Student thesis series INES nr 575

Three-step approach for visualizing climate adaptation strategies at municipal level in Sweden

Matilda Lundström

2022
Department of
Physical Geography and Ecosystem Science
Lund University
Sölvegatan 12
S-223 62 Lund
Sweden

Matilda Lundström (2022).
Three-step approach for visualizing climate adaptation strategies at municipal level in Sweden
Master degree thesis, 30 credits in *Physical Geography and Ecosystem Science*
Department of Physical Geography and Ecosystem Science, Lund University

Level: Master of Science (MSc)

Course duration: *January* 2022 until *June* 2022

Disclaimer

This document describes work undertaken as part of a program of study at the University of Lund. All views and opinions expressed herein remain the sole responsibility of the author, and do not necessarily represent those of the institute.

Three-step approach for visualizing climate adaptation strategies at municipal level in Sweden

---

Matilda Lundström

Master thesis, 30 credits, in *Physical Geography and Ecosystem Science*

Sebastian Bokhari Irminger
The Swedish Geotechnical Institute

Anna Maria Jönsson
Lund University

Exam committee:
Lina Eklund, Lund University
Bernice Hwang, Lund University

Abstract

The ongoing climate change has caused an increase in the global mean sea level, and this sea level rise is predicted to continue during the 21st century. The importance of including climate change in decision making is becoming more and more recognized and increasingly important for decisions yielding consequences on longer time scales. The field of climate change communication is currently expanding, and visualization has here been suggested as an approach to make abstract information appear more concrete. In Sweden local strategies and policies are important in climate adaptation however, barriers exist, for example different views on strategies within municipalities. The aim of this study was to assess the current and potential future use of visualization in adaptive planning in Swedish municipalities in response to a rising sea level. A three-step approach for visualizing climate adaptation strategies at municipal level in Sweden was proposed with the purpose of providing a basis for future planning and corporation. The approach consisted of 1) showing areas at risk, 2) showing the by the municipality suggested adaptive strategies and 3) showing the areas that would benefit from the strategies. This study sought to answer the questions: what is the current use of visualizations in Swedish municipalities regarding communication of adaptive strategies to a rising sea level, and how can Swedish municipalities improve their use of visualization as a tool for climate change communicating regarding a rising sea level in adaptive planning?

In order to fulfill the aim, I conducted three-case studies. Three costal Swedish municipalities, Gothenburg, Malmö and Trelleborg were selected and evaluated regarding their use of visualizations in climate adaptation. I analyzed the municipalities' plans focusing on the use of visualization in adaptive strategies related to sea level rise and evaluated using an analytical framework. The three-step visualization approach was derived from existing literature, and I produced visualizations using Geographic Information System (GIS) tools and Scalable Algorithms (SCALGO) a platform providing large scale data processing of terrain. From the results it can be seen that the use of visualization in adaptive planning differs considerably between the municipalities and is mainly limited to communication of future potential sea levels. The results indicates that an inclusion of the proposed three-step approach in the municipalities´ comprehensive plans would increase the use of visualization and aid the communication of climate adaptation. The potential of using the proposed three step approach was recognized by the participating municipalities, as a tool for aiding the planning and communication of climate change adaptation. Further research is needed evaluating the three-step approach from the perspective of stakeholders and inhabitants as well as regarding the inclusion of uncertainties.

Sammanfattning

Den globala medelhavsnivån har stigit till följd av den pågående klimatförändringen, och denna stigning förutspås att fortsätta under hela 2000-talet. Vikten av att ta klimatförändringen i beaktning vid beslutsfattande blir därför mer och mer betydande, särskilt för beslut som görs gällande under längre tidsperioder. Kommunikation i relation till klimatet, dess förändring samt dess konsekvenser är ett forskningsområde som nu expanderar och användandet av visualisering har här föreslagits som en effektiv kommunikationsmetod. I Sverige skapar oenighet gällande anpassningsstrategier hinder för kommunerna vid planering och implementering av klimatanpassningsstrategier. Syftet med denna studie var att utvärdera den nuvarande samt potentiella framtida användningen av visualisering i adaptiv planering i svenska kommuner i relation till den stigande havsnivån. En trestegsmetod för att visualisera klimatanpassningsstrategier på kommunalnivå i Sverige föreslogs i syfte att ge underlag för framtida kommunikation och planering. Trestegsmetoden gick ut på att visualisera 1) riskområden, 2) föreslagna anpassningsstrategier och 3) områden som skulle dra nytta av anpassningsstrategierna. Denna studie sökte svar på frågorna: i vilken utsträckning används visualisering i kommunikations syfte gällande den stigande havsnivån i svenska kommuner och hur kan svenska kommuner förbättra sin användning av visualisering i adaptiv planering?

För att uppfylla syftet genomförde jag fallstudier av tre svenska kustkommuner, Göteborg, Malmö och Trelleborg. Jag analyserade kommunernas användning av visualiseringar i klimatanpassningssyfte relaterat till den stigande havsnivån och utvärderade detta efter ett ramverk. Trestegsmetoden som jag föreslog i den här studien baserades på befintlig litteratur och visualiseringarna producerades jag i Geografiska Informationssystemet (GIS) med hjälp av Scalable Algorithms (SCALGO) som är en plattform för terrängdata bearbetning. Resultaten visar på att den nuvarande användningen av visualiseringar i adaptiv planering är mycket begränsad och skiljer sig avsevärt mellan kommuner. Resultaten tyder även på att användningen av den föreslagna trestegsmetoden skulle utvidga kommunernas användning av visualiseringar och på så sätt bidra till en mer effektiv kommunikation och underlätta vid planering. Ytterligare forskning behövs för att utvärdera hur trestegsmetoden tas emot av medborgare i kommunen samt för att titta närmare på hur osäkerheter bättre kan inkluderas.

Table of contents

1. Introduction

The global mean sea level is rising, and this is mainly due to the melting of land ice and ocean warming. The thermal expansion of water caused by heating has been the main cause for the rising sea level between the years 1971 and 2018, however the melting of land ice has increased in importance and between the years 2006 and 2018 it was the dominant contributor. It is certain that the global mean sea level will continue to rise over the 21st century (Intergovernmental Panel on Climate Change [IPCC], 2021), however, projections regarding future sea levels are uncertain and with big variations (Oddo et al, 2020). For example, projections for the global mean sea level in 2100 can vary with more than one meter among each other (Oddo et al, 2020).

The disagreement among expert on associated probability distributions cause deep uncertainty in the projections and these uncertainties are sources of implications for management and decision making (Oddo et al, 2020). The importance of including climate change in decision making is becoming more and more recognized and this is increasingly important for decisions yielding consequences on longer time scales. Long term committed decisions are more climate sensitive than short term committed decisions. Examples of climate sensitive decisions are urbanization plans, infrastructure development and risk management strategies (Hallegatte, 2009).

Data from climate models are complex and can be difficult to interpretate without adequate tools (Johansson et al, 2017). The field of climate change communication is currently expanding, with the goal to promote development as well as to mitigate and reduce the effect of climate change. Climate change communication is however challenged by the complexity of climate change which makes it hard to communicate the information to a broader audience. Visualizations meaning visual communication through for example images or maps has been suggested as an approach to make the abstract information appear more concrete (Ballantyne et al, 2018). The practice of visualization can be viewed as preparing information to be used in an effective way (Goosen et al, 2013) and the use of visualizations to communicate climate data can lead to an increased understanding of climate change among community members (DeCock-Caspell & Vasseur, 2021).

In Sweden local strategies and policies are important in climate adaptation. Different views on strategies within municipalities and lack of forums for learning are however obstructing the implementation of such strategies and policies. Climate adaptation seems to be well established in comprehensive and local plans at municipal level in Sweden, however on formative stage, meaning that climate adaption plans, models and actions is not yet fully developed or institutionalized. Currently there is a struggle adopting a sufficient local climate adaptation organization and few municipalities have specific climate adaptation plans (Kristianssen & Granberg, 2021). Uddevalla municipality started a project in 2018 regarding adaptation to climate change and specifically flooding. In their project they use visualizations as a tool to support the development of adaptive strategies by forming a basis for decision makers as well as creating a dialogue between sectors. They use multiple types of visualizations and focus on communicating the municipality's plans to the inhabitants (SMHI, 2021).

This study assesses the potential use of visualization in adaptive planning in Swedish municipalities in response to a rising sea level. This study also aims to explore existing communication approaches for adaptive strategies meeting climate change and propose a novel approach for Swedish municipalities based on recent research findings. In order to fulfill the aims two research questions were developed and these are listed below.

- What is the current use of visualizations in Swedish municipalities regarding communication of adaptive strategies to a rising sea level?
- How can Swedish municipalities improve their use of visualization as a tool for climate change communicating regarding a rising sea level in adaptive planning?

To provide a background information as well as a deeper understanding for the current use of visualizations in adaptation related to climate change, this study reviews existing research on the topic. The background section contains information on how visualization can be used to support climate change adaptation according to the scientific literature.

2. Background

2.1 Climate adaptation on EU level

To support the adaptation to climate change in Europe, The European Climate Adaptation Platform (Climate- ADAPT) provide data and information with the purpose of aiding the adaptation process. The Adaptation Support Tool (AST) is developed to assist policy makers and other coordinators in developing, implementing, monitoring, and evaluating climate change adaptation strategies on a national level. The framework is based on the EU guidelines on developing adaptation strategies which is a part of the EU strategy on adaptation to climate change, as well as experience of EU Member States and the most recent EU research and innovation (Climate-ADAPT, n.d.b).

AST consist of an adaptation policy cycle with six steps: preparing ground for adaptation, assessing climate change risks and vulnerabilities, identifying adaptation options, assessing adaptation options, implementing adaptation, and monitoring as well as evaluating adaptation (Climate-ADAPT, n.d.b). Communication is part of the first and the last step, where the importance of successful communication of climate change adaptation is highlighted and stated as a key to ensure support, participation, and action. To manage successful communication, the most suitable format for the targeted audience most be used, promoting corporations between sectors (Climate-ADAPT, n.d.c).

2.2 Reviewed literature

I carried out a review of existing literature on the topic of visualization of adaptive strategies based on a search in Web of Science the 27th of January 2022. The search was conducted by using the sentence: *visualization of climate change adaptation strategies* in the *Topic* search bar. Fifty articles were found based on the search and then narrowed down to twenty-one articles by analyzing their abstracts and their relevance to the topic. Articles that according to their abstract discussed visualizations in the context of climate adaptation were selected. The twenty-one articles discussing the topic of visualization related to climate change adaptation were then sorted into three categories depending on the main context in which visualization was discussed. These categories were 1) visualizations of climate scenarios, effects, and risks, 2) visualization of adaptive strategies and 3) discussion of different types of visualization methods (Table1). In the first category articles that used visualizations to communicate climate change for example flooding scenarios with the goal of climate change adaptation were sorted. In the second category articles that used visualizations to communicate climate change adaptive strategies were sorted and in the third category, articles that discussed and compared methods for producing visualizations with the aim to aid in climate change adaptation were sorted.

Table 1. A review of existing literature on the topic of visualization of adaptive strategies, sorted into categories depending on the main context in which visualization was discussed.

Visualizations of climate scenarios, effects, and risks			
Author	**Year**	**Topic of visualization**	**Strategies for visualization as written in the article**
Becsi et al	2020	Climate warming scenarios	Impact maps
Burch et al	2010	Flooding scenarios	3D pictures
Carter et al	2017	Climate change scenarios affecting land managers	Spatial visualization
Chen et al	2018	Flooding scenarios	3D landscape visualization
Chiang & Ling	2017	Flooding scenarios	Interactive visualization models & intensity maps
DeCock-Caspell & Vasseur	2021	Coastline changes	Historical photographs
Goosen et al	2013	Climate services	Visualization on maps
Kilsedar et al	2019	Flooding scenarios	3D geospatial data
Lieske	2015	Climate change scenarios affecting communities	Web-based spatial visualization
Mikovits et al	2017	Flooding scenarios	Interactive maps
Pettit et al	2013	Landscape and farm impacts	Geovisualization
Sheppard et al	2011	Climate change scenarios on local scales	2D & 3D landscape visualization
Visualization of adaptive climate strategies			
Author	**Year**	**Topic of visualization**	**Strategies for visualization**
Barron et al	2012	Adaptation to flooding scenarios	2D & 3D landscape visualization
Jenkins, Milligan & Huang	2020	Adaptation of forest ecosystems	Images with explanatory text
Kiss et al	2020	National climate change adaptive strategies	Geovisualization
Zandvoort et al	2019	Adaptation of sustainable landscapes	Visualization on maps & 3D visualizations
Discussion of different types of visualization methods			
Author	**Year**	**Topic of visualization**	**Strategies for visualization**
Auer et al	2021	Climate warming scenarios	-
Ballantyne et al	2018	Climate change scenarios on local scales	Web based visualization with text
Hutton & Allen	2021	Sea level rise	Models, digitalized maps & photographs
Lieske, Wade & Roness	2014	Flooding scenarios	Geovisualization, 3D visualization & web-based GIS
Wright et al	2021	Climate change adaptation on a regional scale	Story maps & interactive tools

Twelve out of the twenty-one reviewed articles discussed visualization of climate change, without visualizing the actual strategies for adaptation. However, climate change visualizations were in all twelve articles discussed in the context of adaptation showing for example flooding scenarios (Burch et al, 2010). The visualizations were supposed to aid and enable the developing of adaptive strategies (Becsi et al, 2020; Burch et al, 2010; Carter et al, 2017; Chen et al, 2018; Chiang & Ling, 2017; DeCock-Caspell & Vasseur, 2021; Goosen et al, 2014; Kilsedar et al, 2019; Lieske, 2015; Mikovits et al, 2017; Pettit et al, 2013; Sheppard et al, 2011).

Four of the reviewed articles discussed the use of visualization of adaptive strategies. The approaches that were used were: 2D & 3D landscape visualization, images with explanatory text, geovisualization (analyzing spatial data with the help of maps) and other visualization methods on maps (Barron et al, 2012; Jenkins, Milligan & Huang, 2020; Kiss et al, 2020 & Zandvoort et al, 2019). The findings in these articles showed that the use of science based visual media like adaptation mapping or other types of visualizations can be used to increase attention, understanding and aid decision makers (Barron et al, 2012). The use of spatial design translating different pathways, can contribute to an increased understanding as well as more transparency, improving the relationship between visualization of adaptive strategies and decision makers. Policy makers should therefore be informed about the spatial implications of different pathways, including information on directions towards more adaptive and sustainable landscapes (Zandvoort et al, 2020). Geovisualization of spatial data when communicating information can lead to better identification of relationships between climate change strategies as well as the areas they affect. It can improve the capture of spatial pattern as well as enhancing perception of digital data (Kiss et al, 2020). The use of some kind of visualization together with explanatory text proved particularly effective for envisioning different scenarios related to climate change and adaptation (Jenkins et al, 2021).

Five articles discussed different types of methods for visualization without focusing on the context in which visualizations were used. Visualization was here discussed in the topic of climate communication, where it could be used to enhance features such as magnitudes and correlations as well as forming basis for action (Auer et al, 2021). The complexity of the visualizations was also discussed. Low-tech techniques could be seen to cause less perceptual stress than complex visualizations such as for example spider diagrams, emphasizing the importance of clear and easy to understand information communication (Auer et al, 2021). The audience's risk precipitation did not seem to be affected regarding the complexity of the visualizations however, the desire to mobilize for political and community advocacy was perceived higher when more advanced visualizations were viewed. This seems to be due to an emotive component absent in less advanced visualizations (Lieske, Wade & Roness, 2014). The importance of data availability for the audience viewing the visualizations was emphasized. When it comes to how well audience responds to different types of visualizations, maps seem to be preferred due to their ability to clearly display data for larger areas (Hutton & Allen, 2021). Another important factor in how the audience perceived visualizations and their message is the area that is visualized. The use of local areas in visualizations reduces the audience´s perceived distance from climate change (Ballantyne et al, 2018).

2.3 The responsibility of the municipalities

The changing climate affect our entire society, making climate adaptation an important issue on all governmental levels. In Sweden climate adaptation is controlled by multiple rules and laws, dividing the responsibility, and regulating legal actions. Sweden has a climate policy framework since 2017, stating that the government should be ruled by climate goals and there is a national strategy for strengthening climate adaptation (klimatanpassning.se, 2021).

The municipalities have an important role in the adaptation to the changing climate of our society. In accordance with the Swedish Planning and Building Act (plan- och bygglagen) the municipalities should include climate related risks, for example flooding scenarios in their comprehensive plans. The municipalities should also assess the possibility to reduce or erase these risks. In the detailed plans the municipalities provide local rules as well as prioritized land use for the area. The municipalities also have the ability to implement local rules in order to specify laws stated in for example the Planning and Building Act and the Environmental Act (miljöbalken). These local rules are binding (klimatanpassning.se, 2021).

The municipalities are responsible for implementing actions regarding climate adaptation through their plans but there are barriers regarding financing, accountability, and cooperation. Uncertainties regarding who should finance the adaptation work and where the responsibility lays, complicates the implementation on a municipality level. Insufficient coordination is also causing difficulties when implementing climate adaptation plans and strategies. In order to deal with these barriers and establish climate adaptation in planning on a municipality level, communication is an important factor. Many different sectors in our society are or is going to be affected by the changing climate and therefore communication as well as integration of plans in processes and sectors are of great importance (Ekholm & Nilsson, 2019).

2.4 Climate change and land use

Land use change and climate change are closely intertwined due to the fact that changes in land use can both affect the climate as well as adapt areas in response to the changing climate (Dale, 1997). In Sweden coastal areas are utilizing their waterfront location in order to attract residents, however the effects of climate change causing sea level rise is here posing as an imminent threat. Municipalities located in southern Sweden are already starting to see the effects of the sea level rise and these climate change consequences are predicted to worsen (Swedish Geotechnical Institute [SGI], n.d).

Incorporating land use into climate adaptation planning can among other factors increase risk resilience and contribute to a long-term sustainable climate adaptation (Elsharouny, 2016). In an ongoing project regarding coastal adaptation through flexible land-use (COALA) led by the Swedish Geotechnical Institute (SGI). They investigate how changes in legislations controlling planning of land-use could potentially allow flexibility in land-use, allowing land use to for example change over time. The project looks into the potential roll of flexibility in planning and flexibility in land use as well as land use functions as long-term adaptation strategies. In adaptive planning solutions involving removing structures or avoiding new construction are not commonly considered however there is potential in the approach allowing a shifting coastline. Areas that are at risk but not impacted can here be used for changeable functions (Swedish Geotechnical Institute [SGI], n.d).

2.5 Cartography and GIS

Cartography is defined as the science as well as the technique of producing maps and products related to maps consisting of digital and analog models of a virtual reality. There are three main focuses forming the core in cartography and these are 1) semiotics, 2) modelling and 3) communication. Semiotics is the cartographic word for map graphics, modelling focuses on relationships in space and time and communication focuses on turning spatial data into spatial information. Another way of describing cartography would be to say that it translates spatial data into spatial information with the use of visualizations. The science of cartography has been practiced for many thousands of years, but it was not established as an independent science until the 20th century (Kainz, 2020).

There are other disciplines dealing with spatial data such as for example geography, remote sensing, geodesy, and geographic information systems (GIS). The disciplines are therefore closely related, and they sometimes overlap each other. GIS was invented in the 1960s and caused a shift in cartography by separating the data in a database from the now digital map device. Before this, cartographers had the database together the visualization on a paper map. GIS focuses on storage, management, and analysis of spatial data but cartographic visualization is also an important part (Kainz, 2020).

3. Method

In order to fulfill the aim of this study I conducted three case studies. Three costal Swedish municipalities were selected and evaluated regarding their use of visualizations in climate adaptation. The three municipalities were Gothenburg, Malmö and Trelleborg. I analyzed the municipalities' plans were focusing on the use of visualization in adaptive strategies related to sea level rise and evaluated using an analytical framework. In this study I also proposed a three-step approach of visualization derived from existing literature, using GIS tools and Scalable Algorithms (SCALGO) a platform providing large scale data processing of terrain. I tested the three-step approach was on strategies planned by the municipalities and evaluated the approach using the same analytical framework. I did also conduct a survey in order to evaluate the three-step approach as suggested in the analytical framework.

3.1 Framework

I used the analytical framework proposed by Wibeck, Neset & Linnér (2013) for evaluating the municipalities use of visualization regarding adaptation to a rising sea level as well as the by this study presented novel approach. The framework was developed for evaluating communication of climate change and intentionally designed for interactive visualizations using information and communication technology (ICT). In this study the framework was used to evaluate the use of visualizations in comprehensive plans which were non-interactive, with the exception for the additional map-tool provided by Malmö municipality. It was also used to evaluate the proposed three-step approach designed to be applicable in the comprehensive plans and therefore non-interactive. Due to the purpose of using the framework for non-interactive visualizations it was adjusted by exclusion of the parts of the framework that refers to the interactive parts of the visualization.

I chose this particular framework due to the fact that it was developed to communicate climate change through visualization which was unlike the other frameworks I found in my search. The focus on visualization in climate change communication was strongly in line with the topic of this study. The framework was adapted to be suitable for non-interactive visualizations and this adaptation of the framework was not deemed to reduce its usefulness.

The framework consisted of three main categories: content, form, and context with different analytical focuses. These categories are further described below.

3.1.1 Content

The first category, content, focuses on the information provided, leading to the use of climate change communication. The analytical focuses are the storyline, data selection, key actors, metaphors, key concepts and prototypical examples. Examples of methods are for example literature reviews and content analysis.

Strong and scary messages can often result in fear instead of spurring engagement, it is therefore of importance to focus on local impacts of climate change, making it relatable on a personal level. The storyline in which the information is presented is of importance due to it containing core messages in a simplified way, therefore the content and the audience perception of the storyline are important dimensions. Metaphors, key concepts, and examples are also a part of “content”, and these can be used to both highlight and hide messages. Powerful symbols, for example pictures of melting glaciers can stir emotions but can also be hard to relate to on a personal level. Therefore, the use of local areas can be better because it feels less distant to the audience.

An important dimension of the content is the data selection and the choice of geospatial and temporal scale. These parameters are important in supporting the storyline as well as making it relatable for the audience. The inclusion of multiple scenarios for specific geospatial areas can make the representation of scientific data perceived as more credible by the audience. The time frame as well as the geospatial scale is of importance to influence the understanding of the audience. It is also important to address the responsibility and key actors. Who are presented as the most influential actors and should therefore be responsible?

This study looked at if background information supporting the visualizations was provided, if the spatial and temporal scales were clear and defined and if the key actors were identified.

3.1.2 Form

Form, meaning the form of communication mediums and formats used, is important to analyze due to its influence on the audience. The analytical focuses are here the visual representation and the ICT tool, the later has been excluded in this study. The selection affect accessibility and the audience prior knowledge should here be considered. Geospatial visualizations meaning visualizations provided on maps as well as landscape visualizations which are visualizations of landscape elements are the two most frequent visualization methods in sustainability. Here a careful selection of colors, symbols, scales and so on is important for the message that should be conveyed. In this study I looked at what the visualizations were showing and what methods were used to convey the visualizations.

3.1.3 Context

Context is the audience interpretation of climate change communication, focuses on how the information is tailored to the audience. The analytical focuses are here the audiences´ expected or perceived need for knowledge, interpretative frames, and preconception. This is a complicated topic because there is often a varying in how climate change is understood in the audience, even when the audience seem homogeneous. Communicators must therefore take the audience´s interpretative frames and preconceptions into consideration, taking into account knowledge level, interests, values and concerns. This study looked at if the visualizations meet the audiences ‘need for knowledge regarding the strategies planned to adapt the municipality to a rising sea level. I here investigated if areas at risk, the suggested strategies and the areas that would receive reduced risk of flooding by implementation of the strategies were visualized.

3.1.4 Relevance

It is also suggested to include an evaluation of the relevance of the visualization, meaning evaluating however the audience think the visualization met their expectations and their need for knowledge. Methods could here consist of for example surveys or interviews, gathering this type of information. In order to evaluate the proposed three-step approach I carried out a survey in this study. The purpose of the survey was more specifically to evaluate if experts in the topic of climate adaptation related to a rising sea level recognized the potential in using the three-step approach as a tool in communicating and aid of planning on a municipal level. The survey was also conducted in order to improve the approach and the visualizations using feedback and comments.

3.2 Visualizing adaptive strategies related to the rising sea level

3.2.1 The three-step approach

In order to clarify and structure climate adaptive strategies on a municipal level, I proposed a new approach for using visualizations in climate adaptation communication focusing on the rising sea level. The proposed method is a three-step approach consisting of three steps focusing respective on risk, strategies, and reduced risk.

1. **Areas at risk**

   The first step regarding risk focused on areas at risk for flooding due to the rising sea level. Here I made visualizations showing future potential water levels on a map in a see-through manner using striped layers, making it possible to view the areas that are at risk for being flooded.

   Visualizing the effects of climate change is important in aiding and enabling the development of adaptive strategies (Becsi et al, 2020). Using local areas in the visualizations also helps the audience perception of the risk, minimizing the view of climate change as a spatially distant problem (Ballantyne et al, 2018).

2. **Suggested/planned adaptive strategies**

   The second step focused on strategies for adaptation to a rising sea level, suggested or planned by or for the municipality. Here I provided visualizations showing areas where adaptive strategies were suggested or planned, as see-through layers on a map.

   Strategies were here categorized after their purpose using the categories: adapt, change land use, and protect. Adapt referred to strategies that reduced the risk of flooding by reducing the consequences of flooding, for example by moving vulnerable installations higher up from the ground. The strategies categorized as change of land use also reduced the risk of flooding by reducing the consequences of flooding but was here achieved by changing the way the land was being used to less vulnerable options. Strategies categorized as protect referred to strategies thar reduced the risk of flooding by reducing the probability of flooding, by for example building walls. More types of strategies than the three discussed here exists however no more types of strategies were present in the result of this study.

Communicating the municipality´s intention to adapt to climate change is important in establishing climate adaptation in planning. It is also important that these plans and intentions are available and understood by affected stakeholders and inhabitants in the municipality as well as among municipalities (Ekholm & Nilsson, 2019).

3. **Areas benefiting from the strategies**
   The third and final step focused on areas that potentially would receive a reduced risk of flooding if actions were implemented to adapt the municipality in accordance with the suggested and or planned strategies. I visualized the areas that would receive a reduced risk of flooding using see through striped layers on a map.

   Visualizing the areas that would potentially receive a reduced risk of flooding due to the implementation of adaptation actions is important in order to evaluate the effectiveness of these actions.

3.2.2 SCALGO and GIS

The aim of the three-step approach was to illustrate the municipalities plans for adaptation regarding a rising sea level in a clear and structured way, providing a basis for future planning and corporation. I created the visualizations following the three-step approach in GIS using flooding simulations performed in SCALGO based on the three municipalities plans and provided plan suggestions for adaptation to a rising sea level.

Scalable Algorithms (SCALGO) was founded to provide massive terrain data-processing technology and realize the potential of high-resolution mapping of the earth using sensors and satellites. It provides the opportunity to create 3-dimensional maps on the surface of the earth. In SCALGO you have the opportunity to simulate among other things flooding scenarios, using sea level or flashflood data. In SCALGO the user also has the opportunity to create elevations in the landscapes, representing for example sea walls or dikes, the user also has the ability to elevate the ground. It is here then possible to extract shapefiles with for example sea level data, water depths data or elevation data to analyze or visualize in other software such as GIS (SCALGO, n.d). In this study I used SCALGO to simulate different sea levels in order to analyze potential flooding scenarios. I did also use the elevation tool to build structures representing the municipalities suggested or planned adaptive actions. I did then extract shapefiles to GIS in order to visualize the result.

ArcGIS is a geospatial software that provides the user with the opportunity to manage, view, edit and analyze geographic data. The software is developed and provided by Environmental Systems Research Institute (Esri) and consists of ArcMap, ArcCatalog, ArcGIS Pro, ArcScene and ArcGlobe. ArcMap is the main part of the software and here users can create maps from scratch (GISGeography, 2022). I used ArcMap in my study in order to produce visualizations following the three-step approach.

In order to produce visualizations showing the first step of the three-step approach, areas at risk I produced flooding simulations in SCALGO by increasing the sea level with the amount that the municipalities planned for in their comprehensive plans. I then transferred the result from these simulations as shapefiles into GIS where I produced the visualizations by layering these shapefiles on top of an imagery base-map with labels. When producing visualizations showing the second step I drew, suggested or planned strategies, areas affected by a strategy were directly on the imagery base-map creating shapefiles based on the information provided in the municipalities´ plans. The exact strategies were often not mentioned, and I had to interpreted these by looking at the suggested actions and the areas they would affect.

In order to produce the visualizations showing the third step, areas benefiting from the strategies, I built the suggested or planned adaptive actions such as for example walls and dikes in SCALGO. I did then perform flooding simulations once again with the adaptive actions in place and I transferred the results to GIS as shapefiles. In GIS I did then cut the result from the flooding simulations without the adaptive actions in place with the files containing areas that would be flooded even if the adaptive actions were in place. By doing this I created shapefiles representing the areas that would benefit from the adaptive actions being implemented. The difference between a sea wall and a dike was considered to be in the material and the shape in this study. A sea wall was considered to be a construction built of a hard material such as for example steel with square proportions and a dike could consist of looser natural material such as sand or soil with a broader base and a rounder top.

I processed the layout in GIS, using striped layers showing flooding scenarios and areas that would benefit from the strategies and see-through layers showing planned or suggested strategies. I then presented the visualizations on three individual maps following each other showing the significance of the implementation of the adaptive strategies as well as the current extent of suggested and planned strategies at a municipal level.

3.3 Case studies

The municipalities that I analyzed in this study are the costal municipalities Gothenburg, Malmö and Trelleborg, they were selected due to their location but also due to their differences in size and population which made the evaluation and the testing of the three-step approach more nuanced. The three municipalities are located in the southern part of Sweden by the coast. They differ in size both regarding area and population with Gothenburg municipality being the most populated and Trelleborg municipality being the biggest in terms of area. For all three municipalities a great part of the areal is taken up by water (Table 2) (Statistikmyndigheten [SCB], n.d.a; Statistikmyndigheten [SCB], n.d. b).

Table 2. The population and area of the municipalities Gothenburg, Malmö and Trelleborg.

	Gothenburg	**Malmö**	**Trelleborg**
Population ~	588 000	352 000	46 000
Total Area~	1 025 km^2	334 km^2	1 177 km^2
Area Water (Sea)~	563 km^2 (55%)	176 km^2 (53%)	834 km^2 (71%)

In this study I used the municipalities´ comprehensive plans and additions to the comprehensive plans in order to evaluate the current use of visualizations in relation to a rising sea level at municipal level (Table 3). In order to test the in this study proposed three-step method on the plans provided by the municipalities additional information was needed. I therefore used additional documents providing more details regarding placements and design of the adaptive actions when producing the visualizations (Table 4).

Table 3. The comprehensive plans or additions to the comprehensive plans that were provided by the municipalities and used in this study to evaluate the use of visualizations related to a rising sea level in the three municipalities.

	Plan documents used in the evaluation		
	Name (Swedish)	**Description**	**Reference**
Gothenburg	Tematiskt tillägg för översvämningsrisker	Thematic addition to the comprehensive plan	(Göteborg stad, 2019)
Malmö	Översiktsplan för Malmö	Comprehensive plan	(Malmö stad, 2018a & 2018b)
Trelleborg	Stigande hav och översvämning	Thematic addition to the comprehensive plan	(Trelleborgs kommun, 2021)

Table 4. The plan documents provided by the municipalities that were used in this study to evaluate the use of visualizations as well as produce visualizations using the three-step approach.

	Additional plan documents used for visualizations		
	Name (Swedish)	**Description**	**Reference**
Gothenburg	Simuleringsuppdrag 3 A	Suggestions for riverbank protection	(Ramboll, 2014a)
	Simuleringsuppdrag 3 B	Suggestions for riverbank protection	(Ramboll, 2014b)
	Simuleringsuppdrag 4 A	Suggestions for river barriers	(Ramboll, 2014c)
Malmö	Strategi mot extrema högvatten I Malmö, Delområde 1 till 3	Plan suggestions regarding flooding	(SWECO, 2018)
Trelleborg	Kustskyddsutredningen Trelleborg	Plan suggestions for coastal protection	(SWECO, 2020)

3.3.1 The municipality of Gothenburg

The visualizations I made for Gothenburg municipality were partly based on a thematic addition to the comprehensive plan focusing on areas at risk for flooding with the aim to present the municipalities goals and suggested strategies to adapt the city. Here the municipality discussed multiple flooding scenarios and two main adaptation actions, riverbank protection and barriers regulating the river inflow (Göteborg stad, 2019). More detailed suggestions for riverbank protection and river barriers were found in reports based on a hydro model, here simulations were carried out based on a 2100 scenario with a 2.55-meter increase in sea level from the Swedish national height system 2000 (RH2000) (Ramboll, 2014a; Ramboll, 2014b; Ramboll, 2014c). The RH2000 height system is based on measurements that were conducted in the years 1979-2003 and resulted in 50 000 fixed points making up the references for height measurements (SMHI, 2022). I used the same flooding scenario as well as the same suggested actions focusing on the central part of the city when creating visualizations of adaptive strategies for Gothenburg municipality.

3.3.2 The municipality of Malmö

The municipality of Malmö is in the process of developing a coastal protection strategy for the municipality. This strategy is going to be included in the comprehensive plan however, this addition is supposed to be completed in 2023 (Malmö stad, 2021) and could therefore not be used for my visualizations in this study. For the municipality of Malmö, I produced visualizations were based on the current comprehensive plan together with the associated interactive tool SMAPS and plan suggestions provided by SWECO (Malmö stad, 2018a; Malmö stad, 2018b; SWECO, 2018). The interactive tool SMAPS is a map tool designed to communicate the suggestion and plans from the comprehensive plan by showing the areas that they apply to, you can here select an area and read about the municipality's suggestions for it. In the comprehensive plan broad suggestions are made regarding adaptation to the rising sea level for different areas along the coast. Detailed plans were measures to adapt the concerned areas were also found in the SMAPS tool. The comprehensive plan states that the sea level is predicted to rise with 50 centimeters relative to RH2000 to the year 2065 and could temporarily reach +3 meters due to storms or other hydrological phenomena. Both the suggestions and the planned strategies were made with a sea level rise scenario corresponding to extreme flooding events 2065, were an increase of 3 meter relative to the RH2000 is predicted (Malmö stad, 2018b). Iused the same flooding scenario and focuses on the central part of the city and the harbor area when producing my visualizations in this study. I used the suggested adaptation actions from the comprehensive plan together with the more detailed suggestions provided by SWECO, the suggested plans were in large similar and consisted of elevating the ground, by building walls or elevating docks along the coast (Malmö stad, 2018b & SWECO, 2018). I also based some visualizations on the planned actions focusing on elevating the ground in the concerned areas (Malmö stad, 2018b).

3.3.3 The municipality of Trelleborg

The municipality of Trelleborg is in the process of making a thematic addition to their comprehensive plan focusing on the rising sea level with the purpose to communicate how the municipality perceive the risk of flooding and present possible solutions. The addition is estimated to be accepted during spring in 2022. The thematic addition takes the entire coastal zone into consideration dividing it up in 18 areas and suggestions are made with a 100-year perspective in mind (Trelleborgs kommun, 2021). Plan suggestions were made by SWECO in 2020 regarding how the municipality could adapt to a rising sea level. These suggestions were made using three time perspectives: 2019, 2065 and 2100 as well as four flooding scenarios. The flooding scenarios used were the mean water level (MW), “normal” high tide with an occurrence of one to two years (NW), high tide with an occurrence of a 100 years (HW100) and very extreme sea level events (VESL) (Table 5) (SWECO, 2020). The suggestions provided by SWECO are very similar to the ones in the thematic addition, but with more detailed plans for adaptive actions (Trelleborgs kommun, 2022 & SWECO, 2020). In this study I used the reports combined when creating visualizations for the municipality of Trelleborg, in contrast to the visualizations done for Gothenburg and Malmö municipality the visualizations were here provided for Skåre an area outside the city center showing the potential and adaptability of the proposed approach.

Table 5. The different water levels that Trelleborg municipality uses in the thematic addition to the comprehensive plan, the water levels are in meters relative to RH2000.

Flooding scenario	2019	2065	2100
MW	-	60	1.03
NW	1.35	1.85	2.35
HW100	1.86	2.35	2.85
VESL	2.35	2.85	3.35

3.4 Survey

I carried out a survey in order to evaluate the relevance of the three-step visualization approach and investigate the potential of the three-step approach in climate adaptive communication and planning related to the rising sea level on a municipal level. The survey was conducted on a first draft of the visualizations following the three-step approach. The survey consisted of four questions and was sent to three representants, one at each municipality together with background information and municipality specific visualizations. The three representants were all experienced in climate adaptation and experts in the respective municipalities´ adaptive planning.
The survey was not conducted anonymously it was sent on email and the responses were collected by email, however the representants are kept anonymous in this report.

The survey consisted of the following four questions:

- Are the presented individual visualizations clear and easy to understand?
- Is the presented three-step approach for visualization of climate adaptive strategies clear and easy to understand?
- Do you see any potential in using the presented three step visualization approach in climate adaptive planning at a municipal level?
- Do you see any potential in using the presented three-step visualization approach in communicating of climate adaptation at a municipal level?

For every question the participant could answer Yes or No, and the option to add an additional comment was provided. The visualizations were a first draft and adjustments were made from the results of the survey.

The difference between a quantitative survey and a qualitative survey largely lays in the end goal, in a quantitative survey the goal is usually to generalize findings from a sample to a larger population while the goal of a qualitative survey is usually to achieve descriptive richness (Usher, 2021). In this study the conducted survey could not be considered a clear quantitative survey nor a clear qualitative survey, but a mix of the two. The four questions with yes or no answers are more quantitative than qualitative, generalizing more than resulting in descriptiveness. However, the additional opportunity to add comments adds a qualitative moment to the survey resulting in some descriptiveness.

In response to the feedback provided through the survey I made improvements to the visualizations. I adjusted the layout to be more coherent, easier to understand and inclusive for people with color vision deficiency and I added areas that does not receive a reduced risk of flooding in Step 3. All areas that are not receiving protection from the adaptive actions can be seen as areas not receiving a reduced risk, however this study uses the term “No reduced risk” when identifying areas that are at risk of flooding and do not receive protection from the implemented actions. I also provided an additional visualization showing the potential of including water depths in the visualizations.

In order to successfully communicate using colors taking color vision deficiency into account, situations where information is conveyed only in the form of color should be avoided. Text and objects should be clearly separated from the background, making text and objects as visible as possible. The use of red colors should be limited or done with caution. In this study I used an eight-color palette, consisting of colors that should be separatable for people with and without color vision deficiency (table 6) (Okabe & Ito, 2002).

Table 6. The eight-colors palette used in the visualizations in this study.

Color name	**R (0-255)**	**G (0-255)**	**B (0-255)**
Black	(0)	(0)	(0)
Orange	(230)	(159)	(0)
Sky Blue	(86)	(180)	(233)
Bluish Green	(0)	(158)	(115)
Yellow	(240)	(228)	(66)
Blue	(0)	(114)	(178)
Vermillion	(213)	(94)	(0)
Reddish Purple	(204)	(121)	(167)

4. Results

4.1 Current use of visualization of adaptive strategies

The result from the evaluation of current use of visualization of adaptive strategies in the municipalities' comprehensive plans or additions to the comprehensive plans shows some differences between the municipalities (Table 7). These differences were found under the evaluation points form and context. The evaluation was done using an adapted version of the framework by Wibeck, Neset & Linnér (2013).

Table 7. The current use of visualization of adaptive strategies in municipality plans evaluated using an adapted version of the framework by Wibeck, Neset & Linnér (2013).

	Gothenburg (Göteborg stad, 2019)	**Malmö** (Malmö stad, 2018a & 2018b)	**Trelleborg** (Trelleborgs kommun, 2021)
Content			
Background information provided	Yes	Yes	Yes
Defined spatial & temporal scales	Yes	Yes	Yes
Defined key actors	Yes	Yes	Yes
Form			
Main purpose of the visualizations	Showing planning levels and flooding scenarios	Showing consequences of flooding	Showing areas at risk and placement of actions
Main method used for visualizations	Visualizations on maps	Pictures	Visualizations on maps
Context			
Do the visualizations provide information regarding risk areas, planned strategies and areas benefiting from the strategies?	It shows areas at risk	It shows the planned strategies	It shows areas at risk, planned strategies and in one case areas that receive protection

In the thematic addition to the comprehensive plan for Gothenburg visualizations were sparsely used. A map showing different planning levels for flooding scenarios was included as well as visualizations on maps showing flooding scenarios. Visualizations were not used showing the suggested strategies or what the implementation of adaptation measures would mean for the areas at risk (Göteborg stad, 2019). In the municipality of Malmö, the visualizations in the comprehensive plan were represented by pictures showing flooded areas around the municipality. With pictures it is here meant photographs of areas in the city that has been edited to show how it would look if the area was flooded, for example showing a street covered in water. Visualizations were not used for showing the suggested strategies nor potential areas benefiting from the strategies (Malmö stad, 2018a). In the interactive map- based program however, the placement for the different suggested and planned strategies were showed by visualizations on a map (Malmö stad, 2018b). In the thematic addition to the comprehensive plan for Trelleborg municipality multiply visualizations were included, mainly on maps. These visualizations were used to communicate areas that at risk of being flooded and placement of suggested adaptation actions. In one case the area that would receive protection from the implementing of one of the adaptive actions was shown (Trelleborgs kommun, 2021).

4.2 Proposed use of visualization

4.2.1 Results from the survey

The results from the survey (table 8) conducted to evaluate the in this study proposed three-step approach shows mixed opinions regarding the first question. Here the representatives desired more coherence and clearer visualizations according to the additional comments. Taking color vision deficiency into account when producing the visualizations was also pointed out as an important layout improvement. The result from the second question shows that all representants considered that the presented three-step approach was clear and easy to understand. The representants also recognized the potential in using the presented three step visualization approach in climate adaptive planning as well as in communication of climate adaptation at a municipal level, according to the third and fourth question. In addition to the comments regarding the layout the inclusion of water depths as well as areas that do not receive reduced risk of flooding was desired.

Table 8. The result from the conducted survey conducted on a first draft of the visualizations in order to evaluate the three-step approach.

Questions	**Representative 1**	**Representative 2**	**Representative 3**
1. Are the presented individual visualizations clear and easy to understand?	Yes	Yes and No	No
2. Is the presented three-step approach for visualization of climate adaptive strategies clear and easy to understand?	Yes	Yes	Yes
3. Do you see any potential in using the presented three-step visualization approach in climate adaptive planning at a municipal level?	Yes	Yes	Yes
4. Do you see any potential in using the presented three-step visualization approach in communicating of climate adaptation at a municipal level?	Yes	Yes	Yes

4.2.2 Proposed use of visualization for Gothenburg

The thematic addition to the comprehensive plan shows planning levels using visualizations but not areas at risk, the suggested strategies or the areas that receive a reduced risk from the implementation of the strategies (Göteborg stad, 2019). This study suggested a three-step visualization approach showing this information in order to provide the municipality with a clear and structured method for visualizing of climate adaptive strategies in planning and communication. Visualizations for Gothenburg were conducted based on two different suggested actions, riverbank protection (Ramboll, 2014a & Ramboll, 2014b) and a river barrier, regulating the river Göta älv (Ramboll, 2014c) (figure 1).

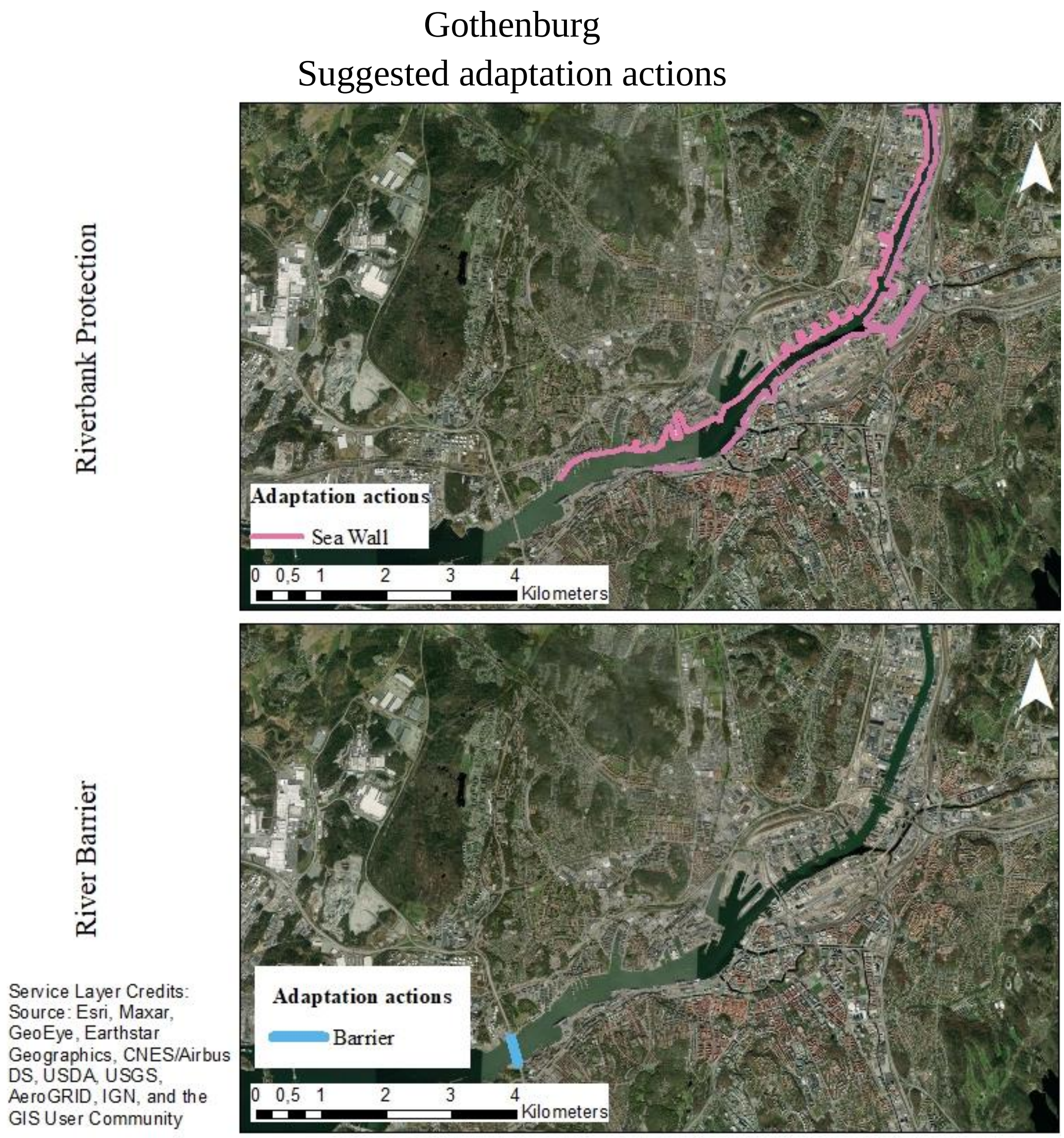

Figure 1. Suggested adaptation action for Gothenburg, riverbank protection by sea walls and a river barrier regulating Göta älv.

Visualizations were provided based on the adaptive actions, riverbank protection (figure 2) and a river barrier (figure 3) showing areas at risk for flooding, the suggested strategy and the areas that would receive a reduced risk of flooding due to the implementation of the adaptation actions

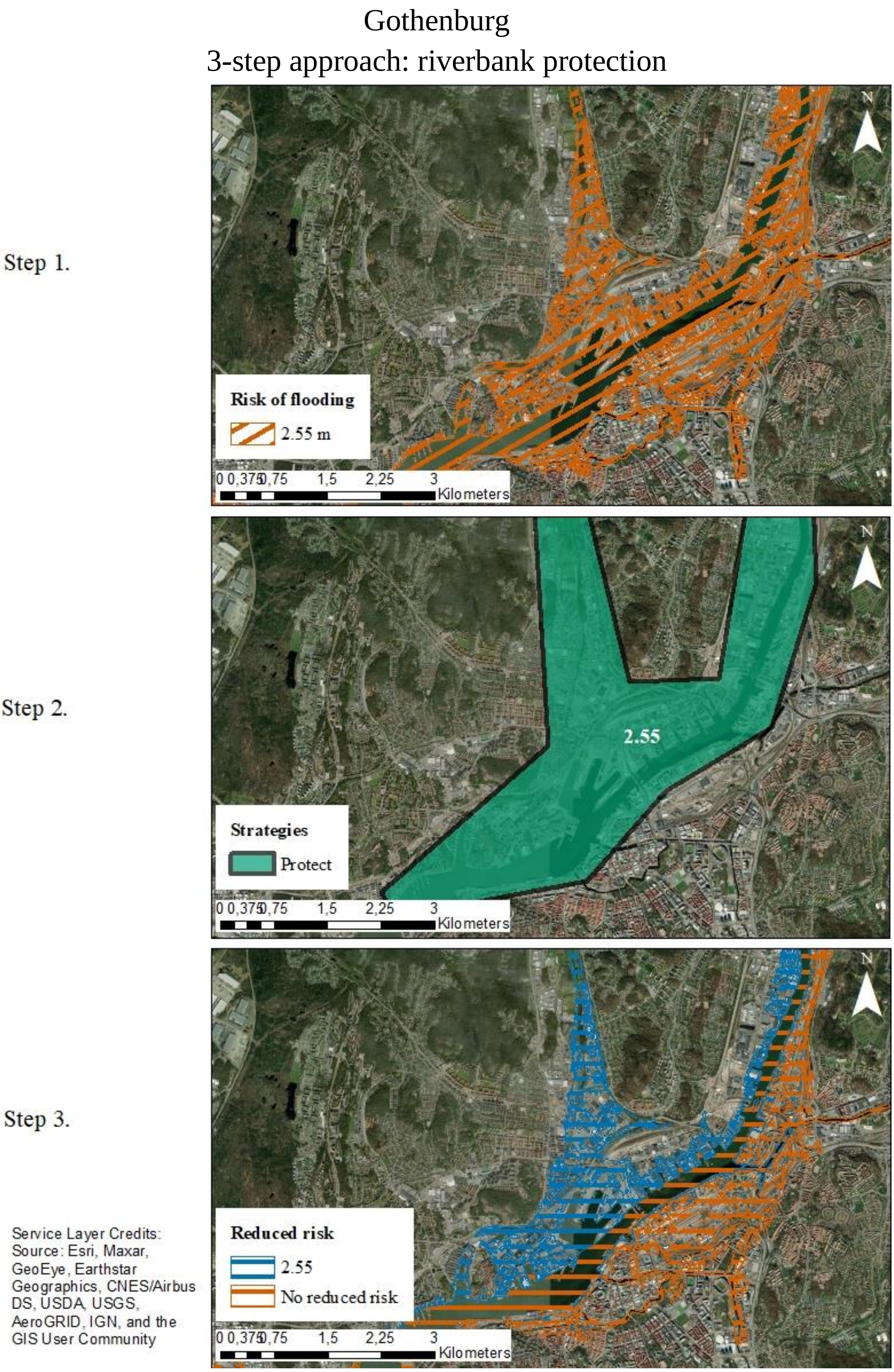

Figure 2. Visualizations based on the suggested action riverbank protection showing areas at risk, suggested strategies and areas that would receive a reduced risk from the implementation of riverbank protection.

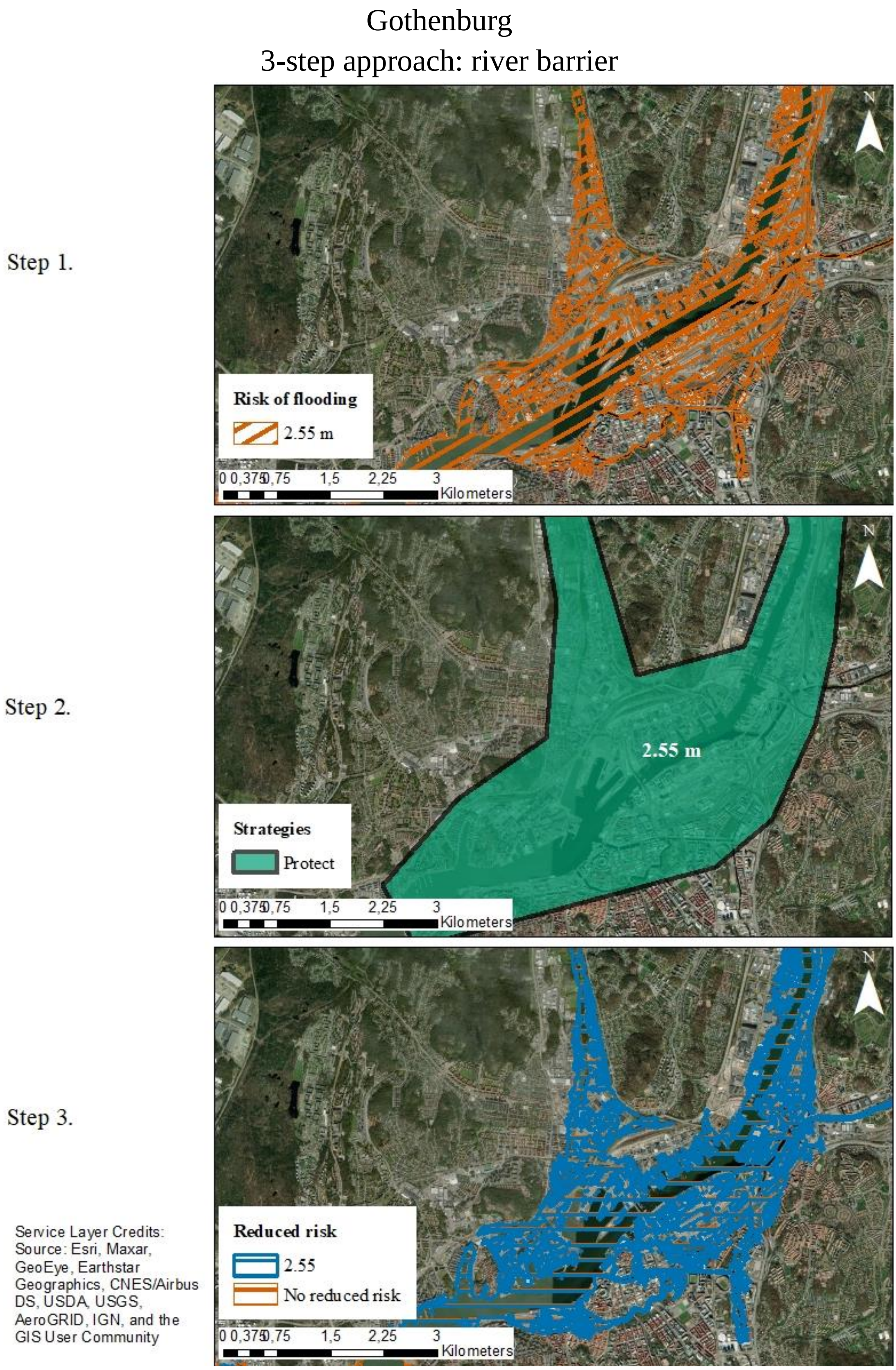

Figure 3. Visualizations based on the suggested action river barrier, showing areas at risk, suggested strategies and areas that would receive a reduced risk from the implementation of a river barrier.

4.2.3 Proposed use of visualization for Malmö

For the municipality of Malmö visualizations were created in order to show the different existing strategy plans as well as how these plans would reduce the risk of flooding in the affected areas. In the interactive map based on the comprehensive plan Malmö uses visualizations to show where strategies are suggested or planned but not areas at risk or areas that would receive reduced risk from the implementation of the strategies (Malmö stad, 2018b). This study proposed using the three-step approach for visualization of the adaptive strategies, in order to enhance the communication of the suggested strategies and their potential importance for Malmö municipality.

Visualizations for Malmö was done by looking at both planned and suggested adaptation actions (figure 4). The planned actions were found in the detailed plans in the comprehensive plan and consisted of elevating the ground (Malmö stad, 2018b). The suggested actions were found in the comprehensive plan together with the plan suggestions provided by SWECO and consisted of elevation of docks, the ground and walls (Malmö stad, 2018b; SWECO, 2018).

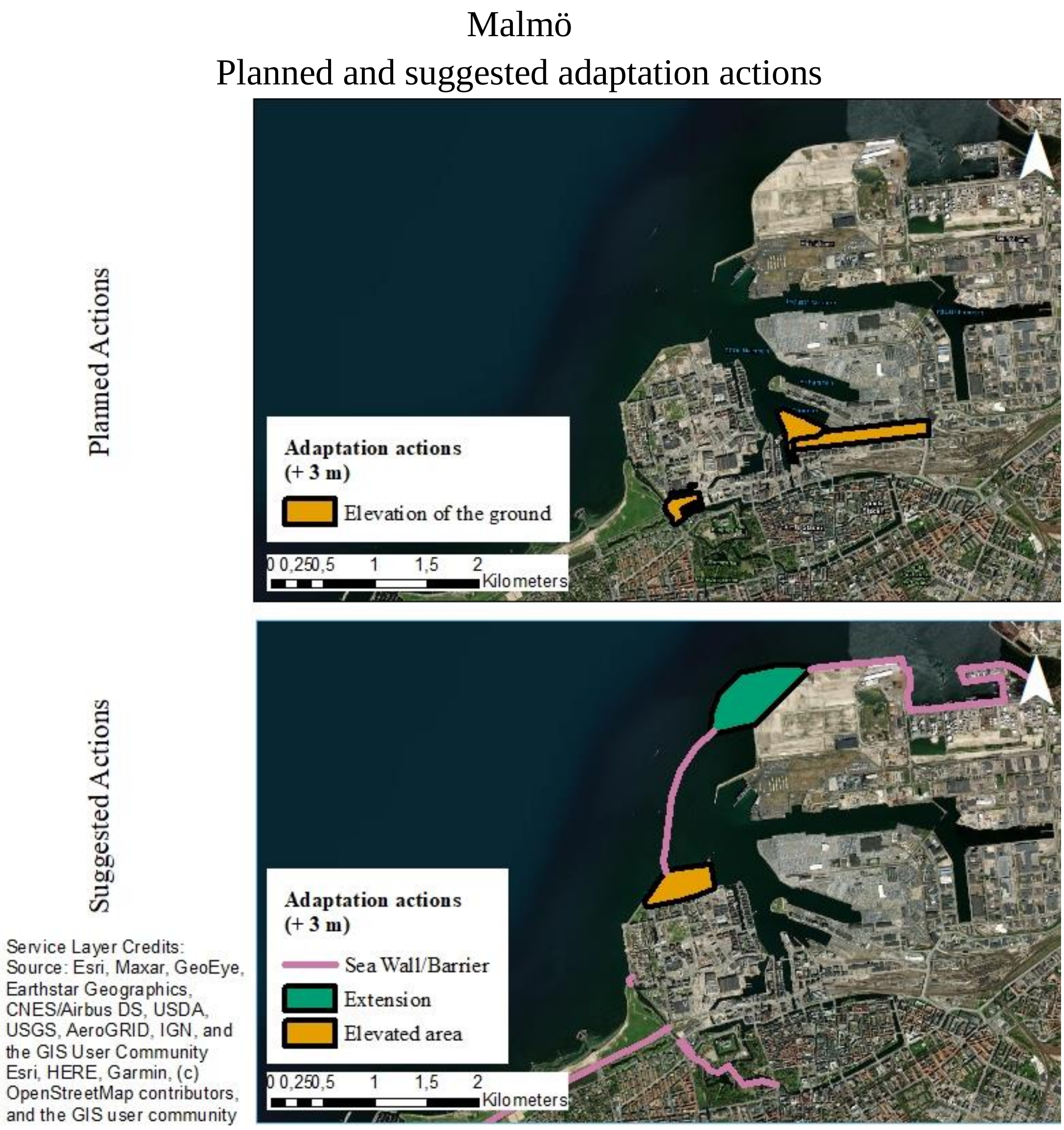

Figure 4. Planned and suggested adaptation actions for Malmö consisting of elevation of the ground respectively a barrier in the harbor.

In the event of an increase of 3 meter in water level from RH2000 water will be flooding the city of Malmö from multiple directions (figure 5) making it complicated to protect larger areas with individual actions.

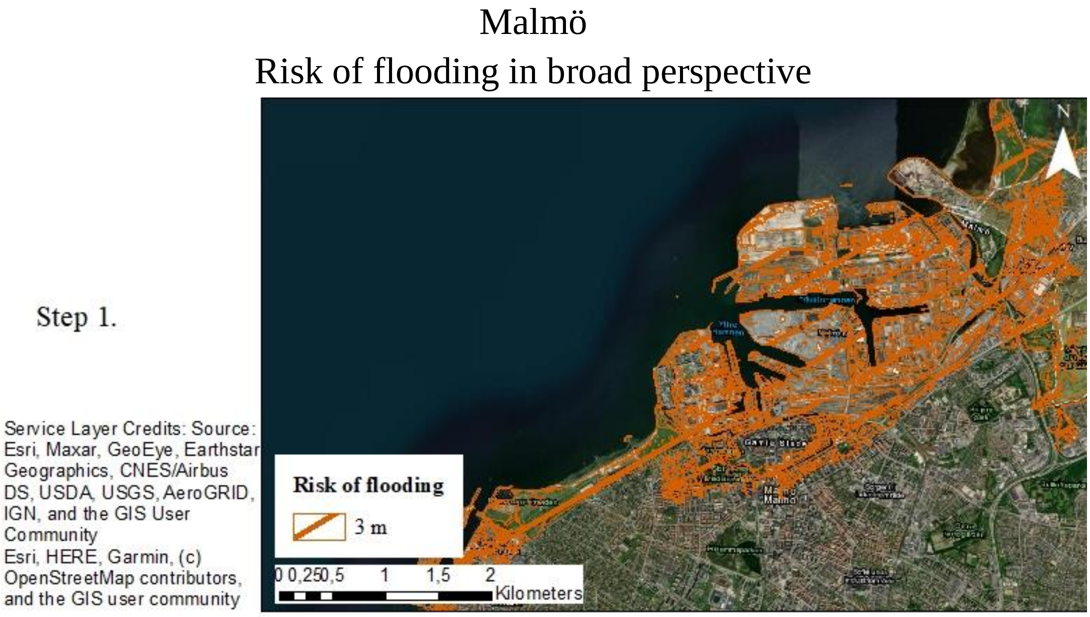

Figure 5. Areas at risk of flooding in case of an increase in water level from the RH2000 with 3 meters.

Visualizations were provided for Malmö showing areas at risk for flooding, the suggested strategy and the areas that would receive a reduced risk of flooding due to the implementation of the planned actions (Figure 6) respectively the suggested actions (figure 7). The suggested actions have little affect if implemented alone however when implemented as part of a continuous costal protection the action reduce the risk of flooding in the area greatly (figure 8).

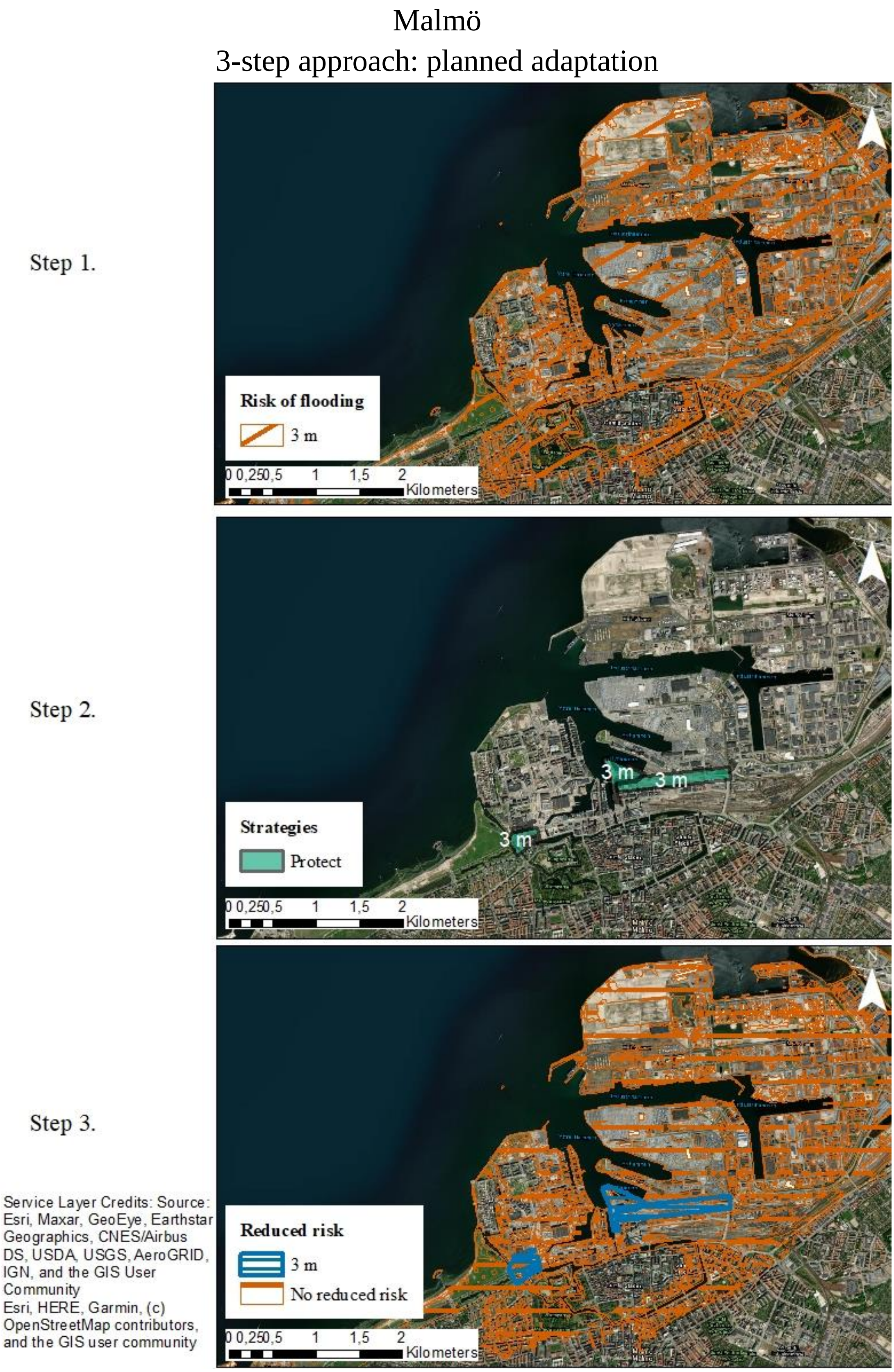

Figure 6. Visualizations based on planned actions consisting of elevation of the ground, showing areas at risk, suggested strategies and areas that would receive a reduced risk from the elevation of the ground.

Malmö
3-step approach: suggested adaptation

Figure 7. Visualizations based on the suggested action a barrier, showing areas at risk, suggested strategies and areas that would receive a reduced risk from the implementation of a barrier.

Malmö

Areas receiving a reduced risk in a broad perspective

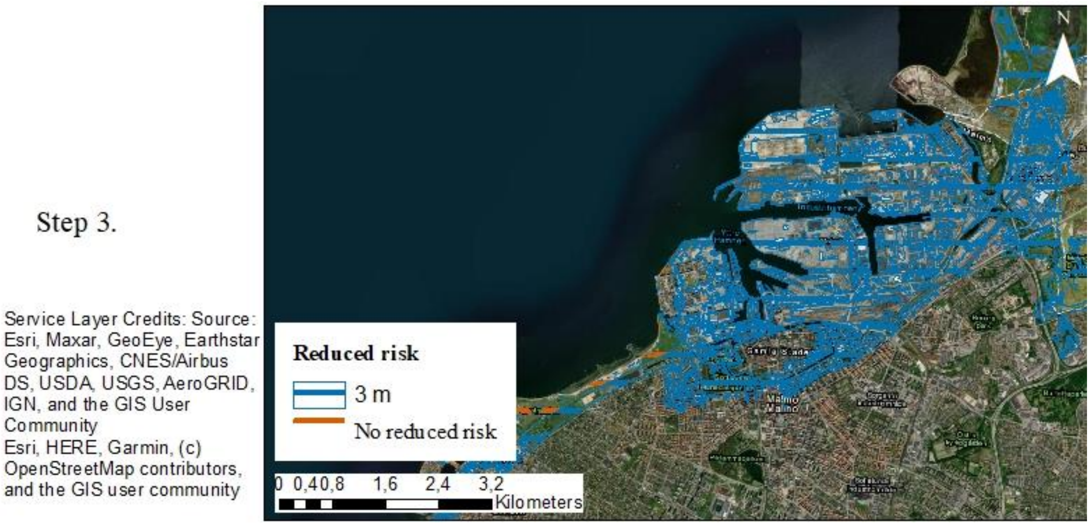

Figure 8. Visualization showing areas that would receive a reduced risk of flooding in a broader perspective when the suggested actions are implemented as a part of a continuous coastal protection.

4.2.4 Proposed use of visualization for Trelleborg

For the municipality of Trelleborg visualizations were made for the area of Skåre showing how visualizations can be used for different areas as well as different approaches. Trelleborg municipality uses multiple visualizations in their thematic addition to their comprehensive plan, showing areas at risk and where actions such as walls adapting the areas will be located. In one case visualizations are used to show areas that would receive a reduced risk from the implementation of adaptive strategies (Trelleborgs kommun, 2021). This study proposed the use of the three- step visualization approach as a way for Trelleborg to further clarify and structure their use of visualizations in climate adaptive planning and communication.

For Skåre visualizations were carried out using three different time scenarios: 2019, 2065 and 2100 as well as multiple flooding scenarios. The visualizations are based on suggested actions provided in the thematic addition to the comprehensive plan and suggestions by SWECO (figure 9) (Trelleborgs kommun, 2021; SWECO, 2020), consisting of local protection and elevation of sensitive objects in the harbor in 2019. For 2065 the adaptation action consists of the building of a wall and dikes as well as an elevation of the harbor. In 2100 the same actions as in 2065 are suggested however elevated to higher levels.

For Trelleborg, Skåre visualizations were provided using the three-step approach showing areas at risk, suggested strategies and areas that would receive a reduced risk of flooding for the years 2019 (figure 10), 2065 (figure 11) respectively 2100 (figure 12).

Figure 9. Suggested adaptation actions for Skåre 2019, 2065 and 2100 consisting of local measures, elevation of sensitive elements, dikes, and sea walls.

Figure 10. Visualizations based on the suggested actions local protection and elevation of sensitive elements in the harbor, showing areas at risk, suggested strategies and areas that would receive a reduced risk from the implementation of local adaptation.

Figure 11. Visualizations based on the suggested actions elevation of the ground, sea walls and a dike, showing areas at risk, suggested strategies and areas that would receive a reduced risk.

Skåre

3-step approach: 2100

Step 1.

Step 2.

Step 3.

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 12. Visualizations based on the suggested actions elevation of the ground, sea walls and a dike, showing areas at risk, suggested strategies and areas that would receive a reduced risk.

4.3 Evaluating the three-step approach

The three-step visualization approach proposed in this study was evaluated in the same way as the current use of visualizations in plans provided by the municipalities, using the framework by Wibeck, Neset & Linnér (2013) (table 9). The approach is suggested to be used as an addition to planning documents at a municipal level. The visualizations would therefore be used in the context of adaptive strategies stated in these planning documents, using the provided temporal and spatial scales as well as key actors. Therefore, the content in which the visualizations are used could not be evaluated.

When it comes to the form of the visualizations, they were made using visualizations on maps. The main purpose of the proposed visualizations is to show suggested climate adaptive strategies regarding a rising sea level as well as how the implementation of these strategies would reduce the risk for vulnerable areas. The visualizations are also intended to show how areas at risk as well as land use for adaptive strategies changes over time. The suggested three step visualization approach provide information regarding risk areas, adaptive strategies as well as areas benefiting from these strategies.

Table 9. The evaluation of the three-step approach using the adapted framework by Wibeck, Neset & Linnér (2013).

Three-step approach	
Content	
Background information provided	Provided through the municipality plans
Defined spatial & temporal scales	Provided through the municipality plans
Defined key actors	Provided through the municipality plans
Form	
Main purpose of the visualizations	Showing areas vulnerable to the rising sea level and strategies planned or suggested with the purpose of limiting the risk of flooding
Main method used for visualizations	Visualizations on maps
Context	
Do the visualizations provide information regarding risk areas, planned strategies and areas benefiting from the strategies?	Yes, all of the mentioned categories

4.4 Land use change in response to climate change

The three-step approach aim to communicate how the future flooding risk as well as the municipalities´ plans to adapt to these risks. This approach can be used to for example show differences in result between two strategies but also show the municipalities´ plans amid different time scenarios, showing how strategies could change over time. In almost all visualizations provided for the case studies the adaptive strategies consisted of protection however other strategies might exist in other municipalities and strategies might change in the future. This can potentially result in changes of land-use over time.For example, depending on flooding and temporal scenarios the strategies can change over time, from for instance protection of the entire area to moving houses from the areas closest to the sea, converting the area to recreantly land and protecting areas higher up (figure 13). Changes in strategies over time might be caused by the protective actions becoming untenable with higher water level or possible economic prospects.

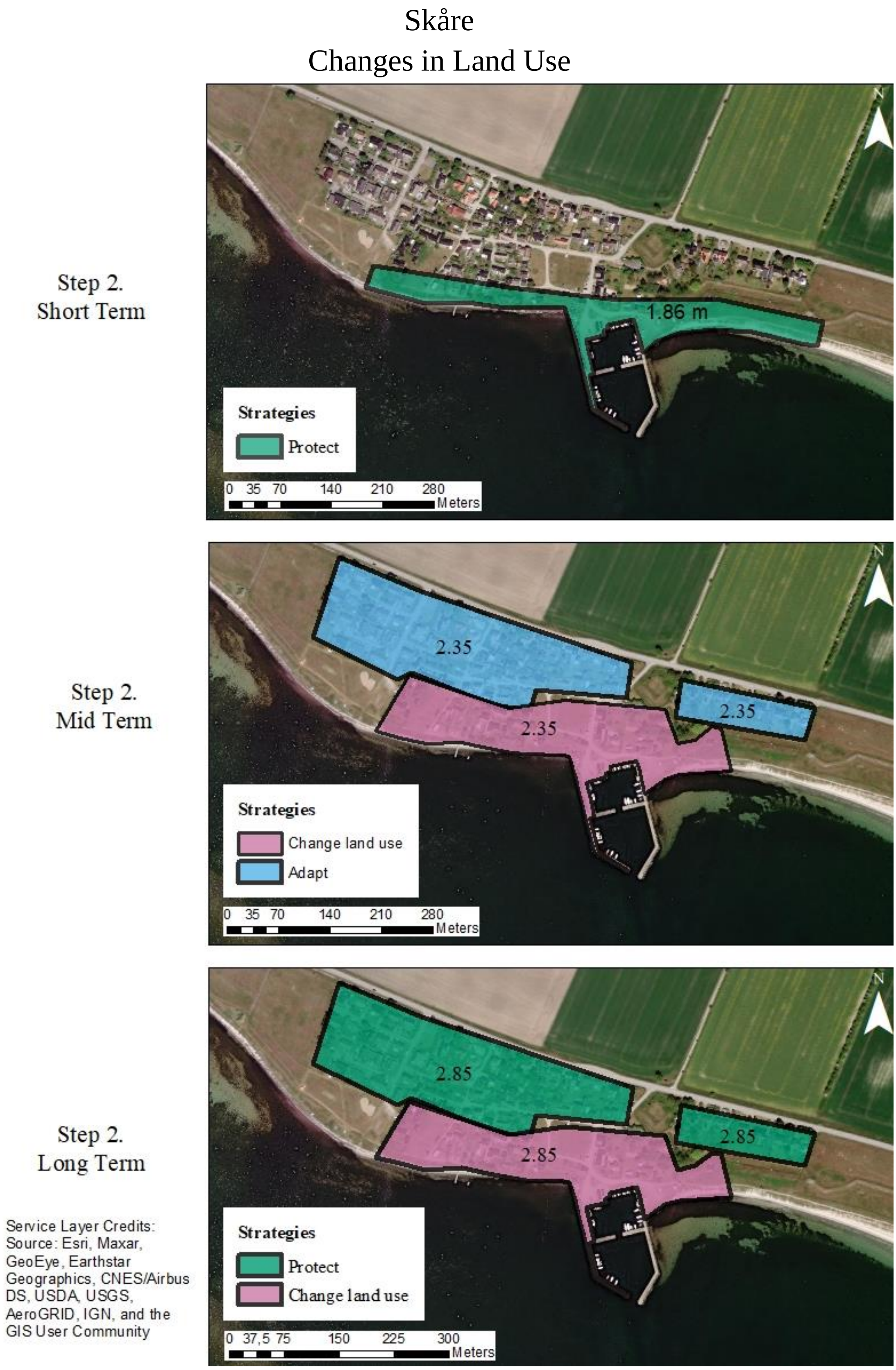

Figure 13. Visualizations showing how strategies can change over time, from protection of the entire area to moving houses from the areas closest to the sea, converting the area to recreantly land and protecting areas higher up. The strategies are made up for this study.

A visualization showing areas at risk of flooding amid different water levels, making it possible to roughly estimate potential water depths in the area was made for Skåre (figure 14). This visualization shows that by including multiple flooding scenarios in step one in the three-step approach more information can be gained. However, an additional map showing the elevation in the landscape would possible further aid in the estimation of water depths in the area.

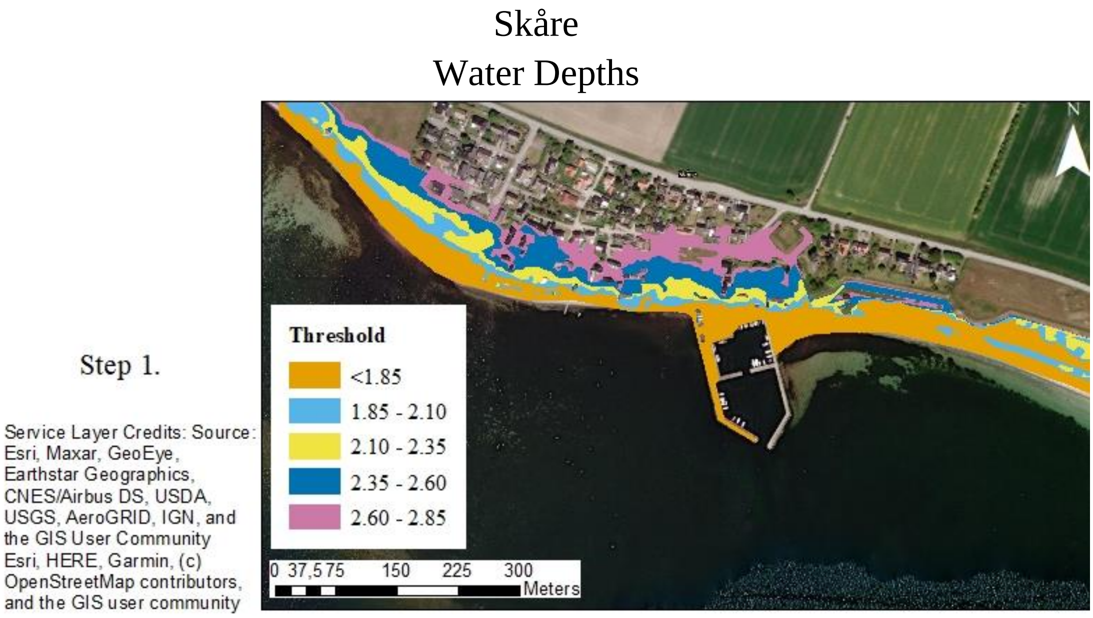

Figure 14. Visualizations showing how water depths could be included in the first step of the three-step approach.

5. Discussion

5.1 Current use of visualizations in Swedish municipalities regarding communication of adaptive strategies to a rising sea level

5.1.1. Current use of visualizations in comprehensive plans

The result from this study shows differences and limitations in the current use of visualization in adaptive planning regarding the rising sea level among the investigated municipalities. When using the framework by Wibeck, Neset & Linnér (2013) it is clear that the municipalities use visualizations in varying ways. The three municipalities all provide background information, spatial and temporal scales as well as key actors, however they use different methods and visualizations for different purposes (Göteborg stad, 2019; Malmö stad, 2018a; Malmö stad, 2018b; Trelleborgs kommun, 2021). Trelleborg is the only municipality out of the three analyzed that is currently working with multiple temporal scales and scenarios, adding important dimensions to the content of the visualizations (Trelleborgs kommun, 2021). Working with multiple scenarios can make the data seem more credible to the audience as well as facilitate the comprehension of in this case adaptation strategies. Working with single flooding scenarios might instead affect the audience in the opposite way, limiting the visualizations to somewhat extreme flooding scenarios by the likes of +2.55 or +3 meter could possibly result in fear discouraging and distancing the audience (Wibeck, Neset & Linnér, 2013).

The differences in the use of visualizations among the municipalities highlights the lacking coherence in climate change communication between municipalities. This incoherence is further amplified by the differences in details in the comprehensive plans and additions to the comprehensive plans provided by the municipalities (Göteborg stad, 2019; Malmö stad, 2018a; Malmö stad, 2018b; Trelleborgs kommun, 2021). Inconsistencies in policies among municipalities can complicate and hinder efficient policy implementation as well as obstruct cooperation between municipalities (Cheng et al., 2021). Climate change is affecting multiple sectors in our society (Ekholm & Nilsson, 2019) and clear communication can here strengthen cooperation between sectors as well as ensuring support, participation, and implementation of action (Climate-ADAPT, n.d.c). It is here the proposed three-step approach is proposed to aid the communication and planning of climate change adaptation.

5.1.2. Current use of visualizations in other documents

In order to perform the visualizations in this study, additional documents other than the comprehensive plans were required. This was due to the fact that the plans provided by the municipality did not include all the details sufficient for producing the visualizations. The details provided by the additional documents mostly consisted of the exact placement for the adaptation actions such as walls or barriers as well as their height and extent.

The use of visualizations in the additional documents mainly provided by consult firms were not evaluated, due to this study's focus on comprehensive plans and communication at a municipal level. Visualizations were however used in these documents in the context of sea level rise, and in some cases in greater extent than in the municipality plans. In the three reports regarding the hydro model from Gothenburg, visualizations were used for among other things to show placements of actions as well as illustration of walls and other adaptive measures (Ramboll, 2014a; Ramboll, 2014b & Ramboll, 2014c). In the plan suggestions for Malmö provided by SWECO multiple visualizations are included showing for example areas at risk, placement of actions and illustrations of different types of actions (SWECO, 2018). This is similar to the plan suggestions provided by SWECO for Trelleborg municipality, which also includes among other things areas at risk, placement of actions and illustrations of different types of actions (SWECO, 2020). Visualizations seems to be used in a greater extent in documents made for the municipalities than in documents provided by the municipalities according to this study´s findings. This shows that the use of visualizations currently is being recognized as a tool in communicating adaptive strategies to the municipalities, with the purpose of facilitating adaptive planning. However, it does not seem to be equally recognized in the communication of plans from the municipality to stakeholders and inhabitants of the municipality.

5.2 The proposed three- step approach

The proposed three- step approach aim to aid Swedish municipalities in their planning and communication of climate adaptive plans by illustrating the municipalities plans for adaptation regarding a rising sea level. The use of the three-step approach is proposed as a part of the comprehensive plan, extending the use of visualizations, and providing basis for clear and structured communication. The result from the survey showed that the representatives from the three municipalities recognized the potential of the three-step approach in communication and planning of adaptive strategies. There were however some delimitations with the survey, mainly regarding that fact that the respondents did not answer anonymously. This might have affected the answers, making them more positive than they might have been if the respondents answered anonymously. Some of the questions might also have been subjected to interpretation from the respondents making the answers less reliable. In order to deal with these limitations future studies in the subject should look into to conduct an anonymous and less interpretable survey. It would also be interesting to extend the survey to more experts but also more municipalities.

In the results from the survey there were some comments regarding the layout of the produced visualizations. These comments resulted in updated versions of the visualizations that were sent to the municipalities. The updates included making the visualizations inclusive for people with color vision deficiency, clearer titles, inclusion of areas that does not receive a reduced risk and map enabling estimations of water depths. In communication the color choices are of great importance. Colors help attracting attention, shaping perceptions, opinions, and attitudes (Carlomagno, 2012). Red is a color that has been found to be associated with danger and is therefore often successfully used conveying danger related information (Pravossoudovitch et al., 2014). However, people with red-green deficiency have difficulties separating the colors of green and red. Therefore, the use of green and red colors can come to cause ineffective and exclusive communication (Hassan, 2019). Color vision deficiency is a genetic condition and a relatively common one. Not taking color deficient people into account when using visual communication is against the universal design principle, stating that all environments and products should be usable by all people, regardless of age, physical attributes, and ability (Nakauchi & Onouchi, 2008). Taking color deficiency into account in this study I did not use red for the purpose of conveying risks, instead other colors were used. Red is an affective color to use in communication due to the fact thar people associate it with danger and using other colors might limit the effectiveness of the risk communication in this study.

When making visualizations suitable for people with color deficiency, situations where information is conveyed only in colors should also be avoided (Okabe & Ito, 2002). This means that if visualizations are understandable in black and white, they are probably efficient in communicating information to a color deficient audience. The visualizations in this study were not in all cases understandable in black and white and this is a major area of improvement in this study. I used a color scheme adapted for an audience with color deficiency and I used thick border lines framing the more see through- layers, I also tried to work with patterns using striped layers. More work could however be done in order to make the visualizations more visible in black and white, for example further exploring the use of pattern.

The results from the evaluation show that an inclusion of the three-step approach in the comprehensive plans would lead to an extended use of visualizations in all the investigated municipalities. For Gothenburg municipality the inclusion of the three-step approach in its comprehensive plan would considerably extend the municipality's communication of adaptive strategies through visualizations. The current use of visualization is limited to showing areas at risk, planning levels and flooding scenarios (Göteborg stad, 2019) and the inclusion of strategies and areas receiving protection could be beneficial aid the municipality in communication and planning. The use of visualization in communicating adaptation strategies to a rising sea level in Malmö municipality show several similarities to the municipality of Gothenburg. Visualizations here shows potential consequences of flooding using pictures and areas with suggested strategies using an interactive map (Malmö stad, 2018a & Malmö stad 2018b). The inclusion of visualizations following the three-step approach would therefore mean an extended use of visualizations for Malmö in their adaptive plans.

Trelleborg municipality is currently using visualizations in a greater extent than Gothenburg and Malmö, showing areas at risk, planned actions and in one case the area that would receive a reduced risk (Trelleborgs kommun, 2021). The inclusion of visualizations following the three-step approach will therefore have less effect on the plans provided by Trelleborg municipality in comparison with Gothenburg and Malmö. However, the inclusion of suggested strategies, showing the areas the municipality seeks to protect and how these changes over time and the use of the three-step approach could potentially strengthen the communication and structure the use of visualizations.

5.3 Climate change adaptation and land use change

Change of land use as an adaptation strategy to the changing climate can reduce both the risk and vulnerability of affected areas (Xu & Jao, 2021). It is therefore profitable to integrate land use into adaptation planning, aiding the limitation of for example flooding. Some areas are more vulnerable or prone to flooding and this should be taken into account in planning (Climate-ADAPT, n.d.a). As seen in the visualizations provided for Trelleborg adaptation of Skåre is recommended in a short-term perspective but in a long-term perspective protection is advised. In this case that does not necessarily result in changes of land use, the area is throughout residential. However, in the additional visualization regarding land use change, it can be seen how climate adaptation strategies changes over time and how this directly influence the land the in the area. Here certain areas are protected as residential areas short term but long term these areas are no longer residential and allowed to flood in favor for the protection of higher located areas. This shows the potential of changing land use as a climate adaptation strategy as well as the importance of flexibility in land use.

5.4 Risk perception and uncertainties

The spatial and temporal scales is of importance when communicating climate change and associated risks (Lieske, Wade & Roness, 2014). Communicating climate change as a distant threat using locations that the audience do not feel connected with can cause the audience to distant themselves from the subject (Pidgeon, 2012). In the comprehensive plans the spatial scale is set to for the audience local areas and visualizing scenarios on locally known locations should therefore aid the audience risk precipitation. Using multiple scenarios and not limiting the communication to distant time scales might also increase the audience understanding of risk. The level of complexity of the visualizations does not seem to impact the perception of risk, however it seems to affect the willingness to engage. More complexity is found to increase the willingness of the audience to take actions (Lieske, Wade & Roness, 2014) and here data availability is emphasized (Wright et al, 2021). Maps have the ability to display data clearly and for bigger areas (Hutton & Allen, 2021) using visualizations on maps as done in the three-step approach should therefore potentially aid in the willingness of the audience to take actions.

Risk-based adaptation strategies often do not take uncertainties into account; however, these uncertainties might be of great importance for the adaptation and risk management (Oddo et al., 2020). The variations in scenarios and consideration of uncertainties are apparent in the plan documents provided in this study. The municipality of Gothenburg and Malmö are using set planning levels, meaning that they are planning after a worst-case scenario sea level. This level is two and a half meter (2.55 m) for Gothenburg (Göteborg stad, 2019) and three meters for Malmö (Malmö stad, 2018b). Trelleborg municipality however incorporates several temporal scenarios with varying water levels, considering uncertainties (Trelleborgs kommun, 2021).

When it comes to communication of these scenarios and uncertainties, the audience understanding varies with the complexity when visualized on maps. The inclusion of uncertainties is important to improve the credibility and properly communicate the information, however when included in visualizations on maps this information might be difficult to meditate clearly and easily understandable. To better communicate uncertainties in climate change scenarios and adaptation, showing uncertainties on separate maps facilities the understanding of the audience (Becsi et al., 2019). In the three-step approach presented in this study uncertainties can be included as done for Trelleborg municipality by showing multiple future possible scenarios for several temporal scales. There are however additional uncertainties regarding the scenario's reliability. This is not illustrated on the visualizations in this study in order to keep a lower level of complexity. This does not mean that uncertainties should be ignored or left out but included on additional maps and described in depth in the associated text.

5.5 Visualizations in decision making and EU policy

There has been an increase in information regarding climate change available to the policy makers, however this is not being well taken up by the policymaking and planning community. There is currently a need for more focus on translating the consequences of climate change to for example land use claims, enabling stakeholders to play a role in the spatial planning process. Climate change adaptation affects multiple different stakeholders which can be challenging, especially when dealing with a high level of uncertainty (Goosen et al., 2013). This study uses visualizations on maps which has proven to be a powerful method for communication climate change, but it can also cause miscommunication when failing to include necessary factors (Becsi et al., 2020). In order to limit miscommunication close interactions between scientists and stakeholders as well as easily comprehendible visualizations are of great importance.

AST is designed for policymakers and stakeholder such as for example decisionmakers at a municipal level. In AST communication is mentioned in relation to preparing ground for adaptation and monitoring and evaluating adaptation. Climate change communication is here viewed to be of importance for the preparing, monitoring, and evaluation of adaptation strategies (Climate-ADAPT, n.d.c; Climate-ADAPT, n.d.e). It is also mentioned in the fourth step related to assessing adaptation option, in the context that assessment should be conducted in order to enhance communication with and among decision makers (Climate-ADAPT, n.d.d). Visualizations are effective communication tools, making abstract information more easily understandable (Ballantyne et al, 2018) and can therefore be argued to be a part of AST, preparing, monitoring, and evaluation of adaptation strategies.

Due to the fact that the visualizations presented in this study shows areas at risk as well as adaptation strategies the three-step approach can be used in the first and fourth step in AST, preparing ground for adaptation and assessing adaptation options. Communication is not mentioned in the second and third step of AST, related to assessing climate change risk and vulnerabilities respectively identifying adaptation options however visualizations could still potentially assist in these steps. The three-step approach could here be used as part of the planning process, showing areas at risk and therefore vulnerable for flooding as well as the usefulness of different adaptation actions by showing areas that would receive a reduced risk of flooding.

The three-step approach proposed in this study aimed to aid climate adaptation related to a rising sea level on a municipal level in Sweden but could potentially be used to communicate other types of climate adaptation and on other levels such as county- or national levels. Other types of climate adaptation could for example be adaptation related to extreme weather, drought or changing temperatures. It would here be interesting to look into if the approach would be suitable to aid in the communication and planning of adaptation related to different threats. It is important to keep the spatial and temporal scales relatable for the audience and therefore it might be more difficult to apply the approach on scales bigger than municipal levels. Further research is needed to look into how the approach could be adapted for bigger scales aiding communication and planning of climate adaptation.

6. Conclusion

Currently in Sweden local adaptation to climate change is important but often hindered by for example different views among decision makers on adaptation strategies within municipalities. Climate adaptation is on a formative stage in comprehensive and local plans at municipal level. The use of visualizations is an effective tool in climate change communication and clear communication can aid in planning of climate adaptation. The current use of visualizations in Swedish municipalities regarding communication of adaptive strategies to a rising sea level is limited in the investigated municipalities Gothenburg, Malmö and Trelleborg. Visualizations are sparsely used in the comprehensive plans, mostly focused on flooding scenarios, however used in a greater extent in plan suggestions provided to the municipalities from consult firms. This shows a lacking coherence in climate change communication between municipalities.

An inclusion of the proposed three-step approach focusing on using visualizations to 1) show areas at risk, 2) show the by the municipality suggested adaptive strategies and 3) show the areas that would benefit from the strategies. would for all the investigated municipalities mean an extended use of visualization related to a rising sea level. The potential in using the three-step approach to aid communication and planning of adaptation strategies related to a rising sea level at a municipal level in Sweden was recognized by representatives for the three investigated municipalities. The result from this study also shows the relationship between climate change adaptation and land use change, highlighting the need for flexibility.

The three-step approach was evaluated conducting a survey between representants for the municipality, specialized in climate adaptation, further research is therefore needed investigating how stakeholders and inhabitants perceive the visualizations produced using the three-step approach in communicating climate change adaptation. Climate adaptation is complicated by the uncertainties surrounding climate change and it is important to communicate and consider these uncertainties at a municipal level. The three-step approach communicates the municipalities plans but does not fully display the uncertainties in the flooding scenarios. Further research is therefore necessary to investigate how municipalities through their comprehensive plans successfully can communicate uncertainties using visualizations.

7. References

Auer, C., Kriegler, E., Carlsen, H., Kok, K., Pedde, S., Krey, V., & Müller, B. (2021). Climate change scenario services: From science to facilitating action. *One Earth*, *4*(8), 1074–1082. https://doi.org/10.1016/j.oneear.2021.07.015

Ballantyne, A. G., Glaas, E., Neset, T.-S., & Wibeck, V. (2018). Localizing Climate Change: Nordic Homeowners' Interpretations of Visual Representations for Climate Adaptation. *Environmental Communication*, *12*(5), 638–652. https://doi.org/10.1080/17524032.2017.1412997

Barron, S., Canete, G., Carmichael, J., Flanders, D., Pond, E., Sheppard, S., & Tatebe, K. (2012). A Climate Change Adaptation Planning Process for Low-Lying, Communities Vulnerable to Sea Level Rise. *Sustainability*, *4*(9), 2176–2208. https://doi.org/10.3390/su4092176

Becsi, B., Hohenwallner-Ries, D., Grothmann, T., Prutsch, A., Huber, T., & Formayer, H. (2020). Towards better informed adaptation strategies: Co-designing climate change impact maps for Austrian regions. *Climatic Change*, *158*(3), 393–411. https://doi.org/10.1007/s10584-019-02602-7

Burch, S., Sheppard, S. r. j., Shaw, A., & Flanders, D. (2010). Planning for climate change in a flood-prone community: Municipal barriers to policy action and the use of visualizations as decision-support tools. *Journal of Flood Risk Management*, *3*(2), 126–139. https://doi.org/10.1111/j.1753-318X.2010.01062.x

Carlomagno, L. (2012). Color, Culture, and Communication. *Less More Architecture Design Landscape*, *16*, 985–988. http://www.webofscience.com/wos/woscc/full-record/WOS:000325109600108

Carter, O., Mitchell, M., Porfririo, L., Hugh, S., Lockwood, M., Gilfedder, L., & Lefroy, E. (2017). Mapping Scenario Narratives: A Technique to Enhance Landscape-scale Biodiversity Planning. *Conservation and Society*, *15*(2), 179. https://doi.org/10.4103/cs.cs_15_121

Chen, A. S., Khoury, M., Vamvakeridou-Lyroudia, L., Stewart, D., Wood, M., Savic, D. A., & Djordjevic, S. (2018). 3D visualisation tool for improving the resilience to urban and coastal flooding in Torbay, UK. *Procedia Engineering*, *212*, 809–815. https://doi.org/10.1016/j.proeng.2018.01.104

Cheng, Z., Nitoslawski, S., Konijnendijk van den Bosch, C., Sheppard, S., Nesbitt, L., & Girling, C. (2021). Alignment of municipal climate change and urban forestry policies: A Canadian perspective. *Environmental Science & Policy*, *122*, 14–24. https://doi.org/10.1016/j.envsci.2021.04.005

Chiang, Y.-C., & Ling, T.-Y. (2017). Exploring Flood Resilience Thinking in the Retail Sector under Climate Change: A Case Study of an Estuarine Region of Taipei City. *Sustainability*, *9*(9), 1650. https://doi.org/10.3390/su9091650

Climate-Adapt. (n.d.a). *Adaptation of integrated land use planning.* Retrieved May 13, 2022, from https://climate-adapt.eea.europa.eu/metadata/adaptation-options/adaptation-of-integrated-land-use-planning

Climate-ADAPT. (n.d.b). *The Adaptation Support Tool – Getting started.* Retrieved January 26, 2022, from https://climate-adapt.eea.europa.eu/knowledge/tools/adaptation-support-tool

Climate-ADAPT. (n.d. c). *Preparing the ground for adaptation*. Retrieved May 19, 2022, from https://climate-adapt.eea.europa.eu/knowledge/tools/adaptation-support-tool/step-1-5

Climate-ADAPT. (n.d. d). *Assessing adaptation options.* Retrieved May 19, 2022, from https://climate-adapt.eea.europa.eu/knowledge/tools/adaptation-support-tool/step-4-0

Climate-ADAPT. (n.d.e). *Monitoring and Evaluating Adaptation.* Retrieved May 19, 2022, from https://climate-adapt.eea.europa.eu/knowledge/tools/adaptation-support-tool/step-6-0

Dale, V. H. (1997). THE RELATIONSHIP BETWEEN LAND-USE CHANGE AND CLIMATE CHANGE. *Ecological Applications*, *7*(3), 753–769. https://doi.org/10.1890/1051-0761(1997)007[0753:TRBLUC]2.0.CO;2

DeCock-Caspell, M., & Vasseur, L. (2021). Visualizations as a tool to increase community engagement in climate change adaptation decision-making. *FACETS*, *6*(1), 240–251. https://doi.org/10.1139/facets-2020-0032

Ekholm, H.M., & Nilsson, Å. (2019*). Klimatanpassning 2019 - Så långt har Sveriges kommuner kommit*. Svenska Miljöinstitutet. https://www.ivl.se/publikationer/publikationer/klimatanpassning-2019---sa-langt-har-sveriges-kommuner-kommit.html

Elsharouny, M. R. M. M. (2016). Planning Coastal Areas and Waterfronts for Adaptation to Climate Change in Developing Countries. *Procedia Environmental Sciences*, *34*, 348–359. https://doi.org/10.1016/j.proenv.2016.04.031

GISGeography. (2022). *What is ArcGIS?* GIS Geography. https://gisgeography.com/what-is-arcgis/

Goosen, H., de Groot-Reichwein, M. A. M., Masselink, L., Koekoek, A., Swart, R., Bessembinder, J., Witte, J. M. P., Stuyt, L., Blom-Zandstra, G., & Immerzeel, W. (2014). Climate Adaptation Services for the Netherlands: An operational approach to support spatial adaptation planning. *Regional Environmental Change*, *14*(3), 1035–1048. https://doi.org/10.1007/s10113-013-0513-8

Göteborg Stad (2019). *Översiktsplan för Göteborg-Tematiskt tillägg för översvämningsrisker.* Stadsbyggnadskontoret. https://goteborg.se/wps/portal/start/byggande--lantmateri-och-planarbete/kommunens-planarbete/oversiktlig-planering/fordjupningar-och-tillagg/oversvamningsrisker---tematisk-tillagg-till-oversiktsplanen

Hallegatte, S. (2009). Strategies to adapt to an uncertain climate change. *Global Environmental Change*, *19*(2), 240–247. https://doi.org/10.1016/j.gloenvcha.2008.12.003

Hassan, M. F. (2019). Flexible color contrast enhancement method for red-green deficiency. *Multidimensional Systems and Signal Processing*, *30*(4), 1975–1989. https://doi.org/10.1007/s11045-019-00638-7

Hutton, N. S., & Allen, T. R. (2021). Perceptions of visual and in situ representations of sea level rise and tidal flooding: The blue line project, Norfolk, Virginia. *GeoJournal*. https://doi.org/10.1007/s10708-020-10356-4

Intergovernmental Panel on Climate Change (2021). *Climate Change 2021- The Physical Science Basis-Summary for Policymakers*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 3−32, doi:10.1017/9781009157896.001.

Jenkins, J., Milligan, B., & Huang, Y. (2020). Seeing the forest for more than the trees: Aesthetic and contextual malleability of preferences for climate change adaptation strategies. *Ecology and Society*, *25*(4). https://doi.org/10.5751/ES-11861-250407

Johansson, J., Opach, T., Glaas, E., Neset, T.-S., Navarra, C., Linnér, B.-O., & Rød, J. K. (2017). VisAdapt: A Visualization Tool to Support Climate Change Adaptation. *IEEE Computer Graphics and Applications*, *37*(2), 54–65. https://doi.org/10.1109/MCG.2016.49

Kainz, W. (2020). Cartography and the others – aspects of a complicated relationship. *Geo-Spatial Information Science*, *23*(1), 52–60. https://doi.org/10.1080/10095020.2020.1718000
Kilsedar, C. E., Fissore, F., Pirotti, F., & Brovelli, M. A. (2019). EXTRACTION AND VISUALIZATION OF 3D BUILDING MODELS IN URBAN AREAS FOR FLOOD SIMULATION. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XLII-2/W11*, 669–673. https://doi.org/10.5194/isprs-archives-XLII-2-W11-669-2019
Klimatanpassning.se. (2021). *Lagar och regler i Sverige.* https://www.klimatanpassning.se/klimatanpassa/underlag-for-klimatanpassning/lagar-och-regler/lagar-och-regler-sverige-1.32576
Kiss, E., Zichar, M., Fazekas, I., Karancsi, G., & Balla, D. (2020). Categorization and geovisualization of climate change strategies using an open-access WebGIS tool. *Infocommunications Journal*, *12*(1), 32–37. https://doi.org/10.36244/ICJ.2020.1.5
Kristianssen, A.-C., & Granberg, M. (2021). Transforming Local Climate Adaptation Organization: Barriers and Progress in 13 Swedish Municipalities. *Climate*, *9*(4), 52. https://doi.org/10.3390/cli9040052
Lieske, D. J. (2015). Coping with climate change: The role of spatial decision support tools in facilitating community adaptation. *Environmental Modelling & Software*, *68*, 98–109. https://doi.org/10.1016/j.envsoft.2015.02.005
Lieske, D. J., Wade, T., & Roness, L. A. (2014). Climate change awareness and strategies for communicating the risk of coastal flooding: A Canadian Maritime case example. *Estuarine, Coastal and Shelf Science*, *140*, 83–94. https://doi.org/10.1016/j.ecss.2013.04.017
Malmö Stad. (2018a). *Översiktsplan för Malmö—Planstrategi.* Malmö Stad. https://malmo.se/Stadsutveckling/Tema/Oversiktsplanering/Oversiktsplan-for-Malmo.html
Malmö Stad (2018b). *Utredningsområde kustskydd.* Malmö Stad. http://kartor.malmo.se/rest/ol/2.1/?config=../configs-2.1/config_op.js
Mikovits, C., Tscheikner-Gratl, F., Jasper-Tönnies, A., Einfalt, T., Huttenlau, M., Schöpf, M., Kinzel, H., Rauch, W., & Kleidorfer, M. (2017). Decision Support for Adaptation Planning of Urban Drainage Systems. *Journal of Water Resources Planning and Management*, *143*(12), 04017069. https://doi.org/10.1061/(ASCE)WR.1943-5452.0000840
Nakauchi, S., & Onouchi, T. (2008). Detection and modification of confusing color combinations for red-green dichromats to achieve a color universal design. *Color Research & Application*, *33*(3), 203–211. https://doi.org/10.1002/col.20404
Oddo, P. C., Lee, B. S., Garner, G. G., Srikrishnan, V., Reed, P. M., Forest, C. E., & Keller, K. (2020). Deep Uncertainties in Sea-Level Rise and Storm Surge Projections: Implications for Coastal Flood Risk Management. *Risk Analysis: An International Journal*, *40*(1), 153–168. https://doi.org/10.1111/risa.12888
Okabe. M., & Ito, K. (2008). *Color Universal Design (CUD)- How to make figures and presentations that are friendly to Colorblind people –.* https://jfly.uni-koeln.de/color/
Pettit, C., Williams, S., Bishop, I., Aurambout, J.-P., Russel, A. B. M., Michael, A., Sharma, S., Hunter, D., Chan, P. C., Enticott, C., Borda, A., & Abramson, D. (2013). Building an ecoinformatics platform to support climate change adaptation in Victoria. *Future Generation Computer Systems*, *29*(2), 624–640. https://doi.org/10.1016/j.future.2011.07.004

Pidgeon, N. (2012). Climate Change Risk Perception and Communication: Addressing a Critical Moment? *Risk Analysis*, *32*(6), 951–956. https://doi.org/10.1111/j.1539-6924.2012.01856.x

Pravossoudovitch, K., Cury, F., Young, S. G., & Elliot, A. J. (2014). Is red the colour of danger? Testing an implicit red–danger association. *Ergonomics*, *57*(4), 503–510. https://doi.org/10.1080/00140139.2014.889220

Ramboll (2014a). Hydrom*odell för Göteborg-Invallning och portar som skyddsåtgärd mot extremt högvatten i havet år 2100 för Mölndalsån och Säveån- Simuleringsuppdrag 3A*. Göteborg Stad Stadsbyggnadskontoret. https://goteborg.se/wps/portal/start/byggande--lantmateri-och-planarbete/kommunens-planarbete/verktyg-for-stadsplanering-2/miljo-och-klimat-i-stadsplaneringen/klimatforandringar-och-extremt-vader/rapporter-och-statistik-om-extremt-vader

Ramboll (2014b). *Hydromodell för Göteborg-Invallning och portar som skyddsåtgärd mot extremt högvatten i havet år 2100 för Kvillebäcken-Simuleringsuppdrag 3B.* Göteborg Stad Stadsbyggnadskontoret. https://goteborg.se/wps/portal/start/byggande--lantmateri-och-planarbete/kommunens-planarbete/verktyg-for-stadsplanering-2/miljo-och-klimat-i-stadsplaneringen/klimatforandringar-och-extremt-vader/rapporter-och-statistik-om-extremt-vader

Ramboll (2014c). *Hydromodell för Göteborg-Storbarriär som översvämmningsskydd vid extremt högvatten i havet år 2100-Simuleringsuppdrag 4A.* Göteborg Stad Stadsbyggnadskontoret. https://goteborg.se/wps/portal/start/byggande--lantmateri-och-planarbete/kommunens-planarbete/verktyg-for-stadsplanering-2/miljo-och-klimat-i-stadsplaneringen/klimatforandringar-och-extremt-vader/rapporter-och-statistik-om-extremt-vader

SCALGO. (n.d.). *About us*. Retrieved June 15, 2022, from https://scalgo.com/en-US/about

Sheppard, S. R. J., Shaw, A., Flanders, D., Burch, S., Wiek, A., Carmichael, J., Robinson, J., & Cohen, S. (2011). Future visioning of local climate change: A framework for community engagement and planning with scenarios and visualisation. *Futures*, *43*(4), 400–412. https://doi.org/10.1016/j.futures.2011.01.009

SMHI (2021). *Visualisering viktigt verktyg när Uddevalla ska bli en bättre stad, fördjupning.* https://www.smhi.se/klimat/klimatanpassa-samhallet/exempel-pa-klimatanpassning/visualisering-viktigt-verktyg-nar-uddevalla-ska-bli-en-battre-stad-fordjupning-1.176601

SMHI (2022). *Höjdsystem och vattenstånd.* https://www.smhi.se/kunskapsbanken/oceanografi/vattenstand-i-havet/hojdsystem-och-havsvattenstand-1.13582

Sonnek, K. M., & Kanyama, A. C. (n.d.). *TEST AV ROBUSTA BESLUTSSTÖDSMETODER*. 51.

Statistikmyndigheten. (n.d.a). *Folkmängd i riket, län och kommuner 31 december 2021 och befolkningsförändringar 2021*. Retrieved June 17, 2022, from https://www.scb.se/hitta-statistik/statistik-efter-amne/befolkning/befolkningens-sammansattning/befolkningsstatistik/pong/tabell-och-diagram/helarsstatistik--kommun-lan-och-riket/folkmangd-i-riket-lan-och-kommuner-31-december-2021-och-befolkningsforandringar-2021/

Statistikmyndigheten. (n.d.b). *Land- och vattenareal per den 1 januari efter region och arealtyp. År 2012 - 2022.* Retrieved April 20, 2022, from https://www.statistikdatabasen.scb.se/pxweb/sv/ssd/START__MI__MI0802/Areal2012N/table/tableViewLayout1/

SWECO (2018). *Strategi mot extrema högvatten i Malmö-Delområde 1 till 3*. SWECO.

SWECO (2020). *Kustskyddsutredning Trelleborg-Idéstudie för högvattenskydd längs Trelleborgs kuststräcka utanför tätorten.* Trelleborgs Kommun.

Swedish Geotechnical Institute (2021). *Projects*. https://www.sgi.se/en/research--learning/var-forskning/aktuella-forskningsprojekt/

Trelleborgs Kommun (2021). Tematiskt Tillägg till Trelleborgs Översiktsplaner-Stigande Hav och Översvämmning. Trelleborgs Kommun. https://www.trelleborg.se/bygga-bo miljo/planarbete/oversiktsplaner/tematiskt-tillagg-till-trelleborgs-oversiktsplaner-for-stigande-hav-och-oversvamning/

Usher, L. E. (2021). The case for reflexivity in quantitative survey research in leisure studies: Lessons from surf research. *Annals of Leisure Research*, *0*(0), 1–16. https://doi.org/10.1080/11745398.2021.1974905

Wibeck, V., Neset, T.-S., & Linnér, B.-O. (2013). Communicating Climate Change through ICT-Based Visualization: Towards an Analytical Framework. *Sustainability*, *5*(11), 4760–4777. https://doi.org/10.3390/su5114760

Wright, J., Flacke, J., Schmitt, J. P., Schultze, J., & Greiving, S. (2021). Comparing Climate Impact Assessments for Rural Adaptation Planning in Germany and the Netherlands. *Urban Planning*, *6*(3), 306–320. https://doi.org/10.17645/up.v6i3.4269

Xu, Y., & Yao, L. (2021). Integrating Climate Change Adaptation and Mitigation into Land Use Optimization: A Case Study in Huailai County, China. *Land*, *10*(12), 1297. https://doi.org/10.3390/land10121297

Zandvoort, M., Kooijmans, N., Kirshen, P., & van den Brink, A. (2019). Designing with Pathways: A Spatial Design Approach for Adaptive and Sustainable Landscapes. *Sustainability*, *11*(3), 565. https://doi.org/10.3390/su11030565