posed by a changing climate.** This will help ensure that these risks are systematically integrated into decision-making processes and will strengthen our resilience against the negative consequences that climate change may bring to our county. At the same time, we aim to harness the positive effects, for example, increased opportunities for our agricultural sector, which may benefit from improved growing conditions and a longer growing season.

We already have access to **climate related data** provided by the Swedish Meteorological and Hydrological Institute (SMHI). We have also developed several regional analyses, for example on future sea level rise and the impact on our natural and cultural environments.

One challenge will likely be engaging the municipalities in our work. We have previously maintained an active network that we plan to reactivate, but it is often difficult to gain commitment from, for instance, political leadership. The work planned for Phase 2, identifying various collaboration forums that can contribute to our analysis, will be an important tool for reaching different target groups across the county. Here, we can make use of existing forums within the County Administrative Board's various areas of responsibility (agriculture, natural environment, spatial planning, crisis preparedness, etc.).

Another challenge may be time. Since **we are constrained by the project timeline,** we need to make use of the existing forums and partnerships available in the county. For example, we are currently collaborating with a project Beredda byar (prepared villages) aimed at strengthening crisis preparedness in two of the county's municipalities. This project could serve as a valuable context where we can engage an existing target group and gather input for our CRA at the local level.

2.1.2 Context

Climate hazards, impacts and risks have been assessed in our region through national coordination efforts (various research initiatives coordinated by the national institutions) as well as through the implementation of the *Regional Action Plan for Climate Adaptation in Västernorrland County* (2018) and its *Follow-up report* (2018-2022). In addition, the Swedish Meteorological and Hydrological Institute (SMHI) supports the regions and municipalities in Sweden with long-term climate data, scenario modeling, and tools like the Climate Change Scenario that helps to assess risks.

The County Administrative Board needs to resume actively working in the areas of climate adaptation and increase awareness among stakeholders in the region. National authorities are actively working to enhance knowledge and provide guidance on the measures needed to strengthen our resilience against the negative impacts of climate change, and we need to highlight this area and intensify efforts throughout the county.

The Swedish *Planning and Building Act*, *the Environmental Code*, and *the Civil Protection Act* highlight the need for implementing climate change adaptation measures on the national, regional and municipal levels.

In the legislation governing municipalities' planning of land and water use (*the Planning and Building Act*), new provisions have been introduced recently to promote more climate-resilient construction. The municipal comprehensive plan, a politically adopted document that outlines the long-term planning for the entire municipality, must now also include:

The municipality's view on the risk of damage to the developed environment that may result from flooding, landslides, landslides, and erosion related to climate change, as well as how such risks can be reduced or eliminated. The Planning and Building Act (2010:900).

There is additional legislation that requires consideration of various risks, including those related to flooding, landslides, and erosion. However, these laws have not yet been updated to address the increased risks due to climate change. Currently, several legislative proposals are under review, aiming to align Swedish laws with evolving European Union regulations in this area.

The *Regional Action Plan for Climate Adaptation in Västernorrland County* (2018 and its update in 2022) highlights **several sectors as vulnerable to climate change**, including infrastructure, developed environment and cultural heritage, land-based industries and tourism, technical supply systems, public health, and natural environment. To address these risks the report addresses a need for stronger collaboration, better data access, and integrated planning across municipalities and agencies.

Moreover, SGI (Swedish Geotechnical Institute) and MSB (Swedish Civil Contingencies Agency) have identified in the report *Risk Areas for Landslides, Erosion and Flooding* (2021) our county, as **a high-risk area for climate-related hazards such as landslides, erosion, and flooding.** This designation highlights the region's vulnerability and the need for targeted climate adaptation measures. The classification is part of a broader national effort to map and manage areas facing the risks of landslides, erosion and flooding.

We are not aware of the outside influences on the problem at this point however it will be investigated during the second phase of this project.

Possible adaptation interventions will be analysed and discussed with the stakeholders during the second and third phases of the project.

2.1.3 Participation and risk ownership

Climate risk ownership in Sweden is distributed across several governance levels: the national government (e.g. Swedish Civil Contingencies Agency), the regional level (Region Västernorrland), the County Administrative Boards as well as municipalities and private landowners. The County Administrative Board plays a key role in coordinating and supporting climate adaptation at the regional level (coordinating climate adaptation efforts across the region, involving municipalities, regional authorities, government agencies, businesses and other stakeholders).

Currently, there is no formal or widely agreed definition of **“acceptable risk”** in the region. *The Planning and Building Act* states that new buildings may not be constructed in areas where there is a significant risk of flooding and other natural hazards. The CLIMAAX project will help to initiate a dialogue on acceptable risks as the project aims to promote greater awareness of responsibility-sharing in risk prevention and climate adaptation. This discussion will be initiated together with our project stakeholders.

During Phase 1, the County Administrative Board of Västernorrland (CABV) identified internal roles, responsibilities, and areas of cooperation within the institution. An inter-disciplinary project team was formed, comprising experts from various units, including the Civil Protection and Emergency Preparedness Unit and the Community Planning Unit, bringing together diverse competencies and a shared understanding.

On May 27, 2025, **an internal workshop** was held where consultants responsible for implementing the Climaax method analysis met with the internal CABV team, which included 23 participants. The workshop discussed the initial CLIMAAX project analysis and explored possibilities for using and further developing the results.

During our participation at the **CLIMAAX workshop in Barcelona**, initial contacts were made with the other CLIMAAX regions, including the Swedish participants.

The County Administrative Board is also part of a regional network comprising climate adaptation experts from various counties in Sweden. On August 22, 2025, our project manager attended a seminar focused on best practices for drafting and updating *the Regional Action Plan for Climate Adaptation*. Regions that have already completed this activity shared valuable insights and experiences related to the writing process.

During Phases 2 and 3, analyses of external stakeholders will be made, and cooperation will be initiated. Those stakeholders will be actively involved in project activities to ensure project ownership, as well as to cover different approaches and competencies. Our aim is to involve 12 stakeholders during the project development phase.

Already identified main stakeholders:

• Planners and climate change strategists in the region's seven municipalities: Sundsvall, Ånge, Timrå, Härnösand, Kramfors, Sollefteå, and Örnsköldsvik.
• Politicians and policymakers of the seven municipalities and of the regional government.
• The Samí villages of Vornese, Jinjavaerie, Jovnavaerie, Paedtievaneri, Ohredakhe, Vilhelmina södra, and Vilhelmina norra.
• Local organisations working with adaptation. For example, the EU-funded project "Beredda byar" (EU CAP, LEADER/CLLD) examines how small, rural communities can prepare for climate change and develop resilient social structures in response.
• Regional fire and emergency services.

As a part of the project, we will collaborate with **existing networks and communication channels** already established within the agency, for example, those involving coordinators for climate issues, contingency planning, and minority groups in the region. Engagement will take place through both information dissemination and interactive formats such as workshops and individual meetings.

In addition to the stakeholders already identified, Phases 2 and 3 will include a **comprehensive mapping of additional stakeholders as** well as representatives from vulnerable groups to ensure broad and inclusive participation. A communication plan will be developed to communicate the project results, furthermore this plan will be adapted to different stakeholder groups.

2.2 Risk Exploration

For the broad screening of the risks during Phase 1, we have taken into account **previous climate adaptation studies** conducted by relevant national agencies, such as the *Swedish Meteorological and Hydrological Institute* or the *Swedish Civil Contingencies Agency*, as well as our own regional analysis and studies – *the Regional Action Plan for Climate Adaptation in Västernorrland (2018)* and its follow-up report (2022).

Our **screening of the risks will be continued in collaboration with identified stakeholders** throughout the entire project implementation period. During Phases 2 and 3 risk discussions will be integrated into regularly organized interdisciplinary workshops and meetings within our institution. The broader risk screening will also be conducted through our participation in several regional and national climate adaptation **knowledge exchange networks,** which include national, regional, and local authorities. The county administrative board of Västernorrland will also participate in relevant regional and national **climate adaptation conferences**. These events will facilitate ongoing risk screening and ensure updates with the most current knowledge.

Our dialogue with municipalities and support for their **municipal physical planning** is also crucial for comprehensive risk exploration. Such collaboration during Phases 2 and 3 will ensure that municipal decisions are informed by broader climate risk assessments and aligned with national and regional adaptation strategies. Our county, as well as municipalities, possess specialized knowledge, data, and tools that help to identify hazards such as flooding or erosion, in addition to the exposures and vulnerabilities of local communities. Therefore, collaboration with local authorities will contribute to the broad screening of risks, especially in shared catchment areas.

2.2.1 Screen risks (selection of main hazards)

Heavy snowfall & Blizzards, and **Heavy Rainfall** were chosen as the most important climate-related hazards to be analysed in this project.

Blizzards are significant weather events, especially in northern and mountainous regions. These events are characterized by strong wind gusts, considerable precipitating or blowing snow, and reduced visibility, often resulting in widespread disruption to transportation, energy infrastructure, and economic activities.

According to the *Intergovernmental Panel on Climate Change (IPCC) 6th report*, extreme winter storms, including snowstorms and blizzards, may increase in intensity and impact despite a general trend toward lower snow cover with warming temperatures. These extreme events are expected to become more frequent in certain regions where cold air masses persist, particularly in areas vulnerable to rapid shifts in weather conditions. Additionally, the combined effects of urbanization and inadequate storm preparedness will likely compound the risks of snowstorms, leading to further economic downturn.

In Sweden, average precipitation is expected to increase. Higher temperatures will cause more rain instead of snow while also melting the existing snow. Consequently, **both snow depth and the number of snowy days is expected to decrease** (SMHI, 2024). Understanding extreme snow events and their associated risks is crucial for developing effective strategies to mitigate and adapt to changing climate conditions.

Within the CLIMAAX framework, a blizzard is defined as a severe storm condition defined by low temperature, sustained wind or frequent wind gusts, and considerable precipitating or blowing snow.

In absolute terms **blizzard** is defined as:

- Mean daily temperature below 0°C
- Amount of snow above 10 cm
- Wind gust velocity above 17 m/s

During **heavy snowfall**, two threshold levels are used:

- 6 cm of snow: Some impact, primarily on transportation
- 25 cm of snow: Major impact, critical infrastructure is seriously affected

It is important to note that the given threshold, 6 cm of snow, does not affect our region in the same way it might affect southern European countries. Sweden is a Nordic country accustomed to such snow conditions.

County-based analysis and data in relation to snow and heavy rainfall

In SMHI's county-based climate analysis from 2015, calculations were conducted to describe future meteorological and hydrological conditions. This work included indicators related to future snow conditions. In 2019, the County Administrative Boards of the seven northernmost counties requested an extended analysis of future snow conditions. The report *"Snow in Future Climate – for the Seven Northernmost Counties"* presents several climate indices based on calculations of snow occurrence in future climate scenarios (SMHI, 2021). These calculated snow conditions are presented in the form of maps, graphs, and tables. The analysis is based on results from the hydrological model's sub-drainage areas in Västernorrland County, using Sollefteå, among other locations, as a reference point.

The report's findings suggest a significant decline in both snow depth and the number of days with measurable snow across nearly all of northern Sweden. These reductions are expected to occur throughout the snow season, with the most pronounced changes projected in parts of Värmland and Dalarna, as well as along the Norrland coast which includes our region. Despite these changes, the number of days transitioning from below-freezing to above-freezing temperatures is expected to remain relatively stable along the Norrland coast.

In Sollefteå, as shown in Figure 1, the average snow depth increases from late autumn, reaching a maximum in February/March, and then decreases. By the end of the century, snow depth is expected to decrease throughout the entire snow season, with larger reductions under the higher emissions scenario RCP8.5. The greatest average snow depth on a specific day is expected to decrease from 35 cm to just over 12 cm under the RCP8.5 scenario.

In late winter, the reductions are expected to be even greater, with May projected to be almost snow-free by the end of the century. The maximum snow depth in Sollefteå is also expected to occur 0.5 months earlier on average, compared to the reference period.

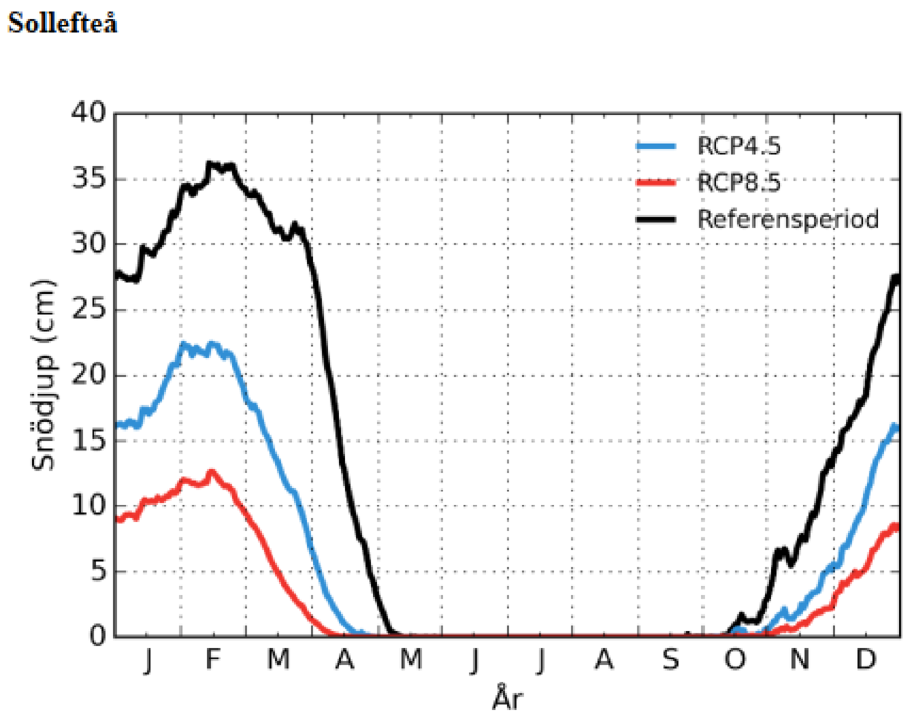

Figure 1 Variation in average snow depth over a year for Sollefteå and during the reference period (1963-1992) and at the end of the century (2069-2098). Source: Attachment of the report "Snow in Future Climate – for the Seven Northernmost Counties".

County-based scenarios for heavy rainfall

According to the projections published by the Intergovernmental Panel on Climate Change (IPCC), the intensity and frequency of intense rainfall events are expected to increase. Moreover, further studies have provided robust evidence that the intensification of heavy precipitation, combined with rapid urbanization, will likely lead to more frequent and extreme flood events. In this scenario, the pressure of the changing flood hazard on communities, their citizens, and their properties is evident. Although there is an ongoing debate on the estimated socio-economic losses that could be observed, there is a consensus that extreme rainfall will substantially increase flood damages if insufficient or no adaptation measures to improve the preparedness and coping capacity of communities are developed and implemented.

In 2015, the County Administrative Board developed a county-wide low point mapping, including flow paths. This mapping is fully available in the County Administrative Board's Climate GIS, as well as for each municipality. The municipalities of Sundsvall and Härnösand have since developed their own more detailed analysis for their central urban areas.

In 2022, the Swedish Civil Contingencies Agency (MSB) was commissioned by the government to develop a standardized method for cloudburst mapping in urban areas. A cloudburst is rainfall during which a large amount of precipitation is discharged during a very short period. The assignment also includes applying the method to a selection of previously conducted cloudburst mappings and making the results available so that they are comparable from a national perspective.

In the county-level climate analysis presented by SMHI in 2015, calculations were provided describing meteorological and hydrological conditions in a future climate. The report states that the annual average precipitation is expected to increase by approximately 20–40% towards the end of the century. The largest increase occurs in spring, where the RCP8.5 scenario indicates a 50% rise in precipitation in certain areas.

2.2.2 Workflow selection

From the screening process it was clear that the most pressing issues rising from a changing climate were heavy rainfall and heavy snowfall & blizzards.

2.2.2.1 Workflow #1 Heavy snowfall & blizzards

Workflow #1 was selected to evaluate and visualize changes in extreme winter precipitation. The calculations were conducted across the entirety of Västernorrland County. Although the region is accustomed to substantial snowfall, the thresholds for heavy snowfall and blizzards were maintained to ensure comparability with other Climaax analyses.

As with all climate change–related risks, the precise impacts of significant increases or decreases in precipitation are difficult to predict. However, potential consequences of increased snowfall and blizzard frequency include disruptions to economic activity, extended travel times, and heightened challenges for isolated communities in accessing essential goods and services.

2.2.2.2 Workflow #2 Heavy Rainfall

Workflow #2 was applied to assess the hazard and risk associated with extreme precipitation events across Västernorrland County during the "rain" season, spanning May to September.

An increase in heavy rainfall can result in significant challenges, including urban flooding that disrupts economic activity, causes property damage, and leads to the shutdown of critical infrastructure. These impacts are not confined to urban centres. Secluded communities within Västernorrland face similar vulnerabilities, particularly in terms of accessibility and resilience.

Conversely, a decrease in precipitation presents its own risks. Reduced rainfall heightens the likelihood of wildfires and poses serious challenges to the agricultural sector, potentially undermining food production and rural livelihoods.

2.2.3 Choose Scenario

2.2.3.1 Heavy snowfall and blizzards

The analysis was carried out for three different emission scenarios RCP 2.6, RCP 4.5 and RCP 8.5 using historical data (ERA5 dataset from1991 to 1995) and a predicted data (EURO-CORDEX dataset for two different time periods, 2045-2050 and 2081-2085) downloaded from the Copernicus Climate Data Store. In this workflow we only looked at data from the snow season, October to March.

2.2.3.2 Heavy Rainfall

In the heavy rainfall workflow, the RCP 4.5 and 8.5 scenarios were used and later compared against each other in order to visualize the differing outcomes. We also chose to not use the pre-processed data available and calculate it using the CLIMAAX Heavy rainfall hazard assessment notebook using the 24h and 3h precipitation datasets. The extreme precipitation used the time-period 2041-2070 for both RCPs with a 10-year return period. For the historical comparison we chose to use 1976-2005. In analysis for Härnösand we used the following return periods 2, 5, 10, 50 and 100 years while the analysis for the entire region used 2, 5, 10, 25, 50, 100, 200, 500 years.

2.3 Risk Analysis

2.3.1 Workflow Heavy Snow and Blizzards

The analysis of extreme precipitation in Västernorrland was carried out according to the workflow described in the CLIMAAX project's handbook "Heavy Snow and Blizzards". The work was carried out using published Python scripts available via the associated GitHub repository (GitHub, 2025).

This workflow was developed to assess the risk of heavy snowfall and snowstorms in Europe but has been applied to specifically analyze the Västernorrland County. The purpose of the analysis was to investigate where and how often extreme snow events occur today and how these may change in the future due to climate change.

2.3.1.1 Hazard assessment

Initially, Västernorrland County was defined as the geographical area of analysis. However, upon reviewing the preliminary results and historical data, it became evident that an expansion of the study site was necessary. In certain cases, the initial outputs appeared incomplete, and a broader scope was required to enable meaningful comparisons between Västernorrland and other regions.

With these considerations in mind, the study area was extended to encompass both Sweden and Norway, thereby strengthening the analytical framework and enhancing the relevance of the findings.

Climate data was then downloaded from the Copernicus Climate Data Store for the different time periods: a historical period 1991-1995 and two future periods 2045-2050 and 2081-2085. Various emission scenarios were downloaded, such as RCP 2.6, RCP 4.5, and RCP 8.5. The script was modified to include the entire snow season, from October to March.

Using daily temperature and precipitation data, snow depth was calculated, and indicators for snowstorms and heavy snowfall were taken as the example values provided in the CLIMAAX notebook. The indicators are days with more than 6 cm or 25 cm of snow, as well as days when all three criteria – snow, cold, and strong wind – are met. The results were presented in probability maps showing the annual risk of heavy snow events in the study site, both under current and future climate conditions. For a complete overview of the results see Appendix 1.

2.3.1.2 Risk assessment

After the hazard assessment was carried out, an exposure analysis was performed where the results were linked to population data. Here, data from the JRC data portal, specifically the Global Human Settlement Layer (GHSL), with a spatial resolution of approximately 1 km x 1 km, were used. To enable overlaying these data with climate indicators, the script was modified to reproject both datasets to the same geographical resolution and extent. The original code published on GitHub did not work as intended, and additional adjustments were made to the visualization functions as one of the maps previously overlapped with another.

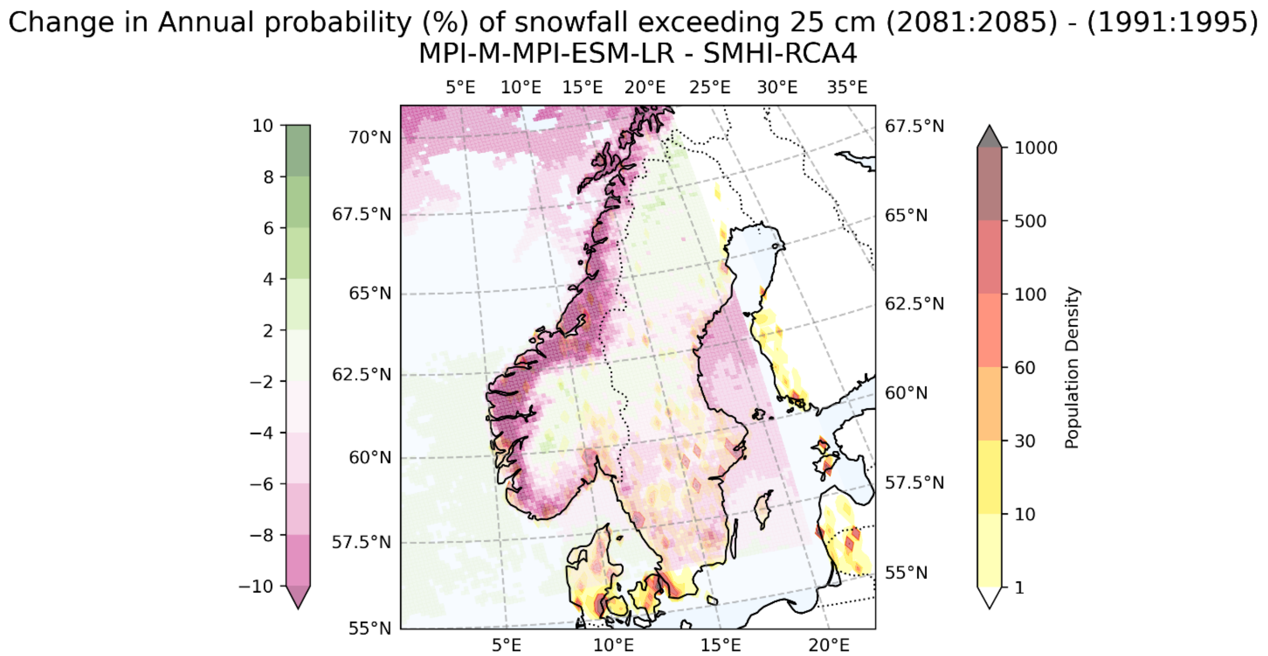

Figure 2 Change in annual probability of snowfall exceeding 25cm, projections for the period 2081-2085 compared against the historical data spanning 1991-1995 under RCP 8.5.

In Figure 2 we can see that for Västernorrland (Västernorrland is located within the “box” created by 15E-20E and 62.5N-65N) we can expect a decrease of snowfall in general. This is true for all three of the RCP scenarios investigated in this report. For a complete overview of the results see Appendix 1.

Table 2-1 Data overview workflow #1

Hazard data	Vulnerability data	Exposure data	Risk output
CORDEX historical data for air temperature, wind speed, mean precipitation flux ***CORDEX RCP scenario data for air temperature, mean precipitation flux and wind speed*** ***ERA5 temperature, wind gusts, snow depth, snow density***	...	***Population data from the Global Human Settlement Layer from JRC***	***Change in annual probability of of blizzard days overlayed with population density*** ***Change in annual probabilty of snowfall > 6cm overlayed with population data*** ***Change in annual probability of snowfall > 25cm***

2.3.2 Heavy Rainfall

The analysis of extreme precipitation in Västernorrland was carried out according to the workflow described in the CLIMAAX project's handbook "Heavy Rainfall". The work itself was carried out using published Python scripts available via the associated GitHub repository (GitHub, 2025).

The purpose of the workflow was to identify how extreme precipitation may change in future climate scenarios and how these changes may affect the region.

2.3.2.1 Hazard assessment

The analysis was based on climate models from the EURO-CORDEX dataset which has a spatial resolution of approximately 12.5 km. The focus was on two time periods: a historical reference period (1976–2005) and a future period (2041–2070) under emission scenarios RCP 4.5 and RCP 8.5. From the climate models, annual maximum precipitation values for different durations, such as 3 hours and 24 hours, were extracted, followed by an extreme value analysis using the General Extreme Value (GEV) distribution. Based on this, precipitation values for different return periods, such as 10-, 50-, and 100-year rains, were calculated.

The results were visualized in the form of IDF (Intensity-Duration-Frequency) maps, showing expected precipitation for different return periods and durations, as well as change maps illustrating the percentage difference between historical and future climates.

The following modifications have been made to the original script: all files have been reprojected, as the results initially did not appear within the Västernorrland area. The CLIMAAX support team has been informed of this adjustment via email.

2.3.2.2 Risk assessment

In the final step of the analysis, the changed precipitation patterns were linked to local impact threshold. This script also required modifications, as it was originally written for an example from Catalonia and by default downloaded data for that area. The script also lacked functionality to import the results from previously conducted calculations. Therefore, this part was reworked to ensure that the correct files from Västernorrland could be read, and these were reprojected again due to problems with the initial projection not working as expected. The CLIMAAX support team was also informed of these adjustments via email.

Afterward, the remaining parts of the script could be run without major adjustments, up to the final code step where different climate models are to be compared with each other. However, this step requires downloading 30 years of raw data for several different models and repeating the entire analysis, which was beyond the scope of the project.

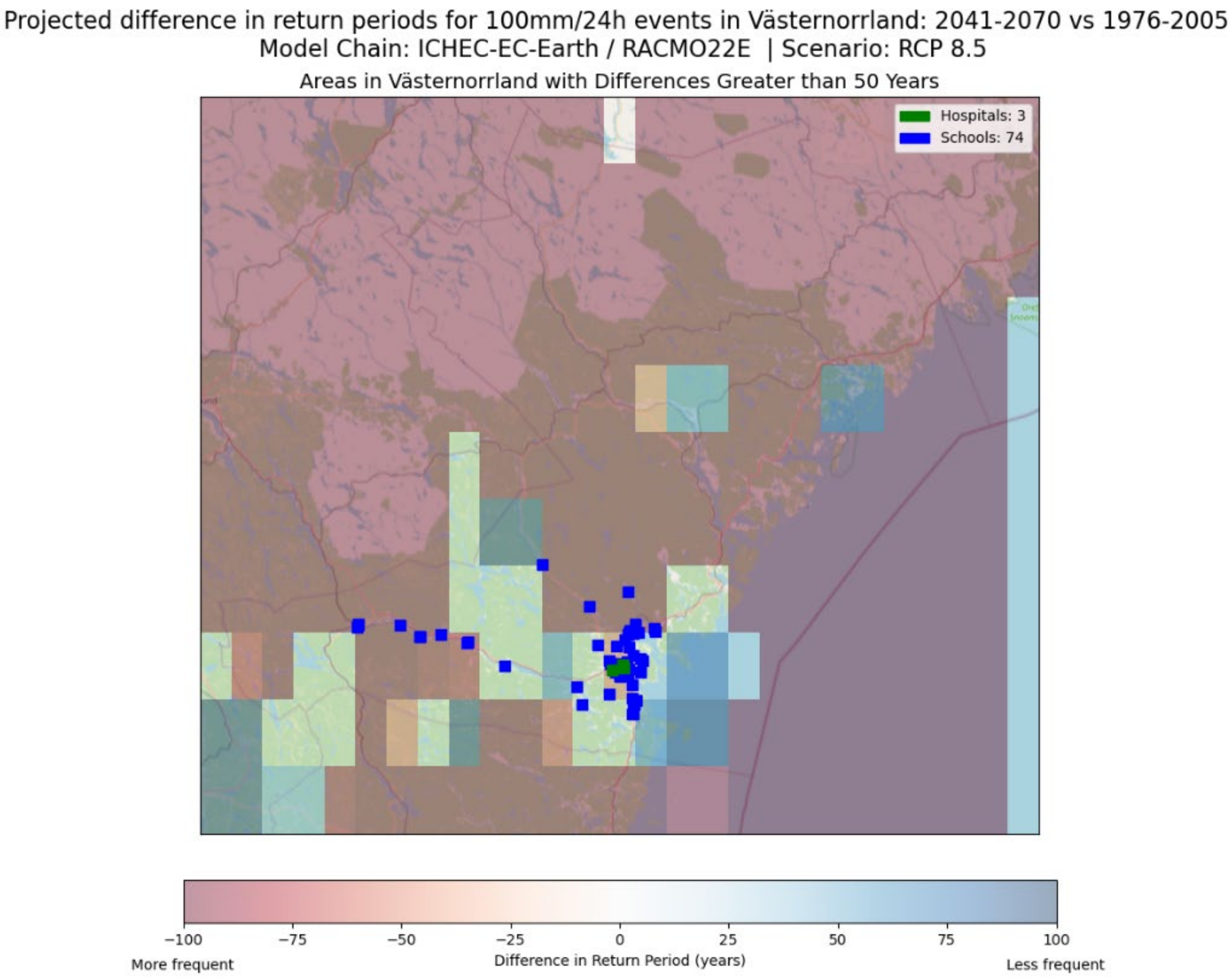

Figure 3 projected differences in return periods for events with a precipitation of at least 100mm/24h compared to the historical baseline under RCP 8.5.

In Figure 3 we see that under RCP 8.5 we can expect a sharp increase in 100mm/24h events throughout Västernorrland. However, the increase in these events is expected to mostly occur outside of the larger towns and cities. The same is true for the period under RCP 4.5 though not to the same extent. The full results of the project can be found in Appendix 1.

Table 2-2 Data overview workflow #2

Hazard data	***Vulnerability data***	***Exposure data***	***Risk output***
Expected precipitation (historical) calculated using the extreme precipitation hazard assessment notebook ***Expected precipitation (future horizon 2041-2070) calculated using the***		***The locations of schools in Västernorrland, imported from Open Street Map*** ***The locations of hospitals in Västernorrland, imported from Open Street Map***	***Projected difference in return periods for 100mm/24h events overlayed with schools and hospitals in Västernorrland for RCP 4.5 and 8.5*** ***More analyses based on the return periods of 100mm/24h events***

Hazard data	*Vulnerability data*	*Exposure data*	*Risk output*
extreme precipitation hazard assessment notebook			

2.4 Preliminary Key Risk Assessment Findings

2.4.1 Severity

The CLIMAAX analysis findings indicate a general trend consistent with earlier SMHI reports (2015) - future climate change is expected to result in a warmer and wetter climate, characterized by decreased snowfall and increased rainfall. These results provide a valuable foundation for strategic-level planning and will be supplemented by localized analyses in phases 2 and 3 that account for our region's specific geography and unique conditions.

2.4.1.1 Workflow # 1 Heavy snowfall and blizzards

The results from workflow #1 point to a decrease of snowy days in general and extremely snowy days (blizzards and days with snow > 25cm) in particular. The decrease in precipitation falling as snow will have an impact on the local flora and fauna, since it expects it to be both cold and snowy during the winter months. While the danger to humans and infrastructure is expected to fall compared to current levels it is important to monitor and explore what other consequences can arise from this decrease.

2.4.1.2 Workflow #2 Heavy rainfall

The severity and urgency of the risks became particularly visible during the report-writing period. On the September 6, heavy rain severely affected our region. The rain caused severe damage to infrastructure – approximately 40 roads and railway (a train carrying hazardous materials as well as a timber train derailed) were affected. Passenger train traffic was suspended northward from Sundsvall. Additionally, many property owners experienced flooded basements and other water damage. Due to flooding at the water facility, residents of one local area were advised to boil their drinking water. Water levels became extremely high in many waterways. The County Administrative Board of Västernorrland activated its emergency response team to manage the situation.

This extreme rainfall event will serve as a significant case study in our analysis of climate-related hazards during project phases 2 and 3. The event highlights the urgent need to strengthen our preparedness for future scenarios and implement proactive measures to minimize environmental and socio-economic impacts. The County Administrative Board of Västernorrland is cooperating with *the Swedish Civil Contingencies Agency* and received *Copernicus EMS On-Deman Rapid Mapping data* related to this event. This data can serve as an event-based storyline for decision-making purposes. It is especially relevant for municipalities in the region which can use it to plan and implement climate adaptation measures if political motivation and resources are present.

Data from this incident, including infrastructure damage, hydrological patterns, emergency response effectiveness, and community vulnerability, will be systematically collected and evaluated. The resulting insights will inform the development of the Climate Risk Assessment (CRA) and its action plan, ensuring strategies are based on empirical evidence and address the specific risks of the region.

2.4.2 Urgency

Heavy rainfall and snowstorms are acute, high-impact events. They can occur with little warning and cause immediate disruption, flooding, power outages, and transport disturbances.

The September 2025 heavy rain event in Västernorrland has also proved how important it is to take action to minimize damages caused by unexpected heavy rain and snow, environmental risks that our project is focusing on. As the temperatures continue to rise, it is expected that similar types of large-scale acute precipitation events will only increase in our region. Furthermore, both the frequency and the extent of heavy rainfall are expected to intensity. More specifically, the results from this project show that heavy rainfall is expected to increase by approximately 20% in both RCP scenarios studied.

In addition, the extreme precipitation will be apparent during winter months in Sweden as well, as both snow depth and the number of snowy days is expected to decrease while average precipitation is expected to increase. During project Phases 2 and 3 our institution will implement an analysis to investigate further heavy rain and snow related hazards and their possible impact on the identified sectors such as infrastructure, agriculture, cultural heritage and ecosystems.

2.4.3 Capacity

The County Administrative Board of Västernorrland is responsible for coordinating climate adaptation efforts in the region. In 2018, our institution published the *Climate Risk and Vulnerability Analysis* and the accompanying *Action Plan*. *The Action Plan* offers guidance to the county's municipalities, authorities, and citizens. It explains how the region may be affected by a changing climate, and what measures can be taken now to address these changes.

In 2022, the County Administrative Board of Västernorrland published a follow-up to the previously released Climate Risk and Vulnerability Plan. This publication presents an overview of climate adaptation measures implemented in the region and supports ongoing climate and vulnerability analysis within the CLIMAAX project.

Our county is also responsible for flood risk management plans that will be developed in the near future and adopted for a specific designated area in the region based on the EU Flood Directive. The development of such a plan will be an additional resource that contributes to minimizing existing risks and avoiding new risks in relation to heavy rain and snow hazards.

The County Administrative Board of Västernorrland's website provides an overview of regional climate adaptation policies, implemented measures, tools for evaluating environmental risks, and links to relevant institutions and knowledge platforms.

Following the heavy rain event in September 2025, the CABV has strengthened its collaboration with national institutions such as *the Swedish Civil Contingencies Agency (MSB)* and *the Swedish Transport Administration*. This enhanced cooperation will support more effective climate risk management in the region. Additional national funding due to the September event is expected to increase regional financial capacity for addressing both the consequences of the event and future climate risk planning. However, many damages from heavy rainfall will require private funding. For example, individual owners of minor roads will be responsible for related costs.

2.5 Preliminary Monitoring and Evaluation

During Phase 1 of the climate risk assessment, we have done a rather thorough analysis of the 2 climate hazards in our region - heavy rain and blizzards. We have used the CLIMAAX methodology during the first CRA phase. Furthermore, we have conducted an initial overview of the existing policies and regulations that affect the climate risks in our region. This analysis will be continued and complemented during the upcoming project phases. The biggest hurdle encountered during phase 1 was analysing the technical data as this data was rather general. During the coming project phases additional work will be needed in order to research and add available national, regional and local data.

During Phase 2 and 3 we will involve all the relevant stakeholders, as per our project plan. The stakeholder meetings will take into consideration the suggestions and recommendations given during the first internal stakeholder meeting during the Phase 1. For example, one of the suggestions was to analyse climate action plans of other administrative boards. Something which we have already begun by cooperating with the Skåne administrative board during Phase 1 (Skåne is also a CLIMAAX project participant). This cooperation will be continued during the upcoming project phases.

2.6 Work plan

We will further develop the findings from Phase 1 by integrating region-specific data to ensure local relevance and applicability. We will include more data and insights on specific hazards such as erosion and landslides caused by extreme precipitation, which have been identified as significant regional risks.

Phase 2 will focus on stakeholder engagement, and stakeholder analysis will be conducted. Workshops with stakeholders, including politicians, planners and climate change strategists from the region's 7 municipalities, will be arranged at different locations in the region, where the results from Phase 1 will be presented and discussed. Moreover, workshops will also be held with representatives from the Samí villages.

Phase 2 will deliver a CRA that builds on Phase 1 findings, regional analysis, and insights gathered from workshops and meetings.

3 Conclusions Phase 1- Climate risk assessment

The initial Phase 1 of the project *"Updating Västernorrland's Climate Risk and vulnerability Assessment using the CLIMAAX methodology"* focused on the exploration of the CLIMAAX framework to assess risks in the region of Västernorrland. The goal was to get familiarized with the CLIMAAX tools and informational platform and apply it to the climate risk assessment in our region.

The CABV successfully formed **an inter-disciplinary internal project team** involving experts from Community Planning, Civil Protection and Emergency Preparedness to ensure a shared understanding and diverse competencies. An external consultant has implemented an initial "*Climate and vulnerability analysis for Västernorrland County* "when using CLIMAAX methodology.

The primary activity in Phase 1 was the application of the CLIMAAX methodology and tools to address the region's specific climate hazards, namely **heavy rainfall and blizzards.** The workflows were implemented for both hazards; however, limitations arose due to the low resolution of available hazard maps. Nevertheless, the use of CLIMAAX tools established a foundation for subsequent project phases, during which national, regional, and local data will be analyzed and utilized.

According to previous national studies, as climate change accelerates, Sweden is expected to be more prone to raining than snowing during the winter season. The CLIMAAX analysis confirmed the regional climate trend reported by earlier studies, concluding that the future climate is expected to be warmer and wetter in our region, characterized by **decreased snowfall and increased rainfall.** The county-based scenarios for Västernorrland with regards to heavy rainfall shows a general increase of about 20% rain in both RCP-scenarios (RCP 4.5 and RCP 8.5). The geographic distribution of maximum daily precipitation showed a concentration in coastal areas.

4 Progress evaluation and contribution to future phases

During Phase 1 CABV successfully tested and applied the CLIMAAX methodology for 2 workflows – heavy snowfall & blizzards, and heavy rainfall. Preliminary hazard and risks maps were produced and discussed during the workshop together with internal county experts. The outputs of this Phase 1 will be used during the Phases 2 and 3.

During Phase 2 our county will focus on the multi-risk assessment in our region (e.g. include the risk of erosion and landslides which are often triggered by heavy rain). The data analyzed during Phase 1 will be complemented by higher-resolution national and regional data. The cooperation with other CLIMAAX regions in Sweden will be continued, especially in respect to national data collection and analysis. Phase 2 will also focus on the external collaboration with relevant stakeholders and expert networks that were identified at the start of the project. The focus will be directed on the exposure and vulnerabilities of the society. In addition, the project will gather the invaluable data and information collected during the heavy rain event that occurred in September 2025. The collected material will contribute significantly to the CRA work.

In summary, the Phase 1 outputs (initial risk evaluation, project stakeholder network development, data collection and methodological gap evaluation) will serve as a foundational basis for the CRA work during Phases 2 and 3 that will focus on more detailed analysis and active cooperation with external stakeholders.

Table 4-1 Overview key performance indicators

Key performance indicators	***Progress***
Using the CLIMAAX Toolbox in 2 workflows, analysing snow and extreme precipitation, (phase 1-3)	Completed. Workflows for heavy snowfall and extreme precipitation were executed.

Key performance indicators	Progress
Regional refined analysis and risk assessment of 2 climate hazards: snow and extreme precipitation (phase 2)	
7 municipalities participate in the analysis (phase 2)	
12 stakeholders (organizations) involved in the process of developing appropriate climate adaptation measures (phase 2-3)	
At least 3 information efforts about the project in our own channels (social media, website for example) (phase 2-3)	
1 final report (phase 3)	
20 organizations have received information about the results of the project (phase 3)	
3 activities to report the project's results to stakeholders in the region (phase 3)	
1 presentation for policy makers (Chairmen of the seven municipal boards in the region) about the results of the project (phase 3)	
…	…

Table 4-2 Overview milestones

Milestones	Progress
M1: Subcontracting (phase 1)	Achieved
M2: Complete CLIMAAX common methodology (phase 1)	Achieved
M3: Attend the CLIMAAX workshop held in Barcelona (phase 1)	Achieved
M4: (Desktop study: analyze between existing CRA and result from CLIMAAX common methodology (M2)	
M5: Complete merging the results of M1 with the outdated regional CRA (phase 2)	

Milestones	*Progress*
M6: Complete stakeholder and network analysis (phase 2)	
M7: Dialogue and workshop with interna and external networks and stakeholders: local actions and needs based on the outcome of M5 (phase 2)	
M8: Case study trip (phase 2)	
M9: Summarize the results (M2-M8) in a CRA (phase 3)	
M10: Desktop study on adaptive pathways and robust adaptation (phase 3)	
M11: Dialogue and workshop with interna and external networks and stakeholders: focus support and implementing adaptive pathways and robust adaptation (phase 3)	
M12: Attend the CLIMAAX final workshop in Brussels (phase 3)	
M13: Complete project result in a report (phase 3)	
M14: Holding final seminar to present the result to interna land external networks and stakeholders in the region (phase 3)	

5 Supporting documentation

- Main Report (PDF)
- Climate and vulnerability analysis for Västernorrland County using the CLIMAAX Methodology.
- Visual Outputs (infographics, maps, charts) shared in the Zenodo repository.

6 References

County Administrative Board of Västernorrland: Regional Action Plan for Climate Adaptation in Västernorrland County, https://www.lansstyrelsen.se/vasternorrland/om-oss/vara-tjanster/publikationer/2018/regional-handlingsplan-for-klimatanpassning-i-vasternorrlands-lan.html, 2018.

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