Deliverable Phase 1 – Climate risk assessment

CLIVAS

Finland, Southwest Finland

Version 1.0 | May 2025

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 1 – Climate risk assessment
Brief Description	
Project name	CLIVAS
Country	Finland
Region/Municipality	Southwest Finland
Leading Institution	Regional Council of Southwest Finland
Author(s)	• Otto Lappalainen (Regional Council of Southwest Finland) • Omar Badawieh (Regional Council of Southwest Finland) • Olli Haapanen (Regional Council of Southwest Finland) • Inkeri Leksis (Regional Council of Southwest Finland) • Katariina Yli-Heikkilä (Regional Council of Southwest Finland)
Deliverable submission date	07/09/2025
Final version delivery date	dd/mm/yyyy
Nature of the Deliverable	R – Report
Dissemination Level	PU – Public

Version	Date	Change editors	Changes
1.0	…	Regional Council of Southwest Finland	Deliverable submitted
2.0	…	CLIMAAX's FSTP team	Review completed
5.0	…		Final version to be submitted

Table of contents

Document Information 2
Table of contents 3
List of figures 4
List of tables 4
Abbreviations and acronyms 5
Executive summary 6
1 Introduction 7
1.1 Background 7
1.2 Main objectives of the project 7
1.3 Project team 8
1.4 Outline of the document's structure 8
2 Climate risk assessment – phase 1 9
2.1 Scoping 9
2.1.1 Objectives 9
2.1.2 Context 9
2.1.3 Participation and risk ownership 12
2.2 Risk Exploration 13
2.2.1 Screen risks (selection of main hazards) 13
2.2.2 Workflow selection 15
2.2.3 Choose Scenario 16
2.3 Risk Analysis 17
2.3.1 Workflow #1: Agricultural drought 17
2.3.2 Workflow #2: Heavy rainfall 20
2.4 Preliminary Key Risk Assessment Findings 24
2.4.1 Severity 24
2.4.2 Urgency 24
2.4.3 Capacity 24
2.5 Preliminary Monitoring and Evaluation 26
2.6 Work plan 27
3 Conclusions Phase 1 - Climate risk assessment 28
4 Progress evaluation and contribution to future phases 30
5 Supporting documentation 32
6 References 33

List of figures

Figure 1 Location of Southwest Finland. 7
Figure 2 The regional adaptation support tool. (Figure from https://www.climaax.eu/handbook/framework/) 7
Figure 3 Importance of the CLIMAAX workflows according to specialists that answered the survey (n=20). 15
Figure 4 Monthly minimum and maximum, first and third quartiles and median flow rates of river Paattistenjoki in Southwest Finland in 2017-2024. Plot produced in Valuma-aluetason vesienhallinnalla kuivuusriskien hallintaa -project with data from Hertta information system of the Finnish Environment Institute. 16
Figure 5 Cumulate precipitation intensity through the growing season. Model pair 0, RCP4.5, 2036–2065. 18
Figure 6 Wheat yield loss from precipitation deficit. Model pair 0, RCP4.5, 2036–2065. 18
Figure 7 Revenue losses of studied crop species. Mean of model pairs 0, 1, 2 and 4, RCP4.5, 2036-2065. Southwest Finland is the area with the black border. 19
Figure 8 Wheat revenue loss without irrigation in Southwest Finland by year (RCP4.5) 20
Figure 9 Annual daily maximum precipitation rates in Turku Harbour 21
Figure 10 Expected extreme precipitation for 24h event during 2041-2070. Under RCO8.5 and ichec_ec_earth/knmi_racmo22e. 22
Figure 11 Extreme precipitation for 2041–2070 under RCP8.5 climate projections modelled with ichec_ec_earth/knmi_racmo22e 22
Figure 12 Shift of frequency for 70mm/24h threshold in 2041–2070 under RCP8.5. 23
Figure 13 Shift of magnitude of extreme rainfall (120mm/24h) in 2041-2070 and hospitals from OSM. 23

List of tables

Table 1 Stakeholders for the climate change adaptation work 12
Table 2 Data overview workflow #1 17
Table 3 Global Climate Model / Regional Climate Model pairs 17
Table 4 Data overview workflow #2 20
Table 5 Finnish Meteorogical Institute's rain warning levels. 21
Table 6 Return periods calculated for FMI's risk levels 22
Table 7 Overview key performance indicators 30
Table 8 Overview milestones 30

Abbreviations and acronyms

Abbreviation / acronym	Description
CRA	Climate Risk Assessment
EU	European Union
GCM	Global Climate Model
NGO	Non-governmental organization
RAST	Regional Adaptation Support Tool
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
WOFOST	World Food Studies Simulation Model

Executive summary

This deliverable represents the work conducted on regional climate risk assessments during the first phase of the CLIVAS project in Southwest Finland. The report showcases the scoping, risk exploration, and risk analysis phases, and reveals how the project team has proceeded in the process of risk assessments.

Climate change adaptation work in Finland has been conducted on national level planning for a long time. Despite this, local and regional level knowledge is still fragmented and largely missing. This is also the case in the region of Southwest Finland where emissions have been cut but adaptation neglected. The project aims to push forward regional climate change adaptation work, support the development and implementation of local adaptation strategies and policies, produce local knowledge on climate risks to improve decision-making, and set effective adaptation measures both at the regional and municipal levels.

The region is facing climate risks that need to be addressed in the near future. This project conducted research on existing knowledge, severeness, and urgency of different risks, and the usefulness of the potential data provided by workflows to the regional adaptation work. After the initial phase, we sent a survey to regional stakeholders to get their views on the selection of the risks and to validify the results of the research conducted. Based on the research and results of the survey, agricultural drought and heavy rainfall were selected as the main risks to be studied in the project.

The project produced risk assessments for agricultural drought and heavy rainfall. Both risks were assessed using several climate change scenarios (RCP), several regional and global climate change models (GCM/RCM) and several time series. Preliminary results show clear rise in precipitation although there is geographical variability. In some areas, precipitation will increase up to 50% but some areas face decreases. Extreme rain events will likely occur in the coastal areas of Southwest Finland. Adaptation strategies must pay attention to the locality of extreme rain events, areas with critical infrastructure, highly populated areas, and the vulnerable archipelago. Agricultural droughts seem to affect the crop yield and revenue negatively, but with milder effects going further in the future. Wheat yield losses were highest amongst the studied species while rapeseed losses were close to none. In the future, adaptation strategies should focus on irrigation availability and crop species selection.

Key takeaways:

- The region is facing climate risks that must be addressed soon. Regional climate work has previously focused mostly on mitigation instead of adaptation which is an issue the CLIVAS project aims to address.
- The project produced risk assessments for agricultural drought and heavy rainfall which were assessed using several climate change scenarios (RCP), several regional and global climate change models (GCM/RCM), and several time series.
- Overall, heavy rainfall events will become more common but there is geographical variability. Adaptation strategies must take the locality of extreme rain event, areas with critical infrastructure, highly populated areas, and the archipelago into account.
- Increased agricultural droughts will result in revenue losses, but increasing mean temperature will mitigate the losses going forward. In the future, adaptation strategies should focus on irrigation availability and crop species selection.
- The results of the risk assessments will be further developed in latter stages of the project.

1 Introduction

1.1 Background

Southwest Finland is a region with a diverse economic structure, a fertile, rural landscape, and a unique environment, located by the Archipelago Sea. The region is home to nearly half a million people of which around 200 000 live in the largest city Turku. Southwest Finland has a major role in Finnish food production and 34 % of wheat and 32 % of the field vegetables produced in Finland come from the region. Other important sectors are marine industry, car industry, health and medicine, tourism, and circular economy solutions.

Figure 1 Location of Southwest Finland.

Overall, Finland can be seen as a model country for emergency preparedness, and climate change adaptation has also been considered in the national level planning for a long time. Despite this, knowledge at the regional and local level is still fragmented and largely missing.

Most regional level initiatives have been focusing on mitigation. This is also the case in Southwest Finland where emissions have successfully been cut in half during the period of 1990–2025 (valonia.fi, 2025). A climate roadmap for the region was drafted in 2023, and 22 of 27 municipalities have also drafted their own climate plans. Overall, however, adaptation work is still in its early phases and concrete adaptation measures have been mostly missing from the plans.

1.2 Main objectives of the project

The aim of the project is to push forward regional climate adaptation planning which has so far been quite limited on the regional level. The main objective of the project is that the CLIMAAX Handbook[1] and the work conducted in the project will support the development and implementation of local climate change adaptation strategies and policies.

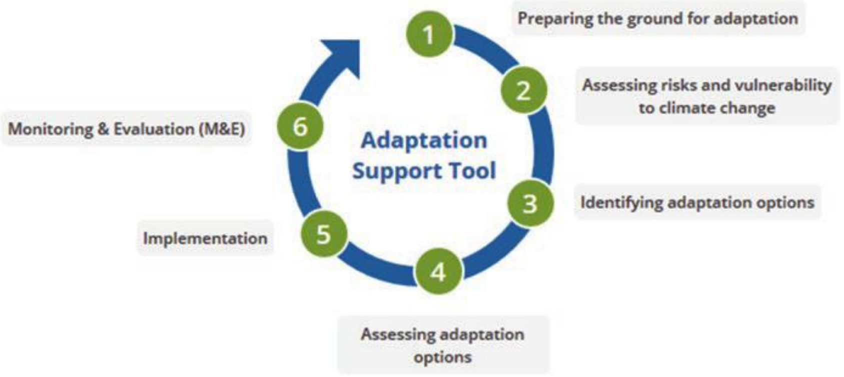

Figure 2 The regional adaptation support tool.
(Figure from https://www.climaax.eu/handbook/framework/)

The project will deal with phases 1–3 of the Regional Adaptation Support Tool (RAST). The first phase has focused on parts 1 and 2 of the RAST tool visualized on figure 2. Work on part 3 of the RAST tool will commence at the end of phase 2 and continue in phase 3.

[1] https://handbook.climaax.eu/intro.html

With the help of risk assessments drafted with CLIMAAX Handbook, the project aims to create novel local knowledge on climate risks to help local decision-makers make informed decisions and set effective adaptation measures both at the regional and municipal levels. The project will assess currently existing adaptation measures and identify the needs for new measures to respond to different kinds of risks. One of the main objectives for the data compiled with the help of CLIMAAX Handbook is to use it to help update the regional climate roadmap so that it would address adaptation measures. Based on risk assessments, the project will also develop tools for municipalities and thus strengthen the capacities of the municipalities to develop their own adaptation measures with uniform practices and indicators. The key risk assessments and the developed adaptation measures are concrete tools that local authorities can use in their work.

Another aim of the project is to increase the awareness of the decision-makers on climate-related risks so that they understand the urgency of adaptation measures. With the help of the risk assessments drafted using CLIMAAX Handbook, the aim is also to create a visual representation on the risks on a local level in order to visualize the magnitude of the local climate-related risks and the urgent need to act before they are realized.

Besides the public sector, the project also aims to interact with academic institutions, businesses (including landowners and farmers for example), non-governmental organizations (NGOs) and local citizens. The aim of this is twofold: by engaging with diverse stakeholders, the project aims to harness collective knowledge to help finetune the risk analyses with local knowledge, and to create a sense of ownership for the development and implementation of adaptation measures. On the other hand, the project aims to share knowledge and raise awareness of climate risks and adaptation in the region which should increase the understanding and the acceptance of local adaptation measures. Making regional adaptation measures a common cause is important for the success of the work on adaptation.

Finally, the project aims to increase the expertise of climate risk assessment methodology not only in the Regional Council and its personnel but also in the municipalities and other partners of the project. Getting to know the tools, data and possibilities of climate risk assessment makes implementing the methodology easier even after the project has finished.

1.3 Project team

- Otto Lappalainen: Project specialist. In charge of overall coordination of the project.
- Omar Badawieh: Project specialist. In charge of the risk assessments created with the CLIMAAX Handbook.
- Olli Haapanen: Project specialist. Expert advisor for the project.
- Inkeri Leksis: Project worker. Assisting the GIS Specialist in the risk assessment work.
- Katariina Yli-Heikkilä: Project specialist. Expert advisor for the project.

1.4 Outline of the document’s structure

The document follows the flow of the risk assessment framework of the CLIMAAX handbook. The document begins with the introduction to the region and its previous adaptation work. After that, the document will present the work on the assessment itself, starting with scoping and proceeding to risk exploration, analysis and the main findings followed by conclusions.

2 Climate risk assessment – phase 1

2.1 Scoping

2.1.1 Objectives

The objective of the Climate risk assessment (CRA) is to produce novel knowledge and understanding on how different weather-related climate risks affect the region of Southwest Finland. Previous assessments have been made in the area and the project aims to fill the gaps in knowledge and to avoid overlapping work. The previous assessments are reviewed in section 2.1.2. The risk assessments conducted with the help of the CLIMAAX Handbook will help the region create spatial representations on selected risks and assess the impacts they will have on different parts of the region in different timeframes and climate scenarios.

Another purpose of the CRA will be to push forward regional climate change adaptation work and cooperation. The expected outcome of the CRA is that the information gathered in them will increase the understanding of local civil servants, decision-makers, and other stakeholders on the impacts of the climate change and on measures to counteract them. The project outcomes will feed knowledge and adaptation measures to both municipal and regional strategies and their implementation (including the regional climate roadmap which is to be updated in the near future).

Regarding limitations and boundaries of the CRAs, the relevance of the data on Agricultural drought CRA poses some limitations for the work. The crops included in the CLIMAAX Handbook's crop list are not totally compatible with crops cultivated in Southwest Finland. Many regionally relevant crops are missing from the crop data which is why the corresponding values for local crops must be acquired and refined by the project team. The data for crop production and aggregated value is also rather old but newer data should be available for the next phase.

It is unclear whether the project can respond to the most urgent real-life needs of the municipalities. For example, representatives of the city of Turku brought up the issue of geographic and temporal unpredictability of local extreme rain events. The city of Turku has had issues with storm water floods as the storm water drains are insufficient and the representatives hoped that the extreme precipitation workflow could help them with the issue. The possibility of modifying the workflow to meet those needs will be reviewed during the second phase.

2.1.2 Context

According to Finnish legislation (Act on Regional Development and the Implementation of European Union Regional and Structural Policy, 756/2021), regional councils are responsible for the strategic coordination of regional development. One of their tasks is to promote the sustainable use of natural resources, climate change mitigation and adaptation, and cooperation in planning a high-quality living environment, as well as to ensure the coordination of such planning with other regional planning processes. This legal mandate ensures that regional councils have a central role in climate change adaptation. However, despite this statutory responsibility, regional-level adaptation planning has not yet been carried out in practice. The lack of clear resources and allocation of responsibilities between different administrative levels (state, regions, municipalities, and ELY Centres) has left a gap between the national policy framework and local-level actions. (Finnish Government, 2023)

At the national level, adaptation is outlined in the National Climate Change Adaptation Plan 2030 (Finnish Government, 2023). However, its implementation relies heavily on local and regional authorities, such as municipalities, regional councils, and ELY Centres, which have neither been allocated sufficient resources nor given clear responsibilities. This creates uncertainty about the division of responsibilities between the state, regions, municipalities, and the private sector.

Regional-level planning for climate change adaptation has been lacking in Southwest Finland as well. While municipalities have implemented individual adaptation measures in, for example, stormwater management, there have not been comprehensive regional perspectives or coordinated strategies behind them. As a result, actions and knowledge remain fragmented.

One of the aims of the project is to fill the gap in knowledge between regional and national level and to provide the regional and municipal actors knowledge with which local adaptation measures can be planned and implemented better. While the work on regional climate change adaptation and risk assessment is still in its early phases, there some risks have been assessed:

- A regional risk analysis for Southwest Finland drafted in 2023 considers all types of risks that might affect the region focusing mainly on risks not related to the environment. In addition to non-climate risks, the assessment reviews flooding, winter-time storms, and the impact of climate change (drought, flooding, storms, pests) on agricultural production and food security. (Varsinais-Suomen alueellinen riskiarvio, 2023)
- Review of regional characteristics and vulnerabilities related to climate change in Finland was conducted in 2023. (Virtanen, 2023)
- Detailed spatial flood risk assessments of the major regional rivers were produced first in 2011 and last updated in 2024. (vesi.fi, s.a.b)
- A coastal flood risk management plan for the coast around the city of Turku is in place for the period of 2022–2027. The management plan includes a risk assessment, proposed measures, and responsibilities of different authorities. (Turun tulvaryhmä, 2022)
- Finnish Environment Institute has produced a map-based service for coastal, fluvial and storm water flooding. These map-based modelings have been done for the whole of Finland. (Finnish Environment Institute, 2024; Vesi.fi, s.a.a)
- An environmental risk analysis of the stormwater overflows for the regional pumping stations was conducted in 2018 and updated in 2023. (Ahonen, 2018; Yli-Heikkilä & Badawieh, 2023)
- The Turku Urban Climate Research Group (TURCLIM) at the University of Turku has been studying the urban heat island effect in Turku since the early 2000s. The results of these GIS studies provide information to support the city's climate adaptation measures (Turku.fi, s.a.a)
- A national drought risk assessment for each municipality in Finland was made in 2023 by Finnish Environment Institute. The assessment reviews the drought risk, hazard, and vulnerability based on a variety of variables from agriculture, industry, and communal water use. (Snellman & Todorovic, 2023)
- A drought risk management plan for the drainage basin of the river Sirppujoki was produced in 2020. Sirppujoki was used as a pilot area and the management plan was the first of its kind in Finland. (Ahopelto, Parkkila & Parjanne, 2020)
- As part of the CLIMAAX project, the workflow on Fire-weather Index was developed using the region of Southwest Finland as one of the two pilot regions. The results for Southwest Finland can be used by the region for deciding on climate change adaptation measures.

The most important sectors in the region of Southwest Finland are agriculture, marine industry, automotive industry, health and medicine, tourism, and circular economy solutions. These industries face the impacts of climate change to varying degrees.

Agriculture is faced with both positive and negative climate impacts. Starting with positives, a warmer climate could lengthen the annual growth period in Finland by 1–2 months and increase the daytime temperature sum significantly by 2100. (Ruosteenoja et al., 2016) The climate change would increase the growth of currently cultivated crops but also allow for the cultivation of new crops like maize. On the negative side, climate change will likely introduce increased flooding and drought, pests and plant diseases. Southwest Finland has been deemed a high-risk area for droughts. The droughts are most difficult in spring when the need for water is also at its highest. On the other hand, when the need for water decreases, heavy rain incidents in late summer are predicted to increase spoiling yields and making harvesting more difficult. (Pilli-Sihvola, 2023; Natural Resources Institute, 2024; Snellman & Todorovic, 2023) Due to increased rains in the winter, more nutrients flow into the Archipelago Sea which is one of the active HELCOM hotspots for agriculture-related eutrophication (HELCOM, s.a.; Virtanen, 2023)

For tourism, there are both positive and negative implications. Tourism could benefit from the longer summer season and from tourists who wish to spend time in a cooler climate. On the other hand, the archipelago is very important for tourism in the region and the effects of climate change are likely to increase the eutrophication of the sea and the amount of blue-green algae, making it less attractive for visitors. While summer is the main tourism season, decreased snow-cover and shorter winters might pose challenges for some operators. (Sustainable Travel Finland, s.a.)

The forestry sector will experience both positive and negative impacts. Even though the longer growing season will likely increase the growth of the trees and shorten the harvest cycles, the negative impacts are stronger. The negative impacts include increased storm damages due to the windstorms and the absence of ground frost in the winter, more difficult winter loggings due to the absence of ground frost, and the increase of pests. Forestry is a business that operates in a long term which makes quick reactions to suddenly changing climate challenging. (ilmasto-opas.fi, s.a.)

The energy sector in Southwest Finland is undergoing a transition towards low-carbon production. Offshore windfarms, expansion of solar energy capacities, hydrogen plants, and biogas facilities are among the energy production methods considered for the future. The diversification strengthens the resilience of the energy system in the long term, but it also creates new vulnerabilities. Offshore wind and solar production are strongly weather-dependent, and extreme conditions such as storms, icing, or prolonged cloudiness may affect supply security. (Pilli-Sihvola, 2023; Virtanen, 2023)

Southwest Finland connects Finland to Scandinavia and Western Europe through strong maritime and air links. The region is also connected to the rest of the country through major road and rail corridors. Changing climate conditions are challenging the transport system. Winters are becoming increasingly snow-free with frequent temperature fluctuations, making roads slippery and driving conditions difficult. In the summer, heavy rainfall and flooding pose challenges. These conditions complicate and increase the need for road maintenance. (Pilli-Sihvola, 2023; Virtanen, 2023)

In addition to private sector industries, the public sector also faces increasing challenges due to climate change. Hospitals and elder care facilities need to address the impacts of heatwaves on the well-being of the most vulnerable people. Urban planning in the cities must also take heatwaves into account. (Kollanus, Halonen & Lanki, 2023) The increasingly heavy rainstorms and warmer winters where most of the water comes down as rain making the ground melt and refreeze create challenges for urban water planning and maintenance. (Ilmasto-opas, 2024)

The impacts of climate change on other fields of industry are likely more indirect. The strongest impacts could be caused by severe disruptions of global supply chains causing longer delivery times, higher costs and lower production output. (Economist Impact, 2024) Additionally, direct impacts to production facilities in Finland could cause economic losses.

Regarding the future of the regional adaptation work, amendments to the Land Use and Building Act are expected to affect the role of the regional councils in spatial planning. The legal enforceability of regional land use plans will likely decrease, making them more indicative than binding which could weaken land use guidance, particularly in areas without detailed local plans making it more difficult to integrate adaptation measures across the region. The Regional Council of Southwest Finland takes part in the EU Mission on Adaptation to Climate Change, which is expected to provide support for planning and implementing of adaptation measures across governance levels, and hopefully also opportunities for additional resources, knowledge exchange, and policy guidance.

As in the case of other wicked problems, the region cannot solve the issue of climate change on its own. Instead, the region is affected by national and international developments. While there are no major currently foreseen initiatives that could directly impact the adaptation work, developments in national and European politics could slow it down if, for example, funding is cut. On the other hand, if funding is increased and both the state and the European Union push for more ambitious adaptation policies, the work on regional adaptation might speed up considerably.

2.1.3 Participation and risk ownership

The Regional Council of Southwest Finland is a valuable partner for and closely connected to the local actors. Regional actors know each other and they get well together.

Table 1 Stakeholders for the climate change adaptation work

National	Regional	Municipal	Others
Ministries	Regional Council of Southwest Finland	Municipalities	Industry interest groups
Governmental agencies and research institutes	The Centre for Economic Development, Transport and the Environment	Municipally owned companies	Other non-governmental organizations
			Enterprises
			Universities and research institutes
			State church
			Citizens

The project has taken the first steps to set-up the stakeholder involvement processes by setting up the project working group and the steering group which consist of regional and national actors.

The project group consists of 8 external experts from five different organizations (City of Turku; Finnish Meteorological Institute; Pyhäjärvi Institute Foundation; Regional Council of Southwest Finland; Southwest Finland Centre for Economic Development, Transport and the Environment). The aim of the project group is to work closely with the project team, to support its work by advising, and to increase the involvement of other organizations in ensuring that the results of the project have broad support in the region.

The steering group consists of external experts from 9 different organizations (Archdiocese of Turku; City of Turku, Finnish Environment Institute; Finnish Forest Centre; Maintenance and Supply Security Centre; the National Climate Unit of the ELY Centers; Southwest Finland Centre for

Economic Development, Transport and the Environment; Union of Agricultural Producers; Union of Agricultural Producers Southwest Finland). The aim of the steering group is somewhat similar to that of the project working group with the exception that it is not as closely involved in project activities as the project working group and it is mostly responsible for helping the project team with the bigger overall picture instead.

Understanding the insights of vulnerable groups and the level of risk that is acceptable are key for successful adaptation plans and they will be studied more extensively in phase 2. To ensure that the risk ownership is as broad as possible and that those groups are involved in the process, the project will contact representatives from various NGOs, and people from different parts of the region to ensure that not only those living in the largest cities are heard. For this, the main groups to be involved have been identified. These groups include farmers, senior associations, disease and disability organizations, nature protection organizations and other NGOs. Besides organizations, the project aims to reach out to common citizens through participatory citizen workshops.

By approaching NGOs and citizens in a geographically representative way, the project aims to make climate change adaptation a common cause for region. For this, the aims, actions and results of the project must be communicated properly to different audiences which requires the use of different media outlets such as social media, blog posts, and press releases but also local workshops and events where it is possible to learn and discuss risks and adaptation directly with citizens.

2.2 Risk Exploration

2.2.1 Screen risks (selection of main hazards)

For the region of Southwest Finland, agricultural drought and heavy rainfall were selected to be covered in the risk assessment. The selection of risks was made based on already existing assessments, the perceived severeness of the risks, and the usefulness of the potential data provided by workflows to the regional work on adaptation.

The risks were first screened by the project team. The team studied the needs and outcomes of the risk workflows of the CLIMAAX handbook, analyzed the severeness of different risks to the region using existing regional and national knowledge, and formed an opinion on which of the risks were to be studied most urgently. It was deemed that all the risks except for the heavy snowfall, were at least somewhat relevant for the region.

River and coastal flood risks are rather well studied in Finland already with maps of flood risk areas already available (Finnish Environment Institute, 2024; Vesi.fi, s.a.a). The flood risk of major regional rivers has been assessed (Vesi.fi, s.a.b) Coastal floods have been assessed and a management plan has been put in place for the coastal area around the city of Turku (Turun tulvaryhmä, 2022). Despite the identified risks, there have been plans to build new residential buildings and schools in areas of high coastal or fluvial flood risk.

The intensity and probability of heavy rainfall events is likely to increase due to climate change. Annual precipitation is likely to increase by 5–15% in the region by 2100. (Ilmasto-opas, 2022). Heavy rainfall events challenge the capabilities of sewage treatment facilities which can lead to flooding of areas that are susceptible for it. With a warmer climate, the snow melts quicker and snow rains down as water more often which increases the risks for flooding during the winter. (Pilli-Sihvola, 2023; Virtanen, 2023) Many cities have already put storm water management programs in place.

In Finland, heatwaves have been mostly occasional and short-term. Due to this, the preparation for them has not been a top priority. The buildings are insulated for the winter which traps heat in the summer. Air-conditioning systems are rare and hospitals and elderly care facilities might be missing them putting the weak and elderly at risk. Finns are accustomed to a colder climate and the mortality rate starts increasing when the daily mean temperature exceeds 15°C (compared to 25°C in the Mediterranean) and significantly increasing when the temperature exceeds 20°C. (Kollanus, Halonen & Lanki, 2023) University of Turku has studied heat islands in the city of Turku. (Turku.fi, s.a.)

Droughts have not traditionally been considered a major risk in Finland even though they have the potentiality to cause significant economic losses. (Ahopelto, Parkkila & Parjanne, 2020) According to national studies, the vulnerability and the risk of drought in Southwest Finland are among the highest in Finland. (Snellman & Todorovic, 2023) Southwest Finland is an important food producing region in Finland and especially the spring-time droughts pose challenges and cause economic losses as artificial irrigation systems are virtually inexistent in the region. (Ahopelto, Parjanne & Tuukkanen, 2024; Virtanen, 2023) In terms of drinking water, Finland is rather well protected but there have already been occasions in some areas of the archipelago where groundwater areas have run dry and other, more expensive measures have had to be taken (see HS 3.10.2022).

Climate change is likely to increase the length of the forest fire season, the number of fires and the burnt area in Fennoscandia. (Kinnunen et al., 2024) Finland is well prepared for forest fires but there have been incidences where the fires have been close to spreading to buildings. The hazard impacts mostly those living in rural and sparsely populated areas. Southwest Finland was one of the pilot regions of the main CLIMAAX project, and the fire weather index workflow has been run for it.

Even though overall windiness is not forecasted to increase with climate change, occasional windstorms are likely to increase in severity. Combined with lack of frost in the ground in the winter, tree damages are predicted to increase causing losses to forest owners and potential danger due to falling trees. (Gregow et al., 2020)

Heavy snowfall and blizzards are not a major risk during winters as such. Instead, the risk occurs when the temperatures fluctuate above and below zero. As the snow melts, it might lead to winter-time flooding. Icy roads and pavements are also a major hazard for people.

As per the instructions of the CLIMAAX Handbook, the project team also consulted the Copernicus Atlas. According to the Copernicus Atlas, the mean temperature in the northern hemisphere is expected to rise more than in the rest of Europe, especially in Finland and northern Finland. Precipitation changes seem to be mild or not enough info is present. In Southwest Finland, the decrease in both the duration and thickness of snow cover is especially interesting because the snow cover has a direct link to drought and precipitation. All in all, the Copernicus Atlas shows the that Northern Europe should be studied more. Much of the information in Copernicus Atlas is not robust enough or has conflicting signals.

After the initial risk exploration phase, local stakeholders forming the project working group and the steering group were contacted to get their opinion on the selection of the risks. The stakeholders were provided with a survey where they had to determine both the importance and usefulness of studying each of the risks found in the CLIMAAX Handbook. The respondents were asked to consider the severeness, urgency, already existing data, and the possible benefits of different workflows to the region.

It was noted that the results of the survey were very similar when compared to those agreed upon by the project team in their initial screening of the risks. In both cases, agricultural drought and heavy rainfall were deemed as the most relevant risks to be studied. Besides them, relative drought, flood building damage, windstorm, and fluvial flooding were seen as rather important risks.

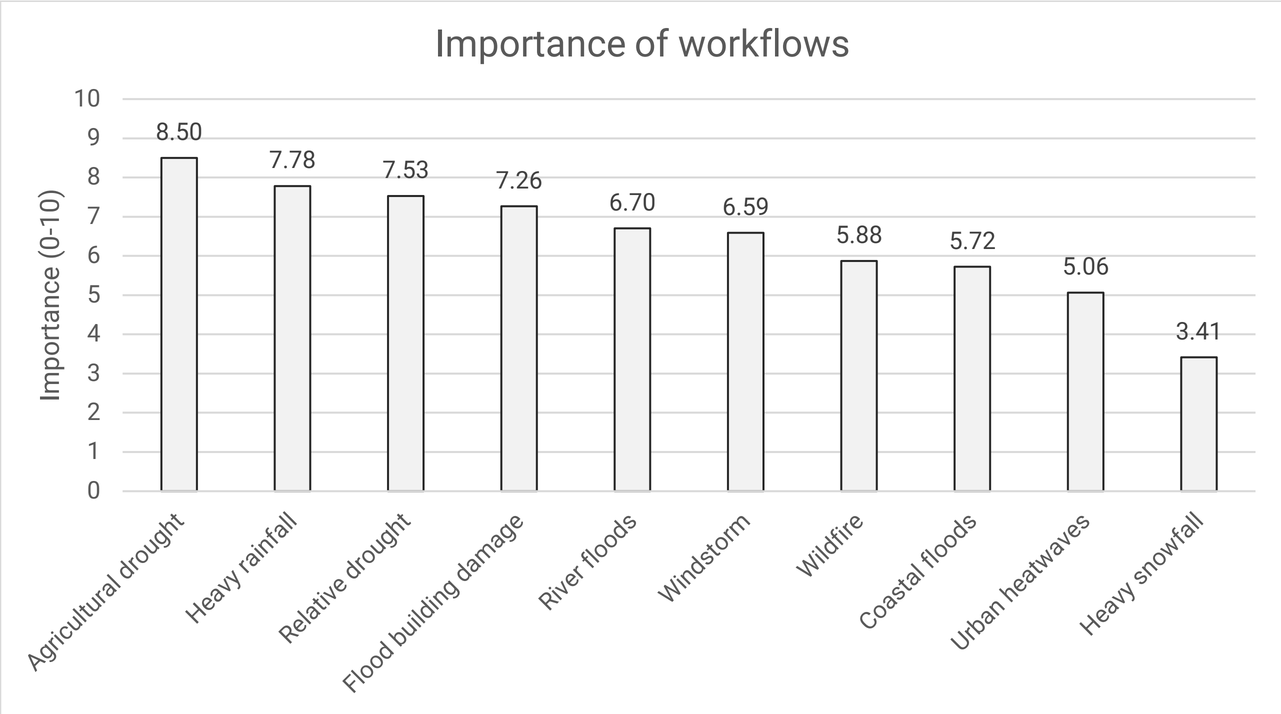

Figure 3 Importance of the CLIMAAX workflows according to specialists that answered the survey (n=20).

2.2.2 Workflow selection

2.2.2.1 Workflow #1: Agricultural drought

Studying agricultural drought was recognized important in discussions held both internally and with stakeholders. The regional drought vulnerability has been pointed out in research as well (Snellman & Todorovic, 2023). The Regional Council of Southwest Finland has worked extensively with farmers throughout the years. Especially during the past few years, the issue of droughts has come up as a pressing issue in cooperation. Dry farmlands together with uneven precipitation, high maximum rainfall, and diminishing snowfall in the winter produce unpredictable farming conditions with high risks for crop loss. Farmers that rely on river water irrigation are especially vulnerable as the flow rates of local rivers can be extremely low during summer months. One example is the Paattistenjoki river running in Southwest Finland that is under heavy agricultural and irrigational use. Its July mean flow rate is only 0.07 m^3/s (Figure 4). When it suddenly rains heavily, the farmland is so dry that it cannot absorb the water which just runs off.

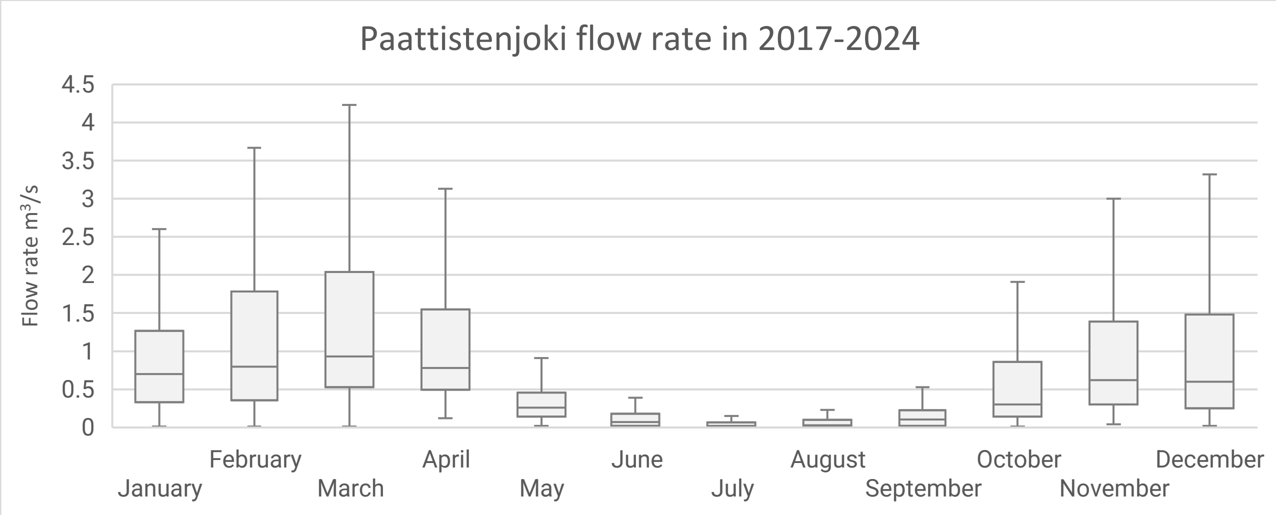

Figure 4 Monthly minimum and maximum, first and third quartiles and median flow rates of river Paattistenjoki in Southwest Finland in 2017-2024. Plot produced in Valuma-aluetason vesienhallinnalla kuivuusriskien hallintaa -project with data from Hertta information system of the Finnish Environment Institute.[2]

2.2.2.2 Workflow #2: Heavy rainfall

Heavy rainfall poses risks primarily on larger cities in the form of storm water floods but also on agricultural areas. Southwest Finland is a coastal region with several larger cities located on the shoreline. Waterfront is an attractive location for city development but it also brings challenges when increasing amount of stormwater is combined with water pushing up from the sea. The expected increase in precipitation will result in more frequent and powerful stormwater floods. Adapting to these changes is crucial in both urban and agricultural areas.

2.2.3 Choose Scenario

RCP scenarios 4.5 and 8.5 were used in the first phase. 4.5 is the middle intermediate scenario between the very stringent 2.6 and the worst-case 8.5. Mirroring to the current nationally determined contributions, RCP4.5 seems to be the most likely scenario currently (Ruuhela et al., 2023). RCP2.6 scenario is a pathway where CO_2 emissions should have started declining by 2020 and by 2100 there would be no emissions. Using RCP2.6 in the workflows has been discussed extensively by the project team but the pathway was considered to be too optimistic. To save time and efforts in phase 1 for studying other, more useful scenarios, we disregarded RCP2.6. RCP8.5 is the worst-case pathway, but the likelihood of it has also been debated. It is still a useful scenario for communicative aspects. The choices for the scenarios will be further reviewed in the second phase. If RCP8.5 is deemed too unlikely we will consider other “worst case scenarios” going forward.

Considering the communicative aspect of the project, we decided to include several scenarios and time intervals. Having different results for example for RCP4.5 and RCP8.5 gives the opportunity to show stakeholders the difference the RCP-scenarios make for each climate risk further underlining the importance of mitigation as one of the adaptation measures. Iterating workflows with different variables does not increase work and time used too much but the information provided is important. Running the workflows with different climate models (regional and global) makes it possible to calculate the average or compare different models to help to choose the best fitting one.

Models, scenarios and year ranges used in workflows are discussed more in detail in chapter 2.3.

[2] See: https://www.syke.fi/en/environmental-data/maps-and-information-services/open-environmental-information-systems

2.3 Risk Analysis

Risk analyses were conducted using workflows from CLIMAAX Handbook[3]. The workflows were not suitable for our case as such, so modifications and additions to the Python code had to be done. Workflow code for agricultural droughts was further developed to extend analysis and merge different runs for more thorough analysis.

2.3.1 Workflow #1: Agricultural drought

Table 2 Data overview workflow #1

Hazard data	***Vulnerability data***	***Exposure data***	***Risk output***
Yield reduction	Irrigation availability	Aggregated Crop Production Value	Potential revenue loss from irrigation deficit in for the selected crops

Agricultural drought workflow uses datasets Available Water Capacity, Elevation and Thermal Climate Zones with crop-specific information on how to calculate the yield reduction under different RCP scenarios and given years. In the workflow, different climate models (mathematical models simulating drivers of climate and their interaction) can be chosen to use for simulation. In the risk assessment phase, crops production, crops value and irrigation data are incorporated to the assessed hazard data to calculate expected revenue loss for each assessed crop.

2.3.1.1 Hazard assessment

NB. The agricultural workflow was updated on 22.8.2025. These assessments have been done before the update. Workflows will be rerun with the updated methods in phase 2.

Table 3 Global Climate Model / Regional Climate Model pairs

Number	**Global Climate Model**	**Regional Climate Model**
0	ncc_noresm1_m	geric_remo2015
1	mpi_m_mpi_esm_lr	smhi_rca4
2	cnrm_cerfacs_cm5	knmi_racmo22e
3	cnrm_cerfacs_cm5	cnrm_aladin63
4	ncc_noresm1_m	smhi_rca4

Hazard assessment was conducted using all the model pairs (Table 3), RCP4.5 and RCP8.5, and three different year ranges as instructed in the workflow. This enabled us to find the best-fitting model pair or whether to use the mean of different model pairs. Model pair 3 could not be used for mean calculation as the points fall in slightly different places compared to other models. In the second phase, it will be whether the model pair 3 could also be included in the calculation. Reviewing risks associated with different scenarios during different time ranges also gives us ample data to work with when the planning for adaptation strategies begins.

[3] https://handbook.climaax.eu/intro.html

Overall, the studied crops are expected to yield losses of 15–35 % depending on the crop species, RCP, year, and the location. Of the crops studied, the yield loss values of wheat are constantly higher than those of barley and rapeseed (Figure 6). In all the studied combinations, the northeast corner of the region has the highest yield loss values. This matches the lower precipitation values forecast in the same area (Figure 5). Coastal areas usually receive more rain which protects them from the losses caused by droughts.

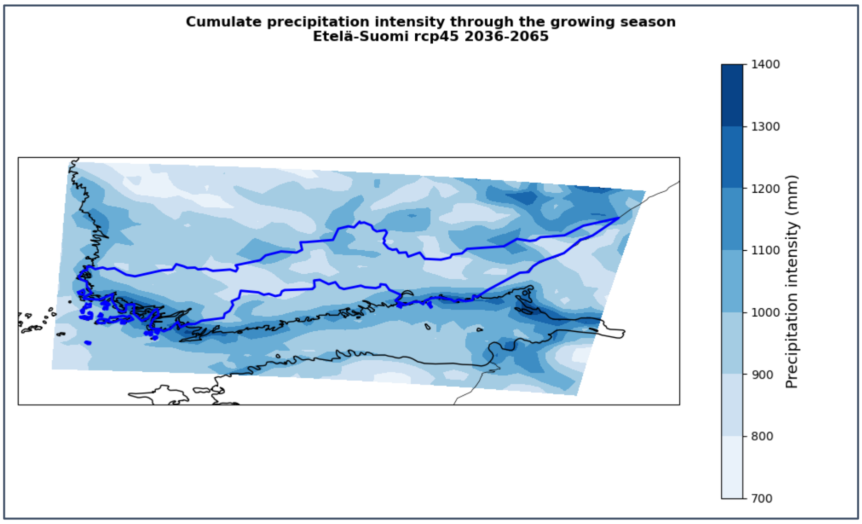

Figure 5 Cumulate precipitation intensity through the growing season. Model pair 0, RCP4.5, 2036–2065.

There are not many differences when comparing different year ranges except for a slight reduction in yield loss rates. Starting from 2026–2045, the yield losses for wheat using RCP4.5 are, for example, around 20–30% which is a rapid change. This raises questions on the accuracy of the results. Running the analysis with the updated workflow in phase 2 might result in different outcome.

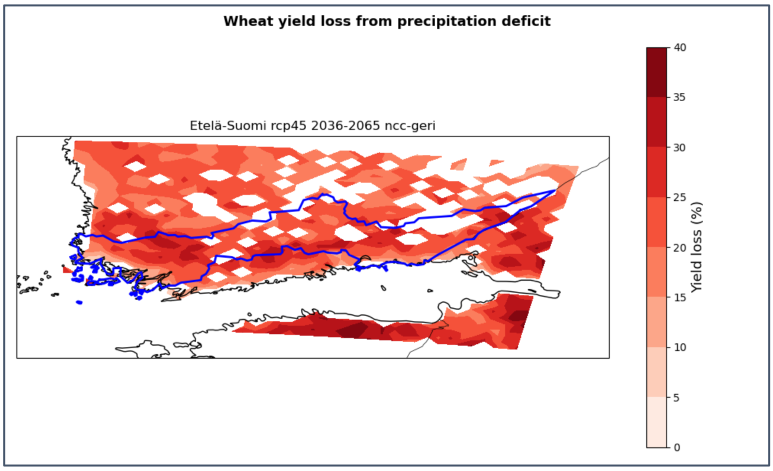

Figure 6 Wheat yield loss from precipitation deficit. Model pair 0, RCP4.5, 2036–2065.

As expected, RCP8.5 results in higher yield loss values when compared to RCP4.5. However, the difference is only slight. RCP2.6 might be added to the analysis to have more comparisons in the second phase

There are previous studies on crop yield levels under climate change (eg. Pirttioja et al., 2019). In the second phase parameters of these studies will be incorporated to our analysis to produce more suitable data. Also, for the future of cultivated crop species (e.g. the increasing farming of rapeseed) will be taken into consideration so that value loss analysis in the risk assessment phase becomes more relevant.

2.3.1.2 Risk assessment

The risk assessment for agricultural drought was conducted using the same variables as in the hazard assessment. The analysis was continued from the workflow to achieve a more thorough understanding of the situation.

Risks were assessed using all the models, RCP4.5 and RCP8.5, and three different year ranges. The resulting value for the risk assessment is revenue loss per area. The analysis used a grid size of 12 km, so the produced value is € lost per 144 km^2. The size of the grid, however, is not precisely 144 km^2 due to projection methods. For the analysis, these values are still considered to be comparable.

The mean of model pairs for each point was calculated (Figure 7). Using the produced mean point values, mean value for the whole of Southwest Finland was calculated (Figure 8). This method for calculating a single value for the whole area can be useful when communicating the results to stakeholders but it carries the risk of oversimplification. As the analysis is conducted for a larger area than just Southwest Finland, it might be feasible to do the same for other Finnish regions as well. The additional work for different regions would be rather small and the regions could benefit from the information on their adaptation work. Reviewing risks associated with different scenarios during different time ranges produces ample data to work with when planning for adaptation strategies.

Similar to yield loss, wheat has also higher revenue loss values compared to other two studied crop species (Figure 7). The value differences between species for revenue loss are however higher than the value difference for the yield loss. When considering the area of Southwest Finland specifically, the yield loss of wheat is up to tenfold compared to the other two studied crop species. On the other hand, geographical differences of yield loss with barley and rapeseed are high. In the region, the revenue loss values of barley and rapeseed are low, but some points in the studied area achieve higher values.

The difference between barley and wheat revenue loss must be examined more closely as the harvest area, crop yield, and value of the two crop species are similar. Yield losses are lower for barley, which might be the main reason for the difference.

Value loss of rapeseed is low overall which is probably due to low production values of the species in the area (only 3 % of agricultural area in Southwest Finland). Rapeseed is also known to benefit from climate change (Peltonen-Sainio et al., 2009).

When examining revenue loss by year, it can be seen that it declines through the years (Figure 8). The decline is more extreme with RCP8.5, indicating that revenue loss is mitigated with climate change slowly after a sudden drop. These results need to be examined more as such

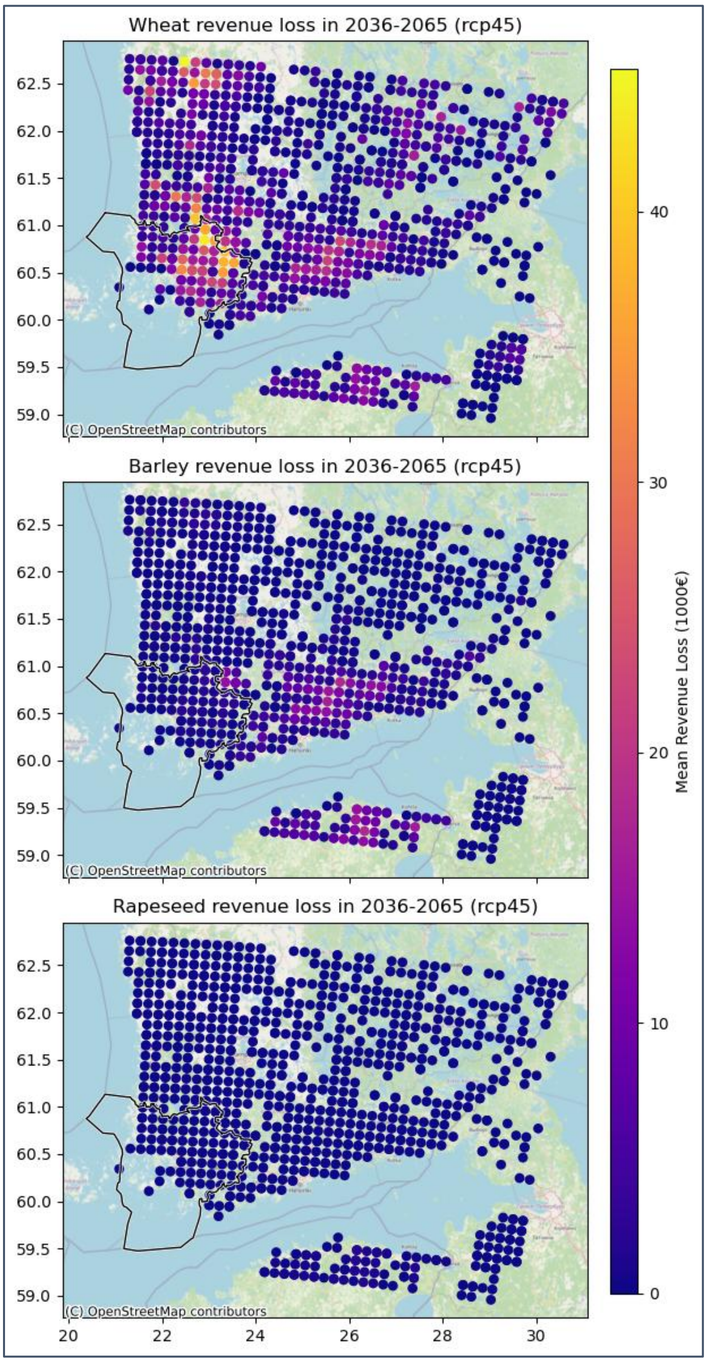

Figure 7. Revenue losses of studied crop species. Mean of model pairs 0, 1, 2 and 4, RCP4.5, 2036-2065. Southwest Finland is the area with the black border.

drastic changes in few years are in conflict with literature. In the same figure, the difference between four model pairs (0, 1, 2, 4) can also be observed. Values from model pair 2 are constantly higher than the others while model pair 4 gives the lowest value loss.

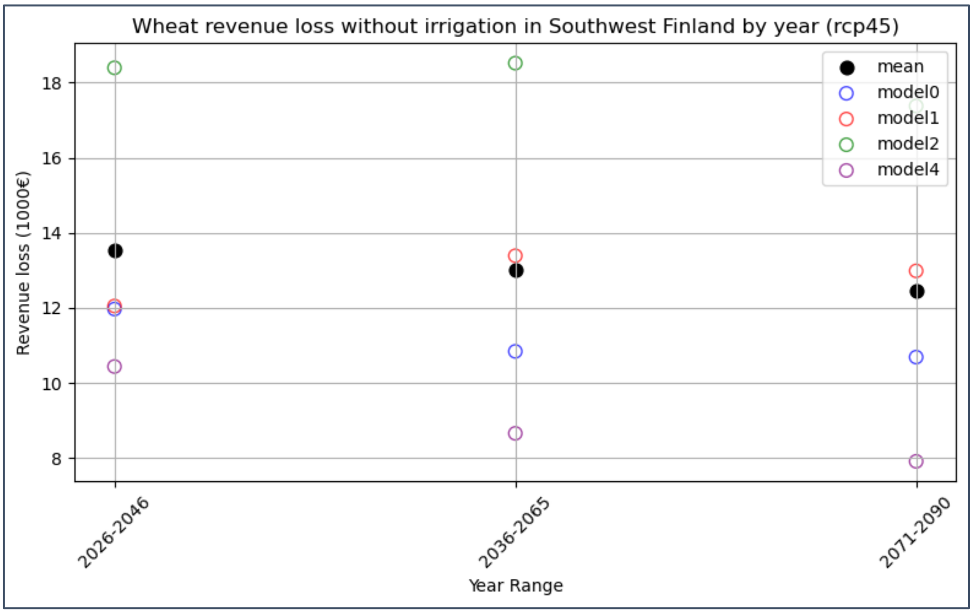

Figure 8 Wheat revenue loss without irrigation in Southwest Finland by year (RCP4.5)

Irrigation levels in Northern Europe and Southwest Finland are low. The most irrigated grid cell in the studied region has 4.6% of irrigated agricultural area. In the second phase, it will be discussed whether low local irrigation levels will have an effect on the capacity or, on the other hand, whether changes in precipitation and temperature will have an impact on the crops used and on the need for irrigation.

2.3.2 Workflow #2: Heavy rainfall

Table 4 Data overview workflow #2

Hazard data	***Vulnerability data***	***Exposure data***	***Risk output***
Precipitation intensity for a given return period, impact rainfall thresholds	Stormwater solutions Flood preparations	Critical infrastructures and population density	Impact rainfall thresholds Shift in magnitude and frequency Heavy rainfall events on critical infrastructure

Heavy rainfall workflow uses historical precipitation data to calculate changes in precipitation in the future under chosen RCP scenarios for given years. In the workflow, different climate models can be chosen for the simulations. Precipitation level changes are compared with given locally specified rainfall threshold levels to assess the frequency and magnitude of heavy rainfall under climate change. These results will then be assessed with geographical information of critical infrastructure, like hospitals and sewage pump stations, to assess the risks for these points.

2.3.2.1 Hazard assessment

In this workflow, the hazard assessment was already done by the CLIMAAX project and the results were offered to be used in the risk assessment. However, TIFF files for critical thresholds were needed to be produced as ready-made data was not available for our area. We used CERRA data to produce a threshold map with 5 km resolution. This was not instructed in the workflow, but we were able to produce it with some help from the CLIMAAX support.

For phase 1, the analysis was done using ichec-ec-earth/knmi-racmo22e models, RCP4.5 and RCP8.5 models, a historical time frame of 1976–2005, and a mid-future time frame of 2041–2070.

Threshold levels given by the Finnish Meteorological Institute's (FMI) levels of rain warnings include 1 h and 24 h thresholds (Table 5).

Table 5 Finnish Meteorological Institute's rain warning levels.

Short term (1h)	Long term (24h)
20 mm (yellow warning)	50 mm (yellow warning)
30 mm (orange warning)	70 mm (orange warning)
45 mm (red warning)	120 mm (red warning)

It is possible to calculate return periods for 3h or 24h in the workflow. FMI produces hourly data, so we have been discussing with FMI experts whether to produce maps with 1h return period in the second phase. For now, the analysis has been done using FMI's long term threshold levels.

Turku Harbour has been identified as one of the main flood risk areas in the city of Turku. In the first phase, Turku Harbour was chosen as a point to consider in the workflow. In the second phase, more points will be chosen if the analysis of the whole area is not considered to be enough. Single point analyses give a different set of visuals which are both easier to understand than maps and easier to communicate to stakeholders.

Annual maximum precipitation in a 24h period differs greatly between the historical run and the RCP8.5 2041–2070 run. Historical data does not show maximum daily precipitations of over 50 mm but, for the period of 2041–2070, there will be several such years (Figure 9). FMI gives out a yellow warning for a precipitation level of 50 mm/24 h and the increase of such days poses risks. Overall precipitation in Turku Harbour is increasing as well according to the analysis.

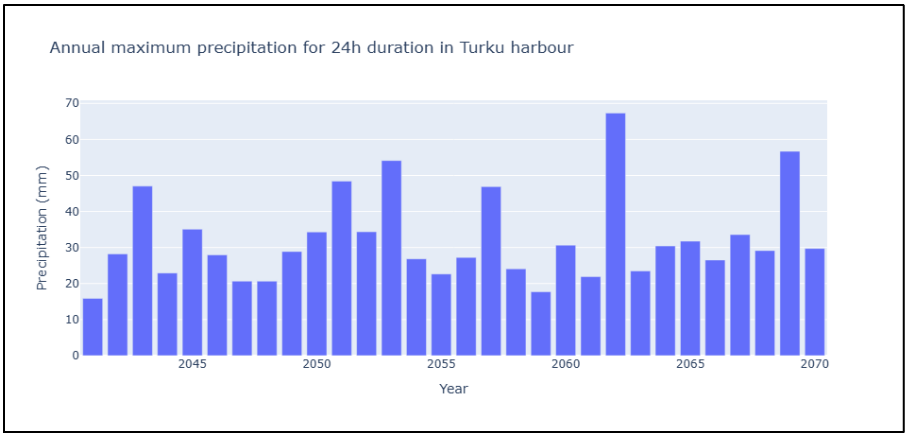

Figure 9 Annual daily maximum precipitation rates in Turku Harbour

The calculated expected return periods tell a similar story: all risks are likely to become more common, especially the milder risks (Figure 10). Return periods of FMI's critical threshold values for the Turku Harbour points were calculated to get more informative numbers to present (Table 6).

This kind of presentation will be useful when continuing on with the work, especially when communicating with stakeholders.

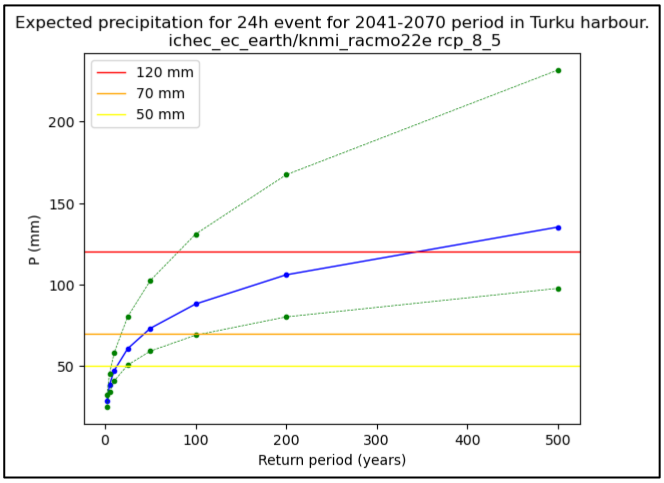

Figure 10 Expected extreme precipitation for 24h event during 2041-2070. Under RCO8.5 and ichec_ec_earth/knmi_racmo22e.

Table 6 Return periods calculated for FMI's risk levels.

Risk level	Return period
Yellow / 50mm	13.1 years
Orange / 70 mm	43.6 years
Red / 120 mm	344 years

When assessing the whole area, the difference between coastal and inland areas becomes clear, like in the agricultural drought workflow. Coastal areas have more precipitation already and the difference will become even larger in the future. Changes in extreme precipitation values varies from -25 % to +25 %. (Figure 11)

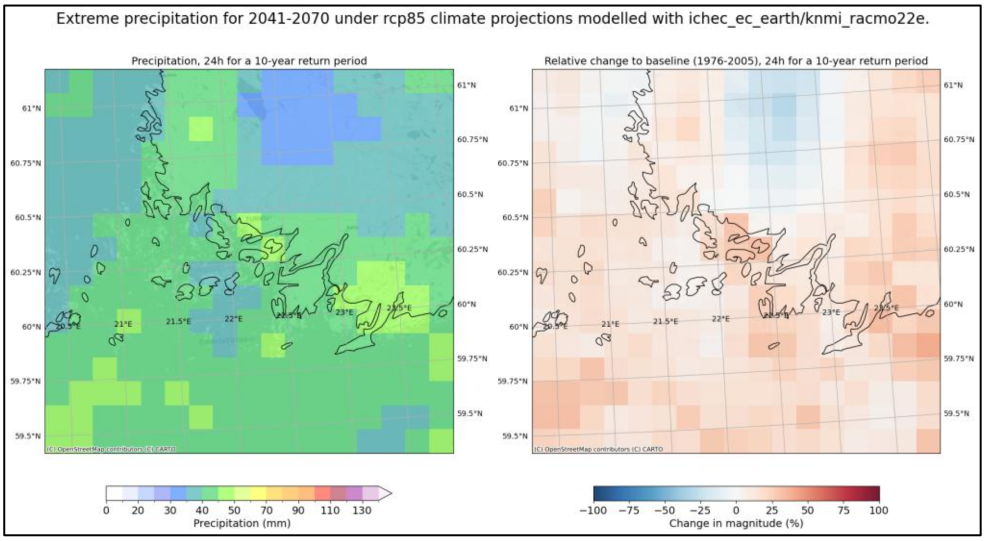

Figure 11 Extreme precipitation for 2041–2070 under RCP8.5 climate projections modelled with ichec_ec_earth/knmi_racmo22e

2.3.2.2 Risk assessment

The risk assessment for the heavy rainfall workflow uses the hazard results. Magnitude and frequency shifts are added to it with critical thresholds. Critical infrastructure is also considered, although this work will be properly expanded in the second phase. The Regional Council of Southwest Finland has already done work on sewage overflows calculating the risks for sewage pump stations (Yli-Heikkilä & Badawieh, 2023). This work can hopefully be continued and expanded using the CLIMAAX workflow.

Cascading effects of flood risks were discussed during stakeholder meetings. The change in sea water levels, more rapid melting of snow cover due to temperature fluctuations, and sudden heavy rainfall can cumulate into extreme floods as happened in November 2024. (TS.fi, 2024) The historic flood resulted in closing of bridges and roads, and damages to buildings and shore structures. We are hoping that this cascading effect can also be integrated into the workflow in the second phase.

The results of the risk assessment follow a similar patter to the hazard assessment. The coastal area will receive more frequent rainfalls exceeding the critical thresholds. The coastal area is also more densely inhabited which means that the flood risks are real. Rainfalls of orange warning level (70 mm/24h) will become a common event in Southwest Finland (Figure 12).

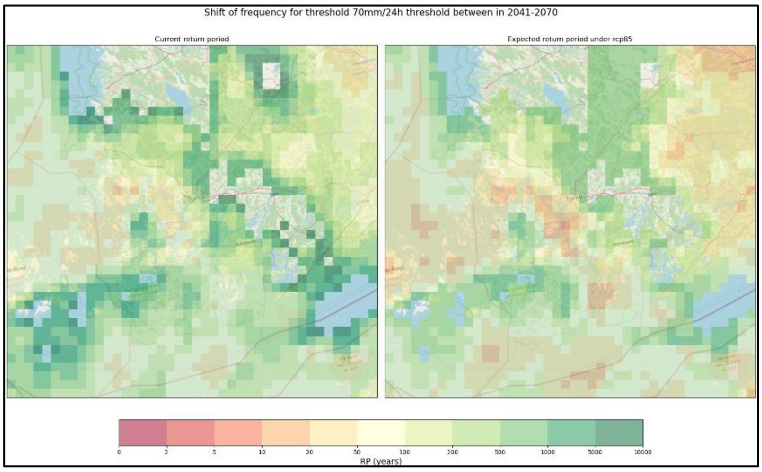

Figure 12 Shift of frequency for 70mm/24h threshold in 2041–2070 under RCP8.5.

Major portion of Southwest Finland will endure rainfalls of the red warning level (120mm/24h) even every 10-50 years.

Changes in heavy rainfall were also assessed from the view of critical infrastructure. In some parts of the archipelago, access to emergency services can be challenging due to long distances and ferry-run connections. The workflow indicates increased heavy rainfalls on the coastal area which needs to be considered in adaptation planning. Hospitals were mapped using OpenStreetMap's database[4] (Figure 13), but the data is incomplete and not fully accurate. Still, several important hospitals in the area are inside of grid cells with significant increase in precipitation. For example, the area where TYKS, the regional main hospital, is located in will see over 40% increase in 70mm/24h rainfalls. Health centers, hospitals and other critical infrastructure need to be manually mapped and assessed in the second phase.

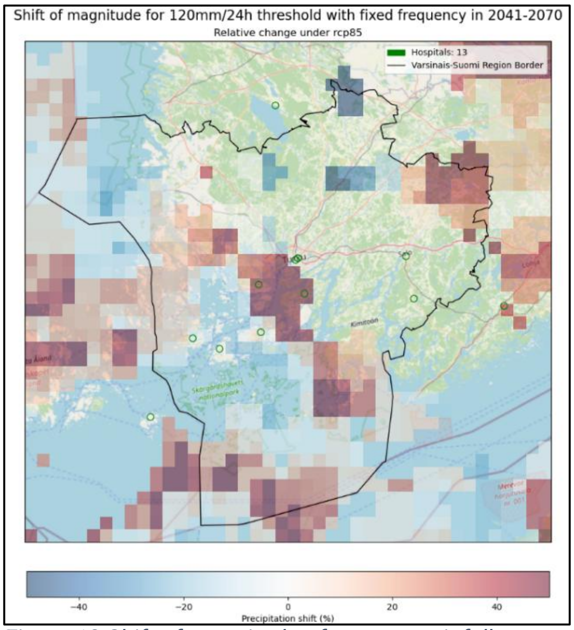

Figure 13 Shift of magnitude of extreme rainfall (120mm/24h) in 2041-2070 and hospitals from OSM.

[4] See: https://wiki.openstreetmap.org/wiki/Healthcare

2.4 Preliminary Key Risk Assessment Findings

2.4.1 Severity

According to the CRA conducted in the project, agricultural droughts seem to affect the crop (wheat, barley, rapeseed) yield and revenue negatively, but with milder effects going farther in the future. The result is a bit mixed when compared to other studies which consider that the risk will likely be more serious in the future with longer and more frequent droughts in Finland. The impacts of climate change can already be seen in the fields causing nearly annual losses to agriculture. Droughts cause increased losses both due to lack of water itself but also due to increased exposure to pests, for example. Droughts also cause additional expenses to farmers due to more expensive production inputs which can lead to financial difficulties. Southwest Finland is one of the most important food producing regions in Finland which makes the region important for national food security. Droughts cause environmental issues too as the following rains spread nutrients to water systems and further increase the eutrophication of the Archipelago Sea. (Ahopelto, Parjanne & Tuukkanen, 2024)

According to the work conducted in the CRA, it was found out that there is a shift in the magnitude and frequency of heavy rainfalls. Other studies support these findings (Luomaranta et al., 2025). Flooding can cause significant economic damage in the region, especially in the cities. Besides economic damage, flood-related tasks can strain the fire department and also cause delays for attending life-threatening medical emergencies. Flooding can also have an impact on the eutrophication of the Archipelago Sea if extra nutrients flow in the sea from fields (Virtanen, 2023).

2.4.2 Urgency

Agricultural droughts are already causing nearly annual economic losses to farmers which means that actions to minimize the damages caused by it should commence as soon as possible. The severeness of the droughts change year by year but according to a multitude of national studies, both their frequency and their severeness will likely increase even if the preliminary results of the CRA show that the yield losses should become lower when time passes. As it's likely that the problem will worsen in the future, damages can be limited with early actions: conducting preventive actions is cheaper than reacting to a crisis afterwards. (Ahopelto, Parjanne & Tuukkanen, 2024)

According to the CRA, heavy rainfalls should increase in both magnitude and frequency in future. They are already causing economic losses which are likely to increase in the future. Urban planning, stormwater systems, and construction and renovation of buildings are done in the long term which means that the future impacts of heavy rainfalls should already be considered in the planning.

2.4.3 Capacity

Agricultural drought

Drought risk has traditionally been undervalued in Finland even if economic losses are already almost annual. The measures to address the issue have been mostly reactive instead of anticipative. The measures have mostly focused on compensating economic losses to farmers via agricultural funding instruments instead of funding measures that solve the problem itself before a crisis has unveiled. There are measures that can be implemented in the farms such as soil actions, improving drought-resistant crop varieties and using irrigation. (Ahopelto, Parjanne & Tuukkanen, 2024) In Turku area, artificial groundwater is used to produce potable water to save other water sources. For Sirppujoki drainage basin, a regional drought risk group has been piloted to respond to the droughts.

Even though there are ways to address the issue, many farmers in Finland are facing growing financial difficulties and for many, the transitional resilience is not at its strongest. Their position in the food value chain is weak and their share of the profits has been sinking for a long time. (Kuhmonen, 2023) Due to this, it is reasonable to ask whether they have enough resilience, money, time, learning capacity, or knowledge to make the transition to more sustainable and adaptive production methods and efficiently implement new measures to address drought related issues.

In Finland, the fields have traditionally not been artificially irrigated and farms have relied mostly on natural sources. Artificial irrigation is more expensive and it has thus been used mostly for valuable crops. In 2020, only 3,1% of agricultural land was equipped with irrigation systems which makes the system vulnerable. Compared to other regions, Southwest Finland does not have many lakes which puts a strain on small rivers and makes increasing irrigation challenging. Finnish farmers have also not shown great interest in investing in irrigation systems. One explanation for it might be that the systems are expensive and the Common Agricultural Policy (CAP) of the European Union has so far not supported the funding of irrigation systems in mainland Finland. (Ahopelto, Parjanne & Tuukkanen, 2024; Ilmasto-opas, 2017b; Natural Resources Institute, 2024; Virtanen, 2023)

Except for a few exceptions, there are currently no robust regional or national interventions implemented for the reduction of agricultural drought risk. In a national guiding document for the governance of the drought risk, it has been suggested that developing early-warning systems and indicators, improving the identifying of high-risk areas, and developing risk management and preparedness plans in cooperation with local farmers suffering from droughts is needed. (Ahopelto, Parjanne & Tuukkanen, 2024)

Heavy rainfall

Overall, Finnish water supply sector is regarded to have good capacity for adaptation. (Virtanen, 2023) When compared to droughts, flooding has a different legal position because flood-based risks are covered by specific laws that require public authorities to address the issue. (Finnish law 620/2010; Finnish government degree 659/2010; EU directive 2007/60/EC) Due to this, there is an array of measures already in place to address these issues.

Many municipalities already have a stormwater management plan in Southwest Finland. The municipalities were also mandated to make risk assessments on potential high risk areas for storm-water floods in 2024 (Kuntaliitto.fi, 2023). It is, however, unclear whether the municipalities have actually made them and whether the findings have led to changes in the planning and construction of new buildings or wastewater pumping stations, for example. Whichever the case, understanding the risks is already a step forward especially for smaller municipalities.

Most of the country is still using the retention factor of 1m³ water for every 100m² of impervious surface. Some of the larger cities such as the city of Turku have introduced a more detailed blue-green factor for urban planning. The blue-green factor considers the amount and quality of vegetation, other surfaces, and stormwater solutions in an area and produces a value for them. If the value is below the target value, more planning must be done on how the targets could be reached. (Turku.fi, s.a.b) There are plans to introduce the blue-green factor to other municipalities in the region as well but more communication and training is required for further implementation.

The environmental risks of the stormwater overflows at pumping stations were studied in 2018 and updated in 2023. (Ahonen, 2018; Yli-Heikkilä & Badawieh, 2023) With the help of the study, it has been possible to identify high risk areas for both the environmental damage and the flood risk. Pumping stations are however still built in high risk due to cost-effectiveness. Many parts of the sewer networks need repairs and the review can be used to pinpoint the most urgent parts of the network.

Heavy rainfall erodes the fields especially in the winter leading to nutrients flowing into the Archipelago Sea. Winter-time erosion amounts to 90% of annual nutrient inflow and causes eutrophication. (Fleming et al. 2023) In the region, the risk has been addressed with buffer zones and year-round vegetative cover in the fields.

Ditching and impervious surfaces have led to the losing of the natural retention and delay capacities of the catchment basins. Despite this, it has not been possible to establish the wide-spread use of nature-based solutions except for a few pilot locations.

2.5 Preliminary Monitoring and Evaluation

We chose agricultural drought and heavy rainfall to be studied in the workflows. They were deemed as the most important regional risks both by the project team and the stakeholders who answered the survey. After running the workflows and assessing risks, it was confirmed that both risks are severe although the agricultural drought is a bit mixed one.

Reflection must be done on what metrics are most usable for adaptation work. Workflows need to be modified even further to provide the stakeholders useful information. Studying more workflows in the project has also been considered which naturally means more work but which would undoubtedly bring more data and knowledge to be used in the regional adaptation work.

Positive feedback was received from local stakeholders regarding real-life usability after showing them preliminary results. Communicative aspects of the project need proper pondering as raw plots and data might be hard to interpret and can lead to wrong conclusions. Instead, there is need for explanations written in plain language when communicating to larger public.

We started with small concerns on how challenging and time consuming the workflows would technically be. Fortunately, at least for the workflows we have completed, the technical running of the code has turned out to be fairly simple. Some aspects of the Python code were new for the person mainly running the assessments, for example projections and modifications from one projection to another, but the CLIMAAX project support team was of great help.

As expected, the localization of the code has been the most challenging part. In the heavy rainfall workflow, the resolution of the EURO-CORDEX was not sufficient so we needed to produce a historical precipitation map using CERRA dataset which took some time. In the agricultural drought workflow, the crop list was noticed to be inadequate for our needs as the list does not cover all the main crops in the region which is something that must be done in the second phase.

Positively, the stakeholders have shown great interest in the project, and many have expressed a specific interest that they truly want to take part in the regional adaptation work. We have included stakeholders in the process of selecting the risks studied in the risk assessment and we also organized meetings for the project working group and the steering group where the preliminary results were presented for them. The stakeholders gave suggestions on who to contact for more information, for which resources to utilize and on how the results could be further utilized for the best of the region. Stakeholders deemed the work done in the project important and that the climate change adaption work in the area should benefit considerably from the work conducted in the project. The importance of producing new information that brings new perspectives and more concrete data was emphasized.

There are already ideas for adding new data for the next phases of the project. Pirttioja et al. (2019) studied crop yield impacts under climate change. Different methods were used to produce crop yield results such as the WOFOST (World Food Studies Simulation Model) model to simulate crop production. This and other studies using WOFOST seem worth looking into if it would benefit our work as well.

Finnish Meteorological Institute has comprehensive open data from over 400 weather stations including hourly precipitation values starting from the year 1959. This data needs to be incorporated to the risk assessment if deemed possible.

Agriculture, drought and climate change have been studied somewhat extensively (e.g. Snellman & Todorovic, 2023)). Precipitation, floods and stormwaters have also been studied extensively. The studies provide useful information on our work and need to be studied carefully. Researchers and other experts have already been contacted to extend the project team's competence and expertise.

2.6 Work plan

In the second phase, the project will further develop the risk assessments with the inclusion of local data to improve their accuracy and make them even more useful for the regional adaptation work. The project will also further analyze existing regional and national data that could be used for the risk assessments. The project will properly kickstart stakeholder engagement process which is needed to bring the lessons learned in risk assessments into practice and, more specifically, into the regional strategy. The aim of the stakeholder cooperation is also to increase the capacities of local stakeholders in understanding the impacts of climate change, adaptation measures and how they could implement them into their own strategies and practice. Adaptation objectives and goals will be specified. The project will also further collaborate with other Finnish regions and institutions.

In the third phase, the results of the risk assessments and stakeholder collaboration will be used to identify and select regional adaptation measures. In wide stakeholder cooperation, the adaptation measures are planned to be included in the regional climate roadmap. Dissemination of project findings and supporting stakeholders in their adaptation work are also very important in the final phase in order to make sure the lessons learned in the project will live after it has ended.

3 Conclusions Phase 1 - Climate risk assessment

The first phase of the CLIVAS project further enhanced the view that the region of Southwest Finland is facing climate risks that need to be addressed in the near future.

The project team conducted extensive background research on how climate change adaptation work has been conducted in Finland. Climate change adaptation work has been fragmented and uncoordinated in the regional level. Despite this, as presented in this document as well, there have still been many assessments and adaptation measures implemented in the region and in the municipalities. Especially water-related risks have been considered in detail in the regional adaptation work.

The main reason for the fragmentation of the regional climate change adaptation work is that the work has been mostly conducted on national level planning. Regions and cities have conducted a lot of climate-related work, but it has focused mostly on climate change mitigation. This is also the case in Southwest Finland where emissions have been successfully cut but adaptation work has been neglected.

The project team conducted extensive research on existing knowledge, severeness, and urgency of different risks, and the usefulness of the potential data provided by the workflows of the CLIMAAX Handbook to the regional adaptation work. After the initial phase, the project sent a survey to regional stakeholders to get their views on the selection of the risks and to validify the results of the research conducted. Based on the research and results of the survey, agricultural drought and heavy rainfall were selected as the main risks to be studied in the project. All of the risks except for the heavy snowfall were deemed relevant for the region. Relative drought, flood building damage, windstorm, and fluvial flooding were regarded as the most important ones after the ones selected for the first phase.

The main result of the climate risk assessments conducted in phase 1 is that both agricultural drought and heavy rainfall are likely to hit the region of Southwest Finland harder in the future due to the impacts of climate change even though there were some mixed results from the agricultural drought workflow. Both risks were assessed using several climate change scenarios (RCP), several regional and global climate change models (GCM/RCM) and several time series.

Preliminary results of the heavy rainfall workflow show a clear rise in precipitation although there is some geographical variability. In some areas, precipitation will increase up to 50% but some areas face decreases. Extreme rain events will likely occur in the coastal areas of Southwest Finland. Adaptation strategies must take the locality of extreme rain event, areas with critical infrastructure, highly populated areas, and the special conditions of the archipelago into account.

Agricultural droughts seem to affect the crop yield and revenue negatively, but with milder effects going further in the future. Wheat yield losses were highest amongst the studied species while rapeseed losses were close to none. In the future, adaptation strategies should focus on irrigation availability and crop species selection.

Both of the workflows will be further developed in phase 2 with localized data which should provide more relevant findings and better real-life usability. The project team were met with some challenges regarding the workflows which have to be further developed to suit the regional needs during the next phase together with the CLIMAAX support team and local experts. The project team has also received some suggestions and ideas from stakeholders to improve the real-life usability of the project results which the project team was not able to address during the first phase but which will be investigated during the next phases of the project.

4 Progress evaluation and contribution to future phases

The progress achieved in phase 1 will directly feed into the following phases of the project.

The project team consisting of a project manager, climate specialist, a GIS specialist, and a trainee was successfully formed in the spring of 2025. The scanning of the risks in the exploration phase, the use of CLIMAAX Handbook and methodology, and the results of the 2 workflows completed in phase 1 increased the knowledge and capabilities of the project team which can be seen as a prerequisite for producing risk assessments of the highest quality and leading effective stakeholder cooperation in the later phases.

The risk assessments based on European data will be the basis for the more detailed assessments using localized data in phase 2 with the help of regional experts and CLIMAAX support team. The work done for the climate risk assessments in phase 1 will directly support the later stages of the project by providing a starting point for the work on identifying regional adaptation options.

The first steps for stakeholder cooperation were taken in the first phase by setting up the project working group and the steering group consisting of local experts with a wide range of expertise. Setting up these groups will benefit the project in the future by giving it the possibility to easily acquire knowledge from these experts who are not directly working for the project. The project has been able to form good connections to regional and national authorities and research institutions which will be of utmost importance to maximize the impact of the project in the next phases. The project has planned the future engagement of stakeholders and citizens and how they could be involved in planning for regional climate adaptation.

Table 7 Overview key performance indicators

Key performance indicators	***Progress***
Phase 1: 2 workflows succesfully applied on Deliverable 1	Workflows on heavy rainfall and agricultural drought were completed in August 2025.
Phase 2: 20 of stakeholders involved in the activities of the project	Stakeholders from 8 different organizations took part in the project working group and steering group work, and contributed to a survey used to map the most relevant risks for the risk assessment.
Phase 1-3: 10 communication actions taken to share results with your stakeholders ***Report on each deliverable***	This deliverable was completed and will be further communicated to stakeholders after accepted. We also plan to produce a shorter and easier-to-read version of it.

Table 8 Overview milestones

Milestones	***Progress***
Test of the 1st workflow made	Test runs on agricultural drought were completed in May 2025.
Attend the CLIMAAX workshop held in Barcelona	Three people from the project attended the Barcelona workshop in June 2025 and presented the project poster.

Milestones	***Progress***
Risk identification – Selecting relevant risk workflows	The risk workflows were selected in June 2025.
Both workflows successfully applied	Workflows on heavy rainfall and agricultural drought were successfully completed in August 2025.
Initial risk assessment	Completed in June 2025.

5 Supporting documentation

The list of supporting documentation on Zenodo includes all the outputs produced during phase 1:

- Main Report
- Agricultural drought workflow datasets and notebooks including visual outputs in .zip format.
- Heavy rainfall workflow datasets and notebooks including visual outputs in .zip format.
- Communication outputs
  - 4 newsletters
    - Newsletter of the Turku-Southwest Finland European Office
    - International Newsletter of the City of Turku
    - Newsletter of the Regional Council of Southwest Finland
    - Newsletter of Valonia
  - 2 news articles showcasing the project in both Finnish and English published on the website of the Regional Council of Southwest

6 References

Ahonen, K. (2018). *TSP Oy:n viemäröintialueen ylivuotojen parempi hallinta – Ympäristöriskianalyysi jätevedenpumppaamoille.* Varsinais-Suomen elinkeino-, liikenne- ja ympäristökeskus, Raportteja 67/2018.
<https://urn.fi/URN:ISBN:978-952-314-760-7>

Ahopelto, L., Parjanne, A. & Tuukkanen, T. (2024). *National Guidelines for the Management of Drought Risks.* Publications of the Ministry of Agriculture and Forestry 2024:26.
<https://urn.fi/URN:ISBN:978-952-366-745-7>

Ahopelto, L., Parkkila, P. & Parjanne, A. (2020). *Sirppujoen vesistöalueen kuivuusriskien hallintasuunnitelma.* Varsinais-Suomen Ely-keskus, 15.12.2020.
<https://vesi.fi/aineistopankki/sirppujoen-vesistoalueen-kuivuusriskien-hallintasuunnitelma/>

Economist Impact (2024). *Climate change's disruptive impact on global supply chains and the urgent call for resilience.*
<https://impact.economist.com/projects/trade-in-transition/climate_change/>

Finnish Environment Institute (2024). *Yleispiirteinen hulevesitulvakartta 2024 (testipalvelu).*
<https://syke.maps.arcgis.com/apps/webappviewer/index.html?id=aa63362413914688b20b29b98f14f456>

Finnish Government (2023). *National Climate Change Adaptation Plan 2030 – Wellbeing, safety and security in a changing climate.* Publications of the Finnish Government 2023:73.
<https://urn.fi/URN:ISBN:978-952-383-585-6>

Fleming, V., Berninger, K., Aikola, T., Huttunen, M., Iho, A., Kuosa, H., Niskanen, L., Piiparinen, J., Räike, A., Salo, M., Sarkkola, S. & Valve, H. (2023). *Rannikkovesien ravinteiden kuormituskatot ja kuormituksen vähentämisen keinoja – Tekninen taustaraportti.* Prime Minister's Office.
<https://julkaisut.valtioneuvosto.fi/handle/10024/165047>

Gregow, H., Rantanen, M., Laurila, T.K. & Mäkelä, A. (2020). *Review on winds, extratropical cyclones and their impacts in Northern Europe and Finland.* Finnish Meteorological Institute, Reports, 2020:3.
<http://hdl.handle.net/10138/320298>

HELCOM (s.a.). *HELCOM Hot Spots.*
<https://helcom.fi/action-areas/industrial-municipal-releases/helcom-hot-spots/>

Helsingin Sanomat (HS) (2022). *Kuivuus veden keskellä.* Helsingin Sanomat, 3.10.2022.
<https://www.hs.fi/kotimaa/turku/art-2000009089539.html>

Ilmasto-opas (2017b). *Suomen maatalous voi sopeutua ilmastonmuutokseen.*
<https://www.ilmasto-opas.fi/artikkelit/suomen-maatalous-voi-sopeutua-ilmastonmuutokseen>

Ilmasto-opas (2022). *Varsinais-Suomi – tyypillistä tammivyöhykkeen ilmastoa.*
<https://www.ilmasto-opas.fi/artikkelit/varsinais-suomi-tyypillista-tammivyohykkeen-ilmastoa>

Ilmasto-opas (2024). *Ilmastonmuutos lisää rakennetun ympäristön tulvariskejä.*
<https://www.ilmasto-opas.fi/artikkelit/ilmastonmuutos-lisaa-rakennetun-ympariston-tulvariskeja>

Ilmasto-opas (s.a.). *Timber harvests are likely to grow, but the risk of damage to forests may increase.* *<https://www.climateguide.fi/articles/timber-harvests-are-likely-to-grow-but-the-risk-of-damage-to-forests-may-increase/>*

Kinnunen, O., Backman, L., Aalto, J., Aalto, T. & Markkanen, T. (2024). *Projected changes in forest fire season, the number of fires, and burnt area in Fennoscandia by 2100.* Biogeosciences, 21:21, 4739–4763. <https://doi.org/10.5194/bg-21-4739-2024>

Kollanus, V., Halonen, J.I. & Lanki, T. (2023). *Helteen vaikutukset ja varautuminen terveydenhuollossa.* Lääketieteellinen Aikakauskirja Duodecim, 139:13, 1127–1133. <https://www.duodecimlehti.fi/duo17765>

Kuhmonen, I. (2023). *Regiimin kahlitsemat? Maanviljelijöiden toimijuus ja maatilojen resilienssi ruokajärjestelmän kestävyyssiirtymässä.* Finnish Journal of Rural Studies, 32:1, 2024. <https://doi.org/10.51807/maaseutututkimus.146599>

Kuntaliitto.fi (2023). *Kuntien arvioitava hulevesitulvariskit alueellaan vuonna 2024.* <https://www.kuntaliitto.fi/ajankohtaista/2023/kuntien-arvioitava-hulevesitulvariskit-alueellaan-vuonna-2024>

Luomaranta, A., Virman, M., Rantanen, M., Hautala, J., Ruosteenoja, K. & Mäkelä, A. (2025). *Observed and projected changes in precipitation across the regions of Finland.* Finnish Metorological Institute, Reports 2025:2. <http://hdl.handle.net/10138/592579>

Natural Resources Institute (2024). *Ilmastonmuutos tuo maataloudelle sekä haasteita että mahdollisuuksia.* <https://www.luke.fi/fi/uutiset/ilmastonmuutos-tuo-maataloudelle-seka-haasteita-etta-mahdollisuuksia>

Peltonen-Sainio, P., Jauhiainen, L., Hakala, K. & Ojanen, H. (2009). *Climate change and prolongation of growing season: changes in regional potential for field crop production in Finland.* The Scientific Agricultural Society of Finland, 18, 171–190. <https://jukuri.luke.fi/items/c4790c1a-1e26-44dc-82bc-95faeec87a28>

Pilli-Sihvola, K., Halonen, J., Meriläinen, J., Laapas, M., Ruuhela, R., Munck af Rosenschöld, J., Hällfors, M., Knuuti, S. & Sorvali, J. (2023). *Risks and Vulnerabilities Related to Climate Change in Finland Background study for the National Climate Change Adaptation Plan 2030.* Publications of the Finnish Government 2023:73. <https://urn.fi/URN:ISBN:978-952-383-566-5>

Pirttioja, N., Palosuo, T., Fronzek, S., Räisänen, J., Rötter, R.P. & Carter, T.R. (2019). *Using impact response surfaces to analyse the likelihood of impacts on crop yield under probabilistic climate change.* Agricultural and Forest Meteorology, 264, 213–224. <https://doi.org/10.1016/j.agrformet.2018.10.006>

Ruosteenoja, K., Räisänen, J., Venäläinen, A. & Kämäräinen, M. (2016). *Ilmastonmuutos lämmittää Suomen kasvukausia*. Suomen Maataloustieteellisen Seuran julkaisuja no 33. <https://doi.org/10.33354/smst.75245>

Ruuhela, R. et al. (2023). *Climate and socioeconomic scenarios for climate change adaptation planning*. Publications of the Ministry of Agriculture and Forestry 2023:4. <http://urn.fi/URN:ISBN:978-952-366-867-6>

Snellman, R. & Todorovic, S. (2023). *Kuivuusvaara ja -haavoittuvuuskarttojen tuottaminen Suomessa. <https://vesi.fi/aineistopankki/2990-2/>*

Sustainable Travel Finland (s.a.). *Sustainable Tourism Guide – Climate Change & Travel.* <https://stfhub.visitfinland.com/guide/climate-change-and-travel>

TS.fi (2024). *Varsinais-Suomen joet tulvivat historiallisella voimalla, teitä suljettu ympäri maakuntaa – katso videot ennätystulvista.* TS.fi, 26.11.2024. <https://www.ts.fi/uutiset/6499877>

Turku.fi (s.a.a). *Climate change adaptation maps.* <https://www.turku.fi/en/climate-change-adaptation-maps>

Turku.fi (s.a.b). *Siniviherkerroin.* <https://www.turku.fi/rakentaminenrakentamisen-ohjeet-ja-lomakkeet/siniviherkerroin>

Turun tulvaryhmä (2022). *Turun rannikkoalueen tulvariskien hallintasuunnitelma vuosille 2022-2027. <https://vesi.fi/aineistopankki/turun-rannikkoalueen-tulvariskien-hallintasuunnitelma-vuosille-2022-2027/>*

Valonia (2025). *Varsinais-Suomen päästöt jatkavat vähenemistään.* <https://valonia.fi/uutinen/varsinais-suomen-paastot-jatkavat-vahenemistaan/>

Varsinais-Suomen alueellinen riskiarvio (2023). <https://sisainenturvallisuus.fi/documents/8347581/8542516/Varsinais-Suomen+alueellinen+riskiarvio+2023.pdf/26821329-3ce4-dc79-fad1-bc8eb524ba83/Varsinais-Suomen+alueellinen+riskiarvio+2023.pdf?version=1.0&t=1680176909075>

Vesi.fi (s.a.a). *Tulvakartat. <https://vesi.fi/karttapalvelu/?&theme=tulvakartat>*

Vesi.fi (s.a.b). *Tulvariskien aluesivut*. <https://www.vesi.fi/tulvariskien-aluesivut-varsinais-suomi/>

Virtanen, K. (2023). *Review of regional characteristics and vulnerabilities related to climate change in Finland – Background material for Finland's National Adaptation Plan 2030*. Publications of the Ministry of Agriculture and Forestry 2023:11. <http://urn.fi/URN:ISBN:978-952-366-588-0>

Yli-Heikkilä, K. & Badawieh, O. (2023). *Turun seudun jätevesiylivuotojen parempi hallinta.* <https://valonia.fi/wp-content/uploads/2025/04/Jvylivuoto_Valonia_loppuraportti_2023_julkinen.pdf>