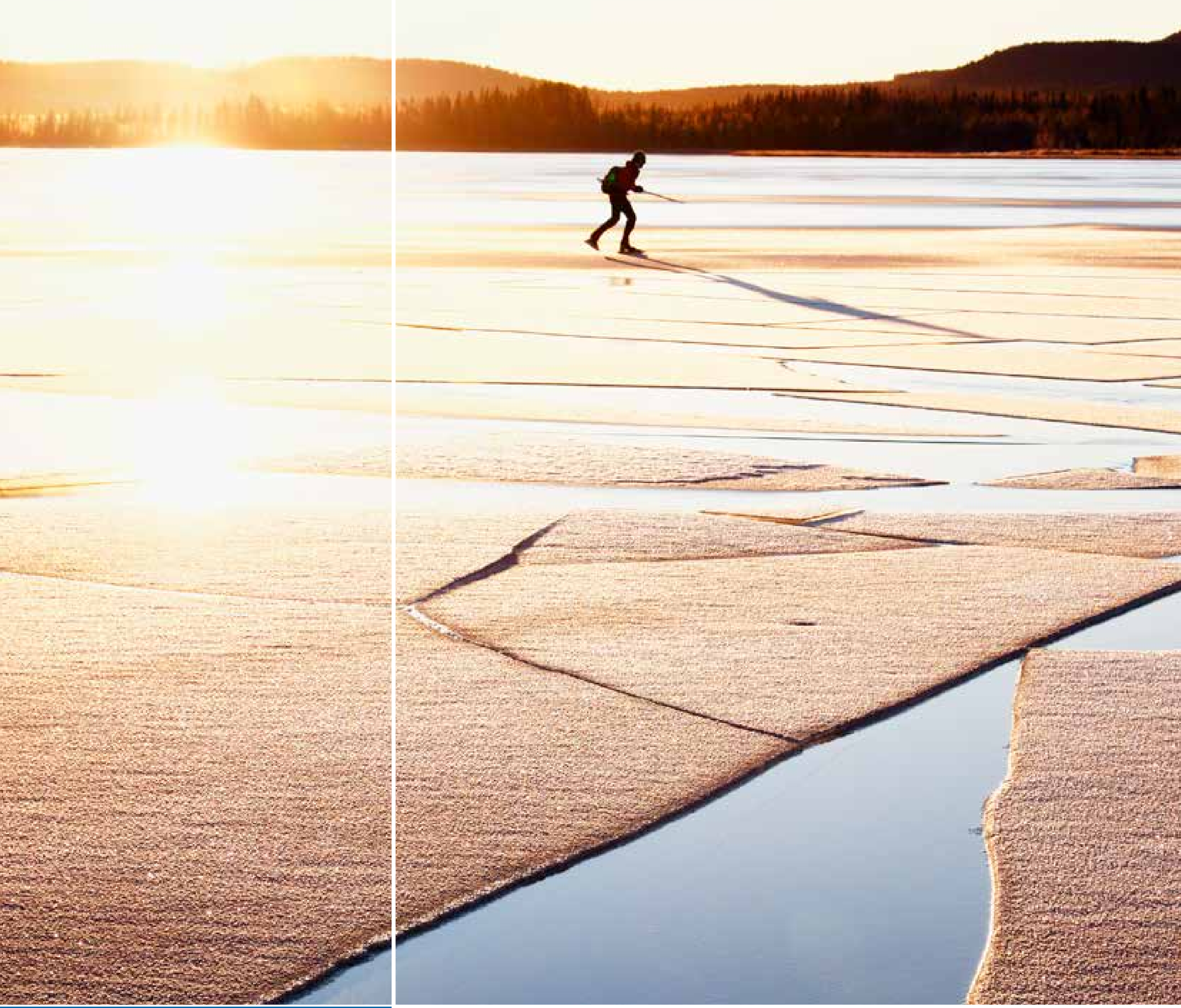

Climate change in Norrbotten County

– consequences and adaptation

Revised version with regional climate analysis from SMHI.
April 2016

County Administrative
Board of Norrbotten

THE COUNTY ADMINISTRATIVE BOARD in Norrbotten County, like all county administrative boards in Sweden, is commissioned at regional level to coordinate work to adapt to changed climate.

The commission involves coordination, consultation and support to municipalities and regional actors in their climate adaptation work.

This report is an update of *Climate Change in Norrbotten County – consequences and adaptation.* County Administrative Board report series, no. 2/2012. The report contains new climate analyses and text from SMHI Klimatologi issue 32, 2015 of Framtidsklimat i Norrbotten.

Introduction

THE EARTH'S TEMPERATURE IS RISING

Global warming is ongoing- in all probability is due to humanity's emissions of greenhouse gases. The rising temperature affects the global, regional and local climate.

Global climate change can affect Northern Sweden through changes in precipitation quantities, rising daytime temperatures, rising water levels and more frequent extreme weather events. And that in turn means increased vulnerability of buildings, infrastructure, critical public services and business. The warmer climate will also offer new opportunities. The growing season is lengthening in forestry and agriculture, and the ice-free shipping season is becoming longer.

The vulnerability of Swedish society to climate change is largely dependent on how much the climate changes and how quickly it occurs, as well as on how well prepared society is to meet the changes. Climate change affects all sectors of the community. Even if we radically reduce our emissions of greenhouse gases today, it will take time for warming to slow. We must also count on changes in the risk of extreme weather. That means we must adapt to both today's climate and the future climate.

The County Administrative Board in Norrbotten County, like other county administrative boards in Sweden, has been commissioned at regional level to coordinate the work to adapt to a changed climate. The commission involves collaborating with among other actors the municipalities in the county, since they are responsible for many vital social services which can be affected by a changed climate.

The commission means coordination, consultation and support to municipalities and regional actors in their climate adaptation work.

Through this publication, the County Administrative Board wishes to disseminate the latest findings on climate change and the results of the report Sweden facing climate change – threats and opportunities (SOU 2007:60) which have significance for Norrbotten. The County Administrative Board intends together with municipalities and other actors in the county to work to:

- Identify further areas which may be affected
- Draw attention to areas where there is need for more detailed investigations and documentation for planning
- Initiate adaptation measures
- Carry out actions to raise competence

The commission may be seen as a complement to work already going on to reduce greenhouse gas emissions and increase energy efficiency.


BEWARE
of falling snow

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The temperature is rising

In the 20th century, the mean global temperature rose by 0.7° C, which in a climate context can be seen as a significant and rapid change. Other signs of change are retreating glaciers, reduced ice cover in the Arctic, rising sea levels and changed precipitation patterns.

In an international perspective, for example with low-lying cities under the threat of flooding due to rising sea levels, Sweden is estimated to escape fairly lightly. As far as Norrbotten is concerned, the climate is estimated to give much milder and shorter winters. The consequences for the county are expected to be less dramatic than for the rest of the country, among other things because our coast in the north benefits from the considerable glacial rebound.

Climate change in Norrbotten County

Background to climate analyses in the report

THE UN CLIMATE PANEL in its report on the Earth's future climate (IPCC, 2013) presented results based on the new possible development pathways, so-called RCP scenarios (Representative Concentration Pathways). RCP scenarios describe the results of emissions of greenhouse gas, the so-called radiation balance, in the atmosphere up until 2100.

In 2014, the government tasked the Swedish Meteorological and Hydrological Institute (SMHI) with carrying out a study for Sweden based on these scenarios. In 2015, the Swedish Meteorological and Hydrological Institute was commissioned to draft climate analyses by county, based on the new climate scenarios. In the analyses, the future climate is described based on observations and calculations in two different RCP scenarios, low emissions (RCP4.5) and high emissions (RCP8.5).

The new analyses for the County of Norrbotten (SMHI Klimatologi no. 32, 2015: Framtidsklimat i Norrbottens län) include maps with climate scenarios for different time periods. They deal with temperature, precipitation, inflow and soil moisture, as well as information about snow. The climate analyses can be used for example for community planning, nature conservation, drinking water issues, agriculture and forestry.

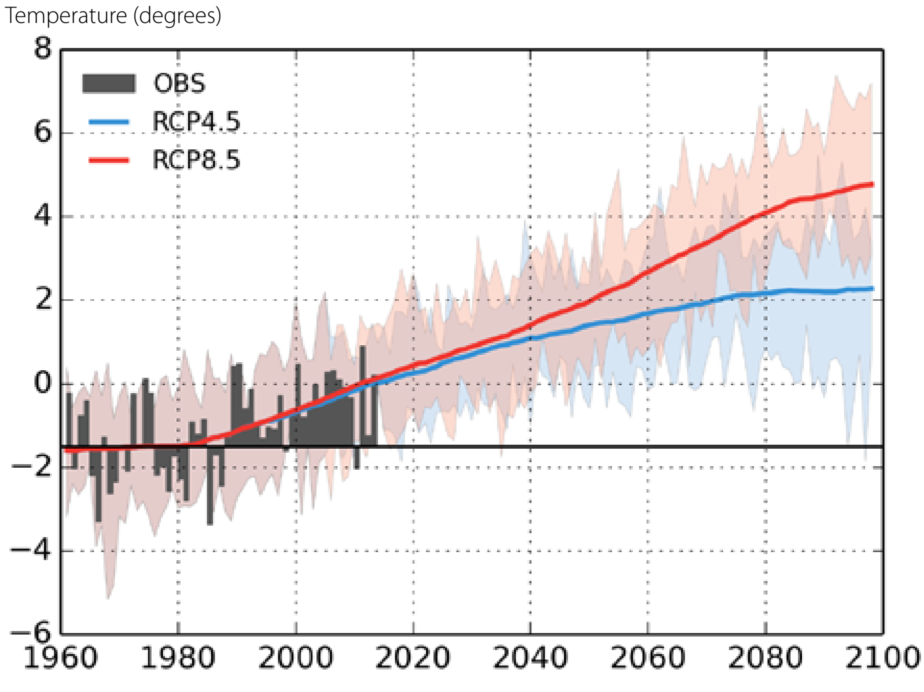
This report contains a selection of results from the county-by-county analysis from SMHI. At the end of this report you will find a register of the complete contents of the county-by-county analysis.

It is difficult to study the future, regardless of the aspects concerned. As regards the future climate, it is a question of highly complex processes. It is therefore not easy to answer all the questions about the future climate.

There are many uncertainties regarding how the climate will develop in all its aspects and how these changes will affect the environment and communities. At the same time, there is a great deal of information to be gleaned from the climate calculations that are made and the material that is presented.

Climate research is constantly presenting new results which can further modify the picture, and of which the reader should be aware. Interpretation of the graphs in the report should concentrate on long-term trends rather than absolute values.

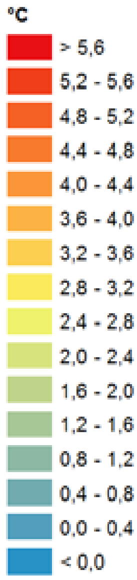
Read more on *www.smhi.se/klimat/framtidens-klimat/klimatscenarier.*



Changes in the mean annual temperature in Norrbotten.

The diagram shows the change in the county as a whole for the two RCP scenarios. Annual values of observed mean temperatures in Norrbotten are marked as bars. The bars show that the mean annual temperature in the county can vary by approximately 4°C. This year-on-year variation will remain in the future, as illustrated by the shaded fields in the diagram. The solid line shows running thirty-year mean values of scenarios to clarify trends. The temperature is expected to rise by several degrees by the end of the century: under RCP4.5 by 3-4 degrees, while RCP8.5 shows a 6° increase.

Changes in the temperature



Estimated change compared to the time period 1960–1990. The maps show mean values over periods of time.

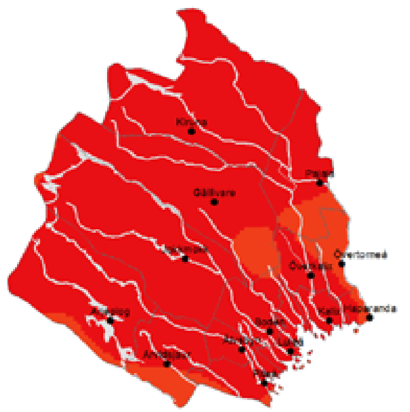
The values are geographically offset to make interpretation easier. The change is shown according to both RCP4.5 and RCP8.5.

In the report from SMHI Framtidsklimat i Norrbotten (Future Climate in Norrbotten), the mean temperature is also presented by year and season.

2021–2050	Mean annual temperature	2069–2098

RCP 4.5

RCP 8.5

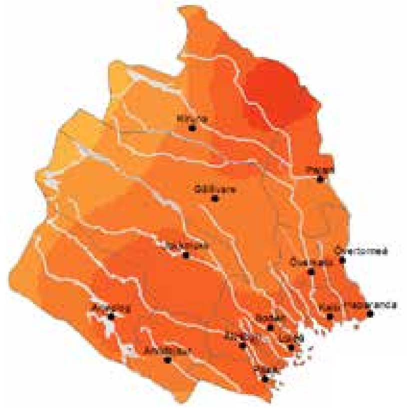


Change in mean temperature, winter

December–February

2021–2050		2069–2098

RCP 4.5



RCP 8.5

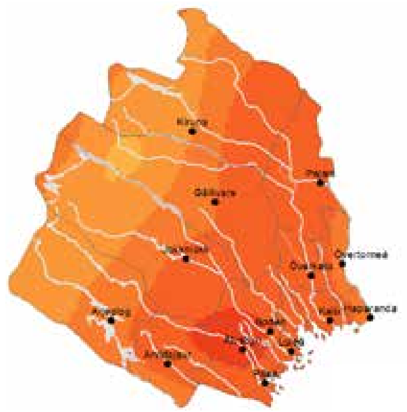
Change in mean temperature, spring

March–May

2021–2050		2069–2098

RCP 4.5

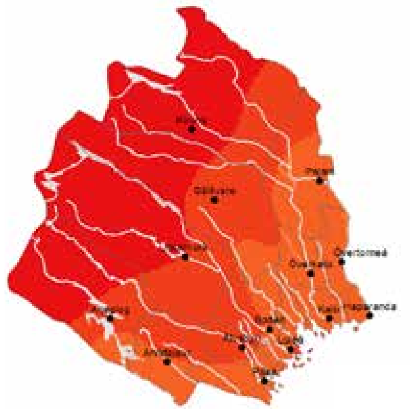
RCP 8.5



2021–2050	Change in mean temperature, summer *June–August*	2069–2098

RCP 4.5

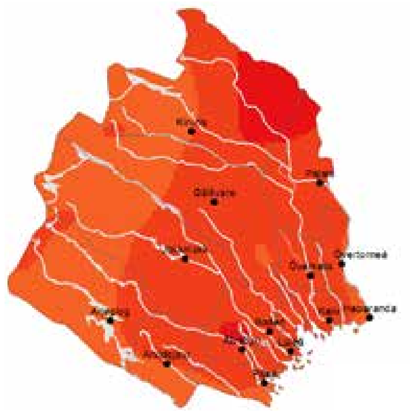
RCP 8.5

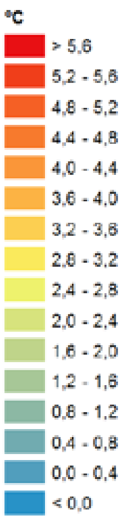


2021–2050	Change in mean temperature, autumn *September–November*	2069–2098

RCP 4.5

RCP 8.5





Changes in precipitation

Estimated future change compared to time period 1961-1990.

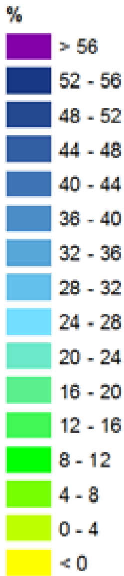
Mean annual precipitation in Norrbotten was 660 mm during the period 1961-1990. The range and snows most in the western part of the county, since the highest ground is there and our weather systems usually come from the west.

In the future climate, precipitation is expected to increase. The increase is greatest in the RCP8.5 pathway, approximately 40 % by the end of the century, while the RCP4.5 pathway gives an increase of about 20 %. The maps show that the increase is greatest in the area north-west of Gällivare.

The maps for the seasons show the mean aggregate value for precipitation per 24 hours for each season.

The values are geographically offset to make interpretation easier. The change is shown for both the RCP4.5 and the RCP8.5 pathway.

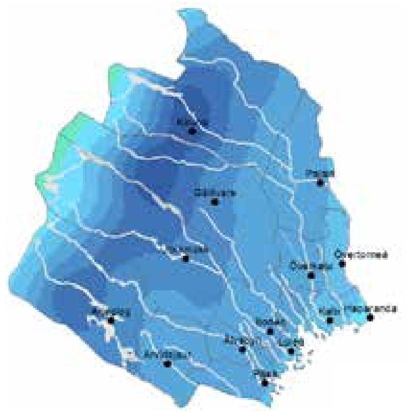
In the SMHI report Framtidsklimat i Norrbotten, the calculated mean precipitation by year and season are both presented.



2021–2050	Mean annual precipitation	2069–2098

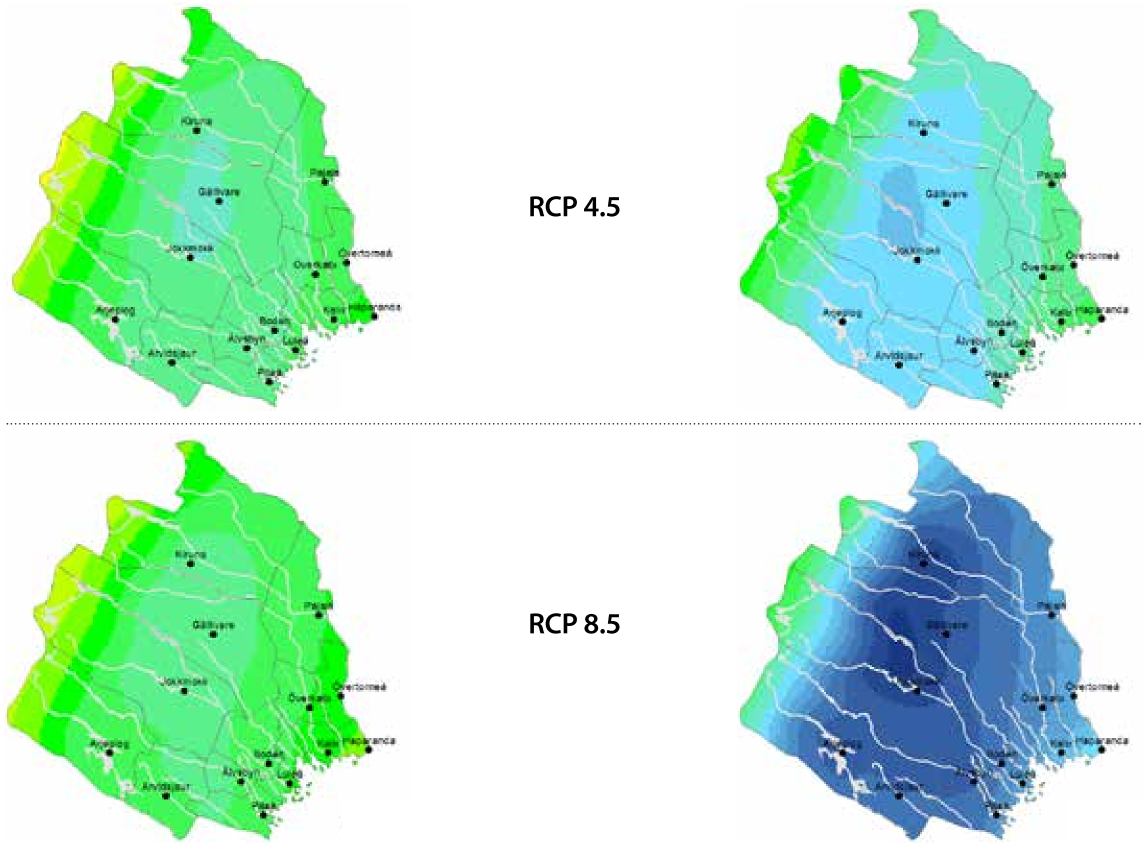
RCP 4.5

RCP 8.5



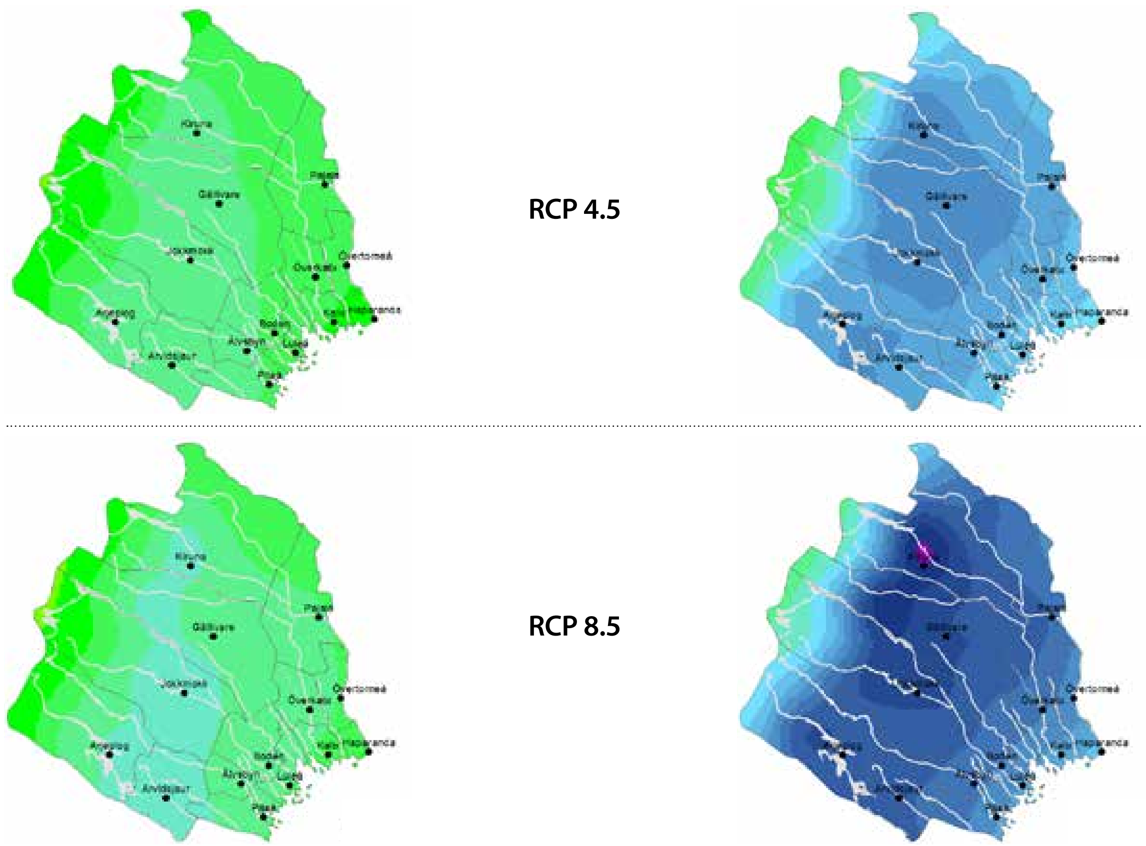
2021–2050 **Change in mean precipitation, winter** **2069–2098**

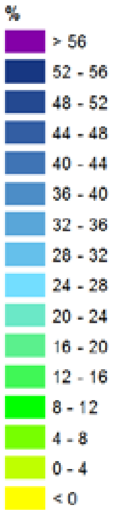
December–February



2021–2050 **Change in mean precipitation, spring** **2069–2098**

March–May





Change in mean precipitation, summer

June–August

2021–2050 | **2069–2098**

RCP 4.5

RCP 8.5

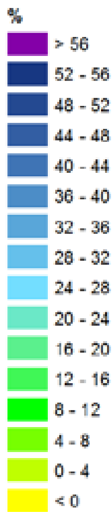
Change in mean precipitation, autumn

September–November

2021–2050 | **2069–2098**

RCP 4.5

RCP 8.5



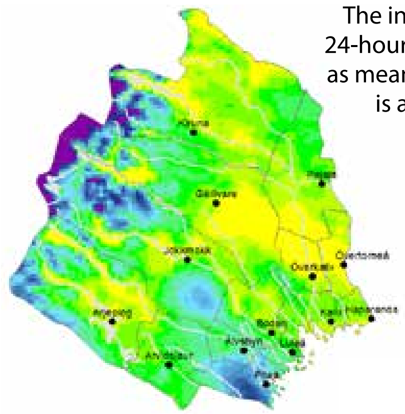
2021–2050	No. days with more than 10 mm precipitation	2069–2098

The maps show the mean values for each year's total number of days when precipitation exceeds 10 mm. It is a measure of the occurrence of large rain quantities which can lead to flooding.

RCP 4.5

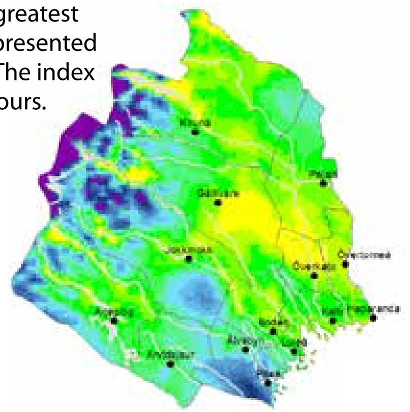
RCP 8.5

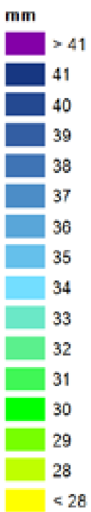
2021–2050	Maximum 24-hour precipitation	2069–2098

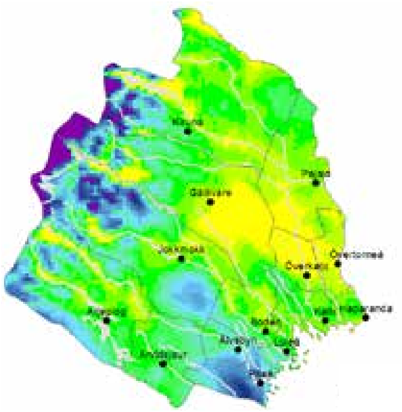


The index is a measure of the year's greatest 24-hour precipitation. The results are presented as mean values for the stated period. The index is a measure of the risk of downpours.

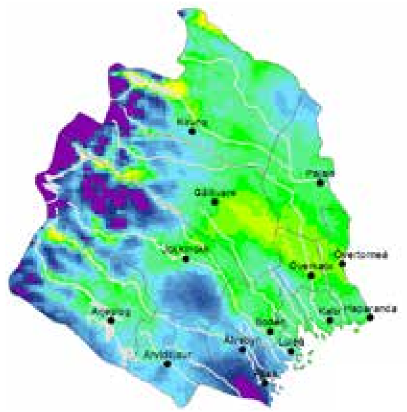
RCP 4.5







RCP 8.5



Snow cover

Number of days with snow cover with at least 5 mm water content

The map images show the number of days of snow cover with at least 5 mm water content. It gives an idea of how long on average the ground is snow-covered and can be of interest in the planning of infrastructure, tourism and outdoor recreation facilities, reindeer herding, nature conservation actions and environmental monitoring.

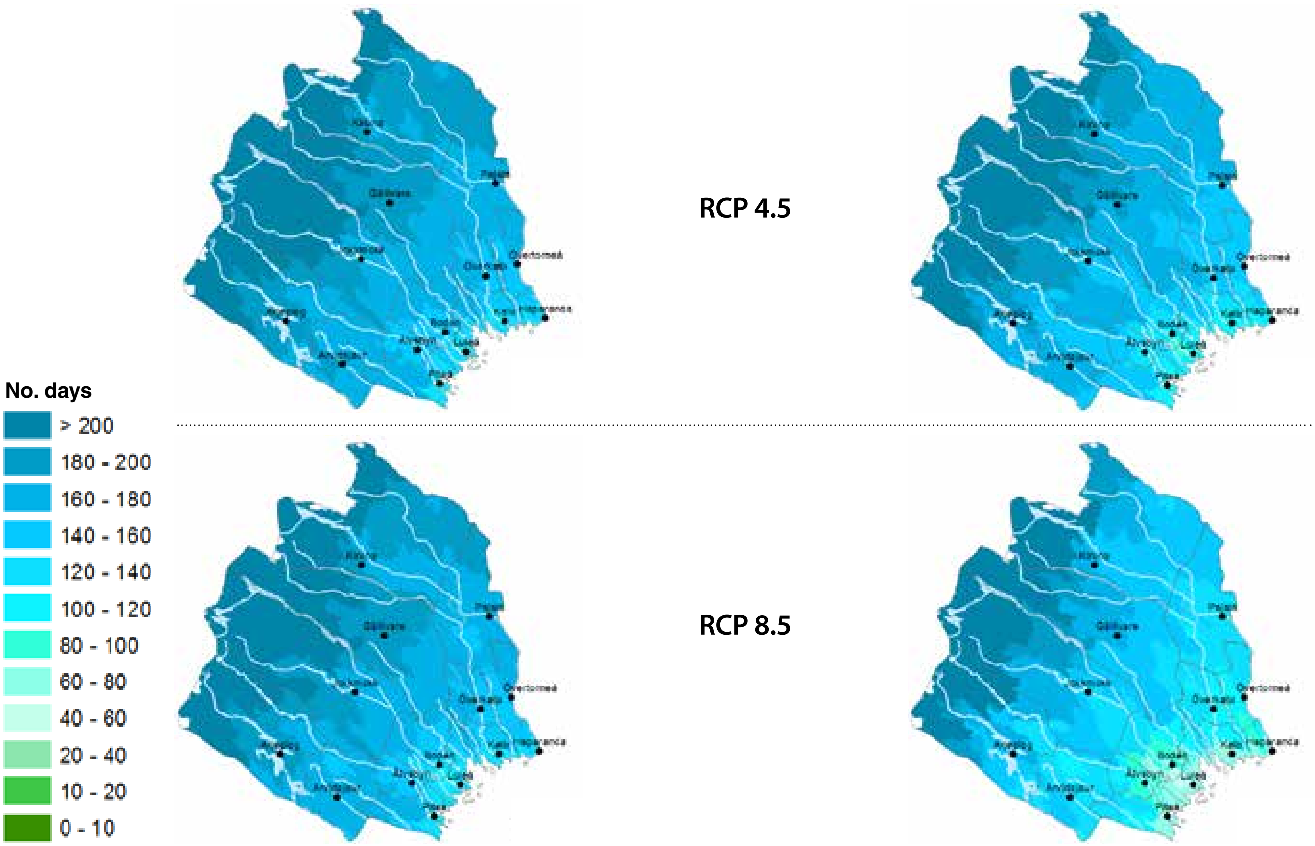
Number of days with snow cover with at least 20 mm water content

The map images show the number of days of snow cover with at least 20 mm water content. This can be interpreted as the number of days when skiing conditions are good. The maps give an idea of how snow conditions change and can therefore be used for long-term planning of tourism and outdoor recreation facilities.

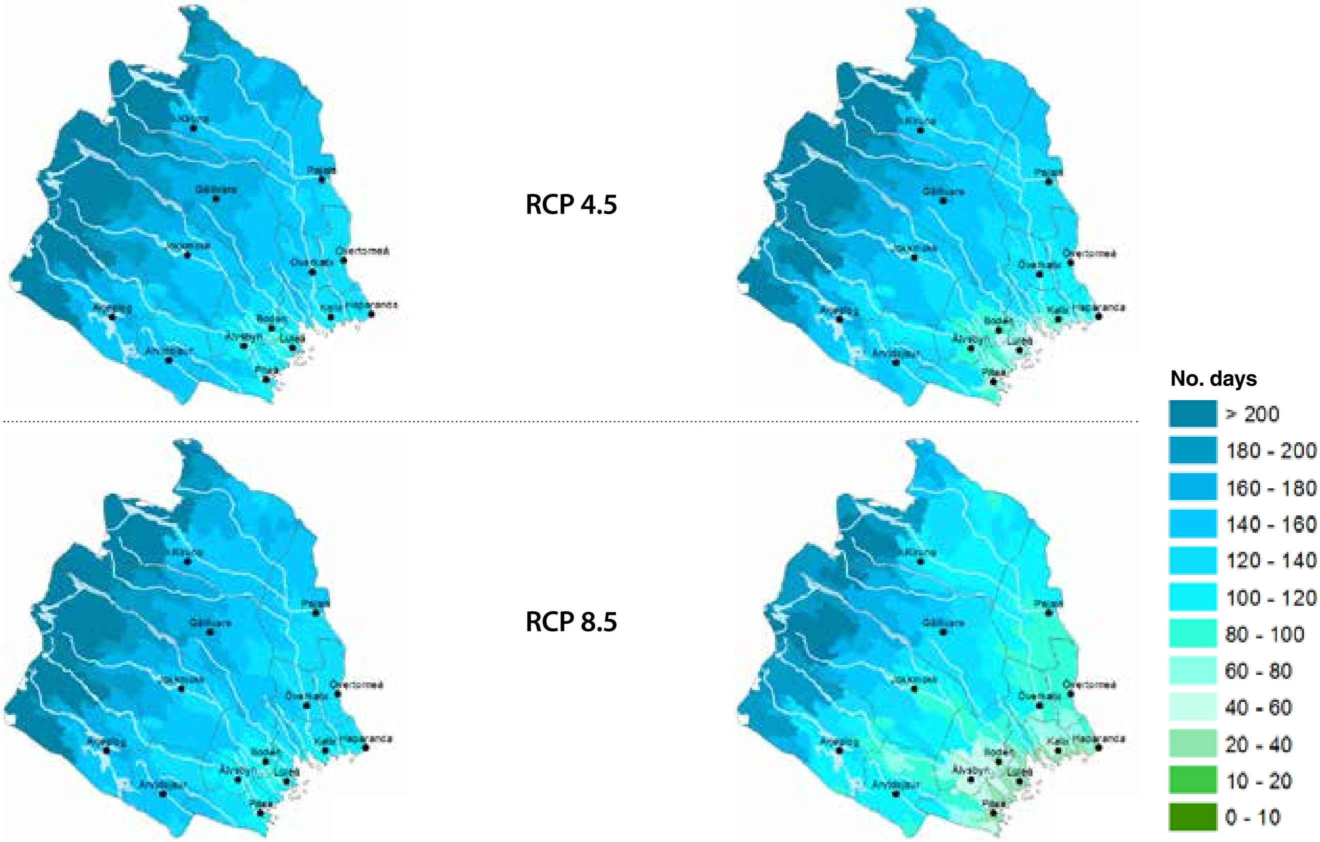
Changed maximum snow cover

The index indicates the maximum (greatest) snow cover in terms of water content. The maps show as a percentage the change compared to the mean values for the reference period. The index gives an idea of the maximum amount of precipitation that is stored in the snow cover in winter. This is significant to the water flow in spring and is of interest in hydropower regulation. The index can also be interesting regarding snow loads on structures.

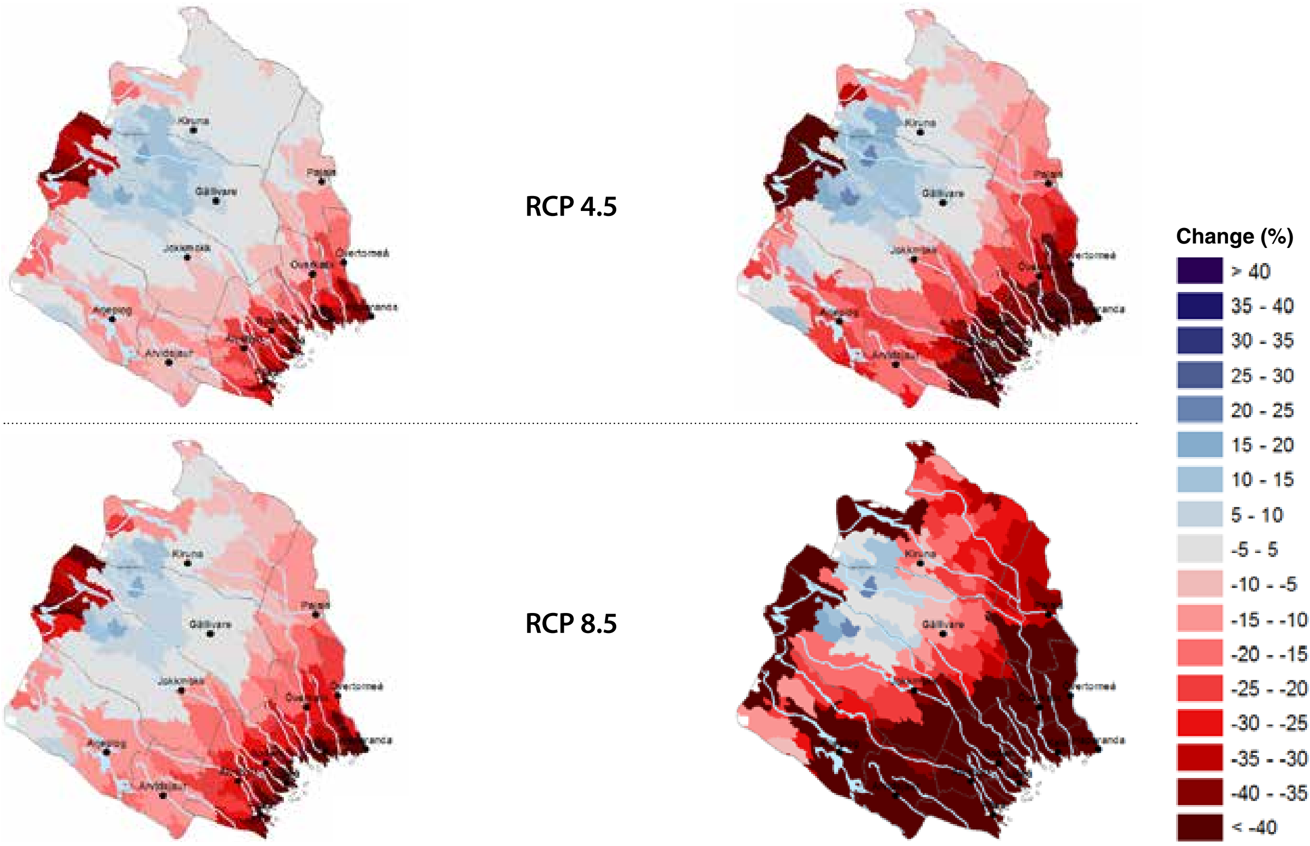
2021–2050 | **No. days with snow cover with over 5 mm water content** | **2069–2098**



2021–2050	No. days with snow cover with over 20 mm water content	2069–2098

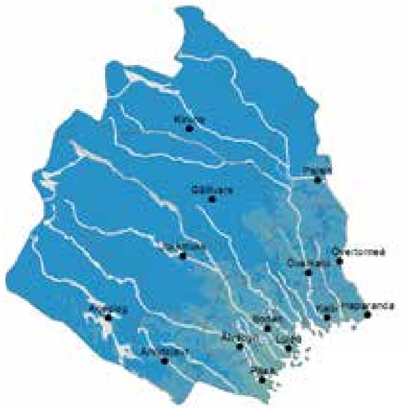


2021–2050	Changed maximum snow	2069–2098



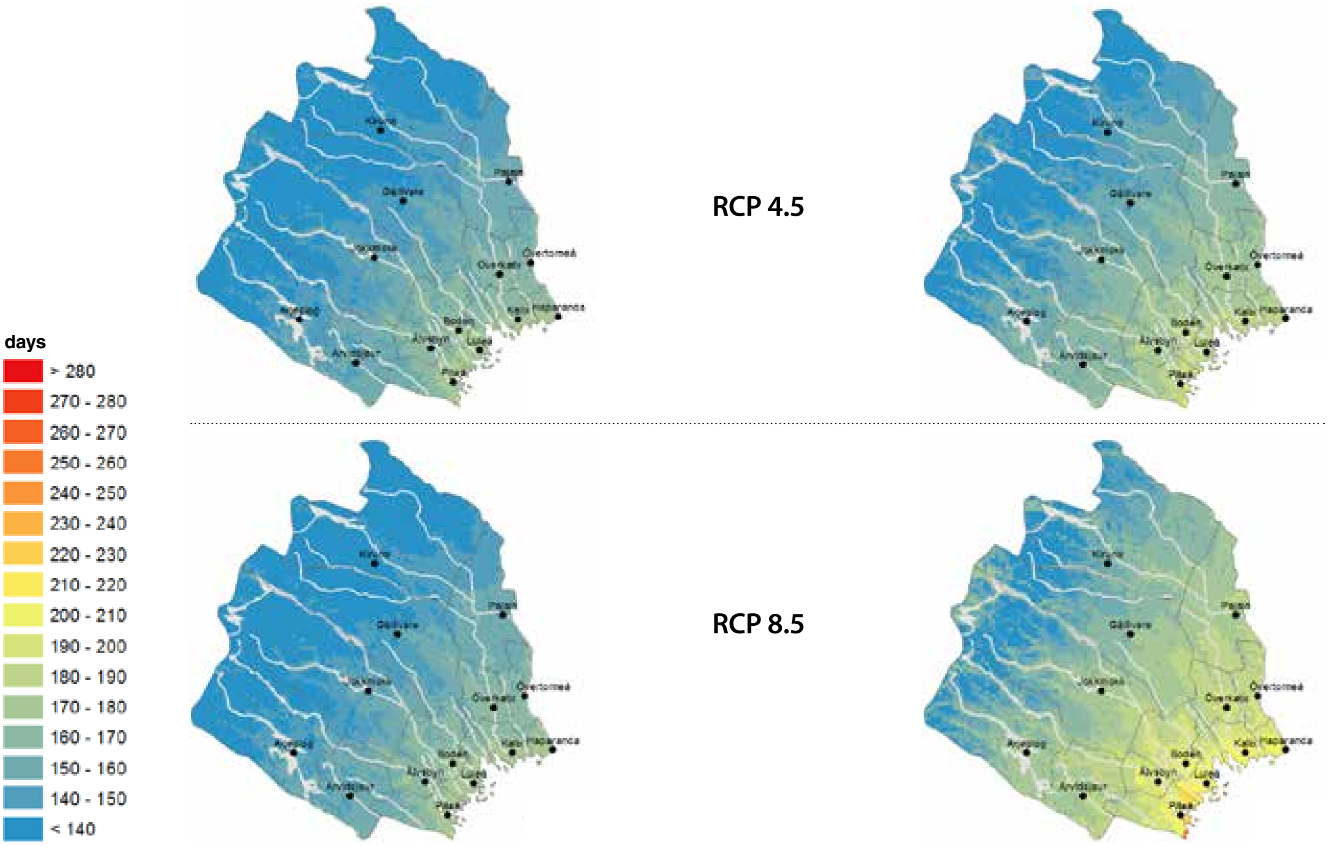
Growing season

The length of the growing period
The length of the growing period is defined as the difference between its starting point and finishing point. The starting point is the first day in the year in a continuous four-day period when the mean 24-hour temperature is above 5°C. The finishing point is the last day of the year's last continuous four-day period with a mean 24-hour temperature above 5°C. The index is based solely on temperature and does not take into account solar irradiance.



Observed length of growing season 1991–2013

2021–2015	Growing season length	2069–2098



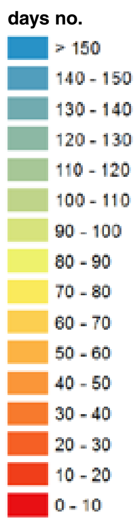
Start of growing period
The starting point is the first day of the year in a continuous four-day period when the mean 24-hour temperature exceeds 5°C. The index is based solely on calculated temperatures and does not take into account solar irradiance. Together with the length of the growing period, the index gives an indication of future conditions for sowing and harvesting times.

Observed start of
growing period 1991-2013

2021–2015	Growing season start	2069–2098

RCP 4.5

RCP 8.5



Inflow

The maps on the following pages present calculations of future hydrological conditions regarding total inflow. As regards Norrbotten, the observed increase in total inflow is approximately 10-15% by mid-century, an increase which will continue until the end of the century. The diagrams indicate that the increase in inflow by the end of the century will be approximately 10-30 % for RCP4.5 and approximately 20-40 % for RCP8.5.

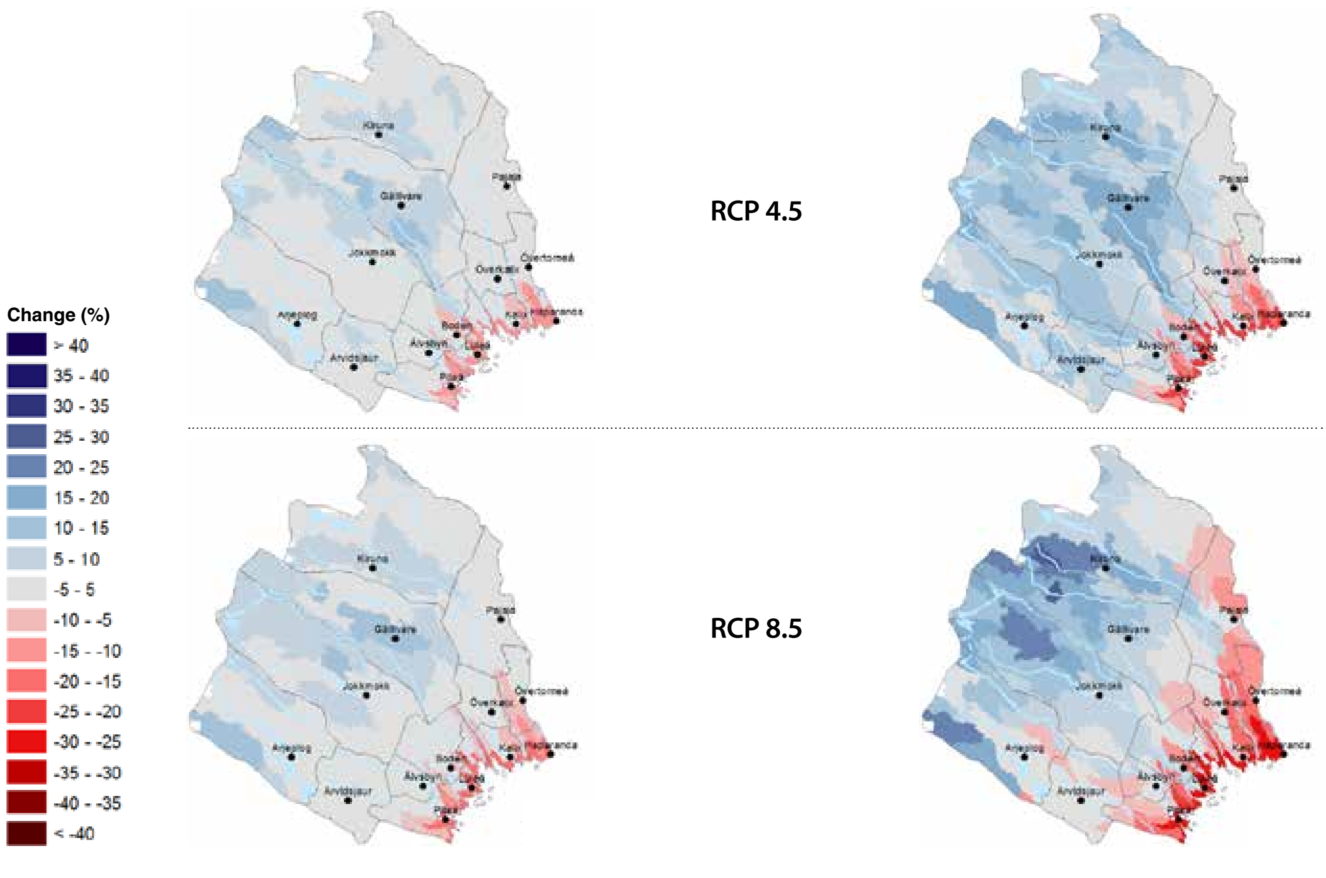
The biggest change in total inflow will be as regards the winter period, and nearing mid-century a general increase is seen countywide. The increase will continue until the end of the century and the difference between the two scenarios is indicated. RCP8.5 gives a particularly big change in winter inflow and shows by the end of the century an increase of over 100 % for most watercourses. Even the lower scenario, RCP4.5, gives major increases for all watercourses (40-100 %).

In springtime an increase is seen in the total reduction or unchanged total inflow for most of the watercourses. The exception is the Lule River at Staloluokta, where the inflow will increase somewhat until the end of the century. The difference between the two RCP scenarios is small.

Changed total ten-year inflow

The maps show the change as a percentage compared to the mean value for the reference period. The index refers to the total 24-hour average inflow with a return period of 10 years. The maps and diagrams give an idea of how relatively frequent high flows will increase or decrease and where this will take place. This is of particular interest to areas today prone to flooding.

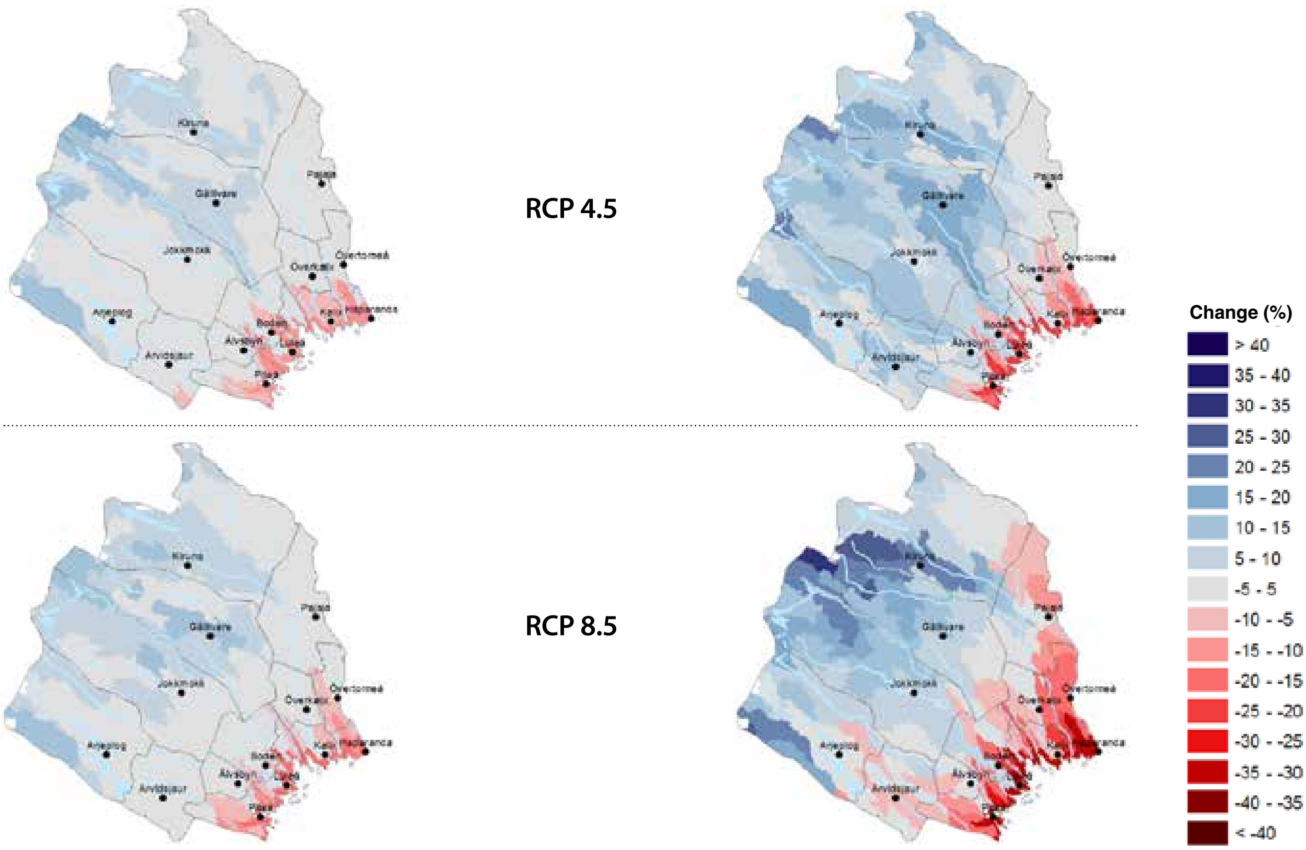
2021–2015	Changed total 10-year	2069–2098



Changed total 100 year inflow
The maps show as a percentage the change compared to the mean value for the reference period. The index refers to total mean 24-hour inflow with a return period of 100 years and can offer help in assessing flooding risks around lakes and watercourses.

The maps show close similarities to the ten-year inflow with decreasing 100-year inflow for most watercourses in the south-east part of the country, and an increase in the mountains.

2021–2015 **Changed total 100-year inflow** 2069–2098



Annual dynamics of inflow in large watercourses in Norrbotten

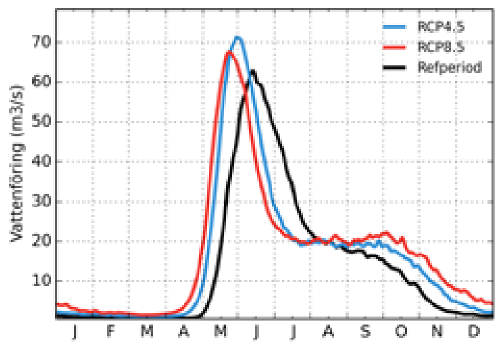
Inflow varies from year to year and throughout the year depending on the interaction between and variations in precipitation, temperature, snow cover, ground moisture and evaporation. As regards the watercourses however we usually see recurring annual dynamics throughout the year. Changes in seasonal processes can be of major importance to water supply, the environment and biodiversity, flooding risks and hydropower production.

In the figures, the mean values for inflow annual dynamics are shown. The black line represents the reference period 1963-1992 and the other two lines represent the future period 2069-2098. The blue line denotes the mean value of calculations according to RCP4.5 and the red line represents corresponding data for RCP8.5.

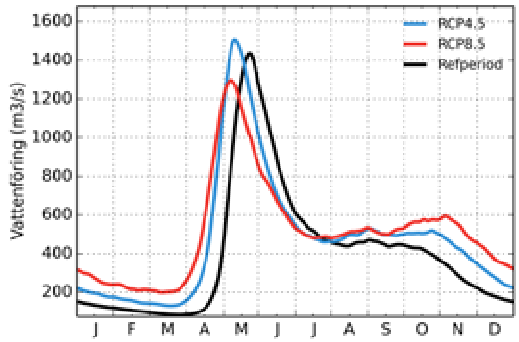
All watercourses show clear seasonal patterns through the reference period, with spring flow peaks, low summer flows, higher autumn flows and lower winter flows. There are of course variations between the different areas and variations from year to year.

The future scenarios show earlier spring flow peaks and higher winter and autumn flows. The change in inflow in summer is not as pronounced, and varies from area to area. For the more southerly watercourses, the effect on the dynamics throughout the year is towards a more equalised pattern with higher inflow during autumn-winter and lower during spring-summer. For these watercourses, the summer inflow also appears to decrease, and the season starts earlier.

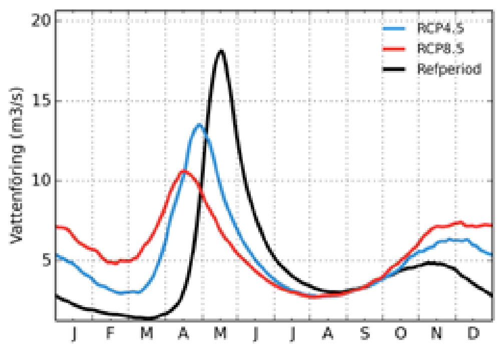
There are also diagrams for the period 2021–2050. For this period, the difference with regard to the reference period is judged to be less pronounced.



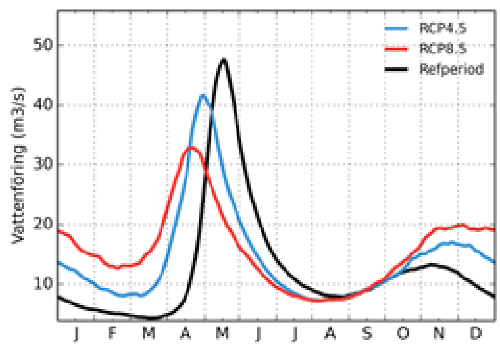
Upper Abiskojokk River



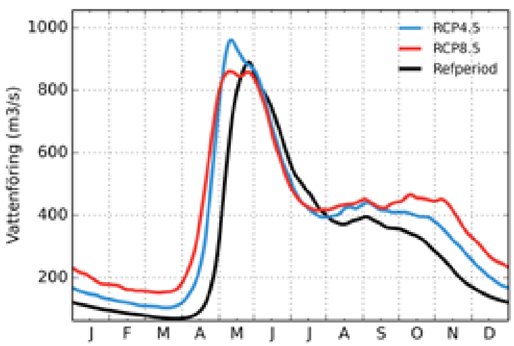
The River Torne



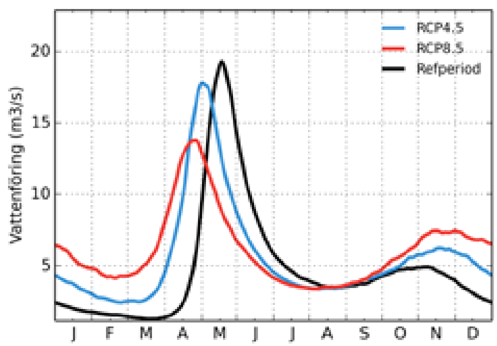
Keräsjoki River



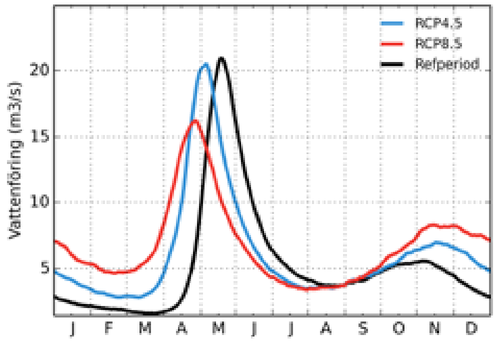
The River Sangis



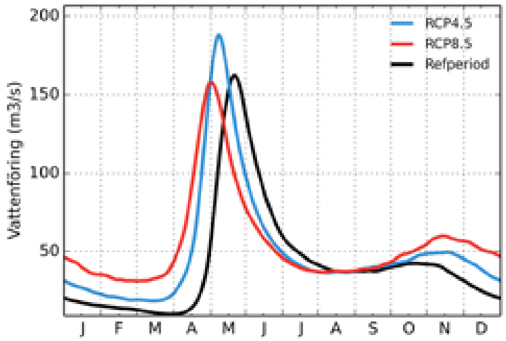
The River Kalix



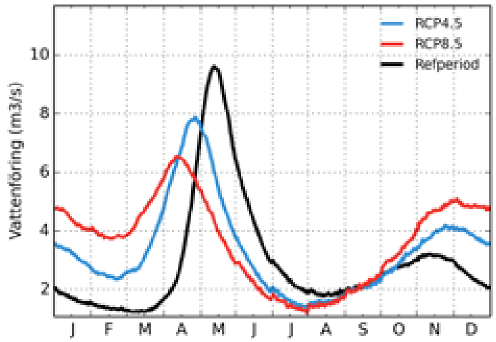
The River Töre



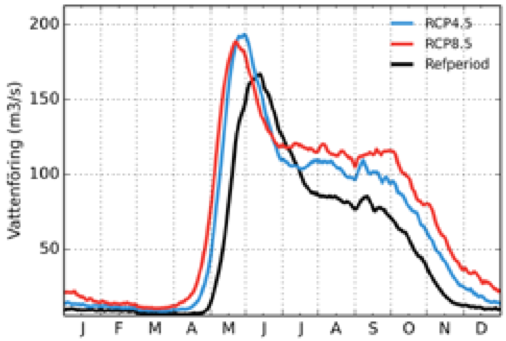
The River Jämtö



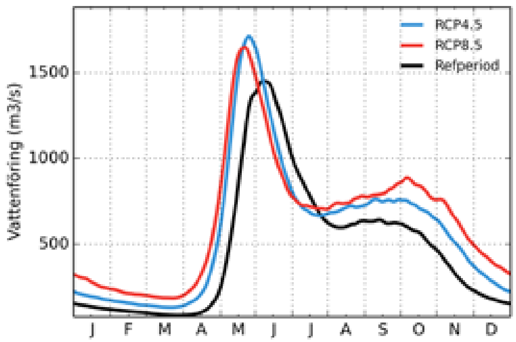
The River Råne



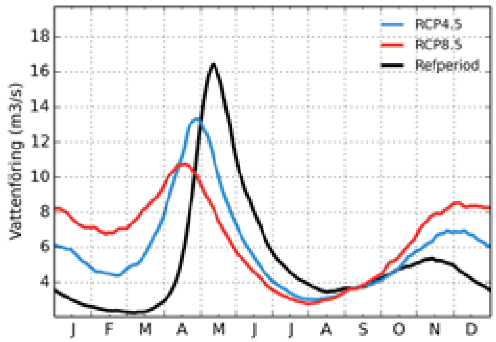
The River Altersundet



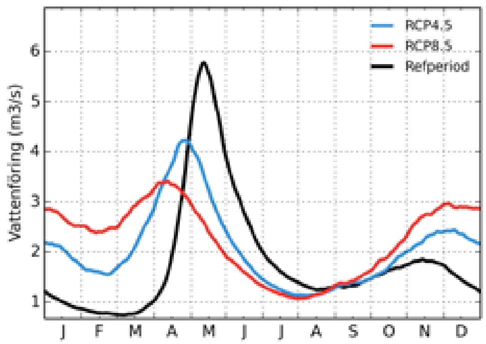
The River Lule, Saltoluokta



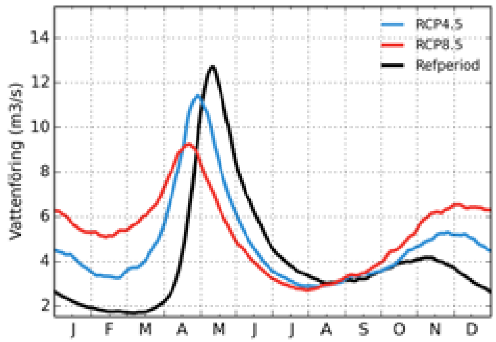
The River Lule



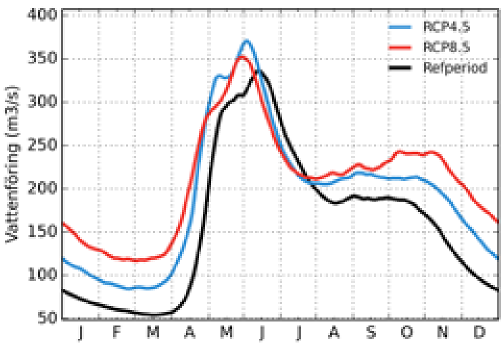
The River Alån



The River Rosån



The River Alter

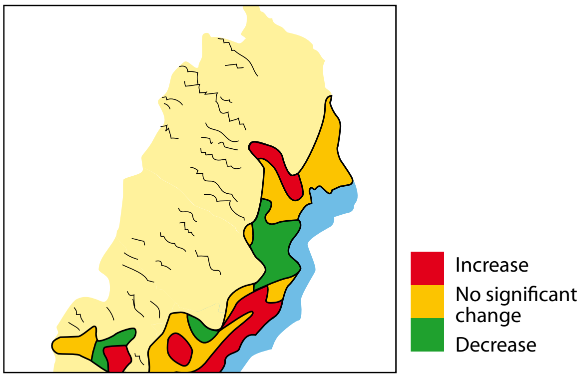


The River Pite

Soil conditions[4]

There is further material in the SGI report *Översiktlig klimat- och sårbarhetsanalys – naturolyckor (dnr 2-1006-0454).*

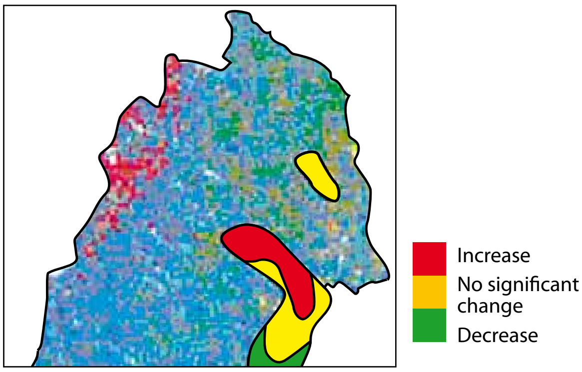
Erosion



Changes in tendency towards erosion due to climate change up until the period 2071-2100.

In parts of northern Sweden the tendency towards erosion will increase due to increased precipitation and thereby increased run-off. Outside the marked areas on the above map, there are other smaller areas which may be sensitive to erosion, for example areas of glacial lake sediment

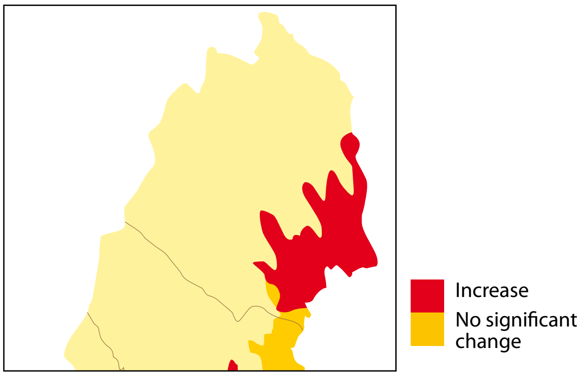
Ravine development



Change in tendency towards ravine development due to climate change up until the period 2071-2100.

In northernmost Sweden there are areas where the tendency towards ravine development will increase due to increased precipitation and thereby increased run-off.

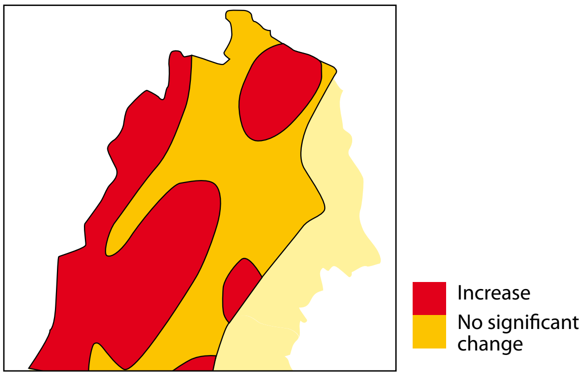
Landslides and collapse



Change in the tendency towards landslides and due to climate change up until the period 2071-2100.

In the coastal regions of Norrbotten the frequency of collapse and landslides is expected to increase due to increased precipitation and therefore increased run-off and increased pore pressure.

Moraine slides and turbidity currents



In the mountain regions of northernmost Sweden, the tendency towards moraine slides and turbidity currents will increase due to increased summertime precipitation and higher frequency of intensive rain and thereby increased erosion.

[4] SGI Varia 571 general assessment of earth movements in connection with changed climate.

Consequences and adaptation proposals

The following compilation highlights how society can be affected by increased vulnerability as a consequence of climate change. The emphasis is on consequences that are estimated to occur in a longer perspective. The material is based on information from the state *Commission on Climate and Vulnerability (SOU 2007:60).* The selection comprises factors relevant to Norrbotten County as regards the consequences of climate change and extreme weather events, as well as the adaptation measures proposed by the *Commission on Climate and Vulnerability.* The SMHI report climate analysis for Norrbotten County and the SGI report *Översiktlig klimat- och sårbarhetsanalys* (General Climate and Vulnerability Analysis) form the basis for the material.

The description of consequences and proposed adaptation measures has been divided into the following seven areas:

- Communications
- Technical supply systems
- Structures
- Land-based industries and tourism
- Natural environment and environmental goals
- People's health
- Effects of global change

Communications

THE RISK SITUATION for roads and railways is affected by how surrounding areas look and how they are used. Also, the design of constructions forming part of road or railway structures affects the risks.

As regards the surroundings, topography, soil type and the effects of water are the most significant factors. Steep inclines, soil types such as silt, clay and sand, and the effects of precipitation and running water can have a negative impact on stability. Where these factors combine, for example along many of the river valleys in northern Sweden, safety levels may be low. The risk of flooding is naturally greatest in low-lying areas adjacent to lakes or watercourses.

The use of surrounding land is also of crucial importance to safety with regard to landslides, collapse and erosion. The changes in risk levels can take place over a long period or almost immediately. One example of creeping change is drainage installed in surrounding forestland or farmland but subsequently not maintained. Dam constructions that are not maintained upstream of roads or railways can also present risks through collapse. Rapid changes can be due to forest felling, whose effects can be made even greater by subsequent scarification.

Exploitation of natural land for paved surfaces, or the new construction or alteration of surrounding structures also affect the run-off situation.

The design of road and railway structures also has an impact on the risk of landslides, collapse and erosion. This applies to the design of dewatering installations such as ditches, culverts and drainage, the extent of erosion barriers and the resilience and design of earth constructions.

Roads

Roads	Technical life in years (median)
Road surface	25
Pavement structure	50
Bridge, span >200m or tunnel, >1000m	150
Other bridges, tunnels	100

Consequences

Climate change has a long-term effect on the decay of roads, both as regards load-bearing capacity and durability. Temperature and water supply (seasonal ground frost, run-off) are the most important climate factors in this context. Flooding of roads and underpasses is expected increase in the whole country.

The older road network is judged to be particularly vulnerable since high pore pressure was not fully considered when determining dimensions. There is practically no knowledge of which roads have inadequate safety margins.

Both state maintained and municipal roads will be affected by the consequences.

The frequency of landslides in clay and silt areas is expected to increase in the long-term along the coast of northernmost Sweden. For some road sections, conditions are unacceptable or will be, even in the short term with regard to landslide safety, ongoing ravine developments or landslides along sandy river stretches. The stability of steep sandy riverbanks is affected by climate change in the same way as in landslide and silt areas.

Damage to the road network

The frequency of road damage due to local intensive rain may increase considerably.

Roads may be wholly or partially (landslide, road washed away) damaged through erosion during high water flows. In the event of major road damage, indirect consequences can arise in the form of transport disruptions, damage to infrastructure and buildings.

Flooding will primarily affect low-lying roads near watercourses. The consequences will in general be limited to impact on the loadbearing capacity.

Bridges over small watercourses are judged vulnerable during increase water flows due to short-term intensive rain. Low-level bridges in combination with increased flow may dam up watercourses.

Subsequent erosion damage in the form of the washing away of bridge supports and pit formation in the foundation plate mean an increased risk of reduced load-bearing capacity. As regards the risk of road bridges being affected by high flows, this depends on the level of the bridge above the highest water level. Most vulnerable are the bridges built in the last 20 years and older bridges shorter than 8 m.

Decay of concrete structures

Construction elements of bridges are exposed to road salt and temperatures varying around zero. Owing to this, concrete structures in bridges age considerably faster than other concrete.

An increase in the number of zero crossings gives both more freezing cycles and more road salt, which increases decay and corrosion damage. In the inland areas of northern Sweden, possible introduction of salting could quickly lead to older bridges being affected by salt frost damage.

Ice accretion on bridges

In cold and humid weather, accretion can occur on cables and pylons. There is then a risk of lumps of ice falling on road users.

Temperature change

Increased temperatures and consequently shorter periods of seasonal ground frost can cause problems in areas where seasonal ground frost is used as a resource. This applies for example to industrial roads which are important in the region (for example in forestry). A changed seasonal ground frost period in combination with a higher water table can also increase the risk of road deformation.

A consequence of the expected increase in the number of zero crossings (occasions when the temperature changes from above zero to below zero or vice versa) is that freezing cycles will become more frequent. This can result in increased use of road salt, which in turn creates the need to protect drinking water reservoirs against the impact of the run-off of road salt (chloride).

Increased temperatures mean shorter winters, which can reduce the use of studded tyres, which in turn will reduce wear on roads.

PROPOSED ADAPTATION MEASURES

Risk inventory of vulnerable road sections. Coordinated analysis of the risk of landslides and flooding.

More attention to the risks of landslides and collapse when determining the dimensions of and constructing roads. Stricter functional demands.

Routines for monitoring land use that impedes or affects infiltration, pore pressure, run-off, etc.

Reduce risk of landslides by strengthening foundations, installing landslide warning systems and preparing/improving detour routes.

Reduce the risk of roads being washed away by protecting culvert openings from blockage, reinforcing Road embankments, installing extra culverts, extra maintenance of culverts.

Since extreme flows in small watercourses are expected to increase, it is urgent to identify and remedy vulnerable culverts under high road embankments.

Expanding and bringing forward studies regarding blockage of culverts and small tubular bridges.

When starting projects, make demands on the elevation of roads in relation to water levels.

Review dimensional requirements for roads and road embankments based on 100-year floods.

Increased monitoring and follow-up of new constructions.

Adaptation of winter road maintenance, with a recommendation for increased preparedness in northern areas of Sweden. Reclassifying for winter road maintenance.

The constantly ongoing replacement of bridges, development of the durability of concrete and the choice of anti-skid measures mean that the negative consequences of increased numbers of zero crossings can be reduced.

Snow volumes

The change in snow volumes is not judged to bring extra costs in a national perspective if there is a redistribution of funds from south to north.

Railways

The expected life of railway network facilities is affected by traffic intensity, maintenance frequency, and construction year. With continual maintenance, the expected life of the track can be up to 40 years. Points have an expected life of 20 years, culverts and bridges up to 100-years. The signalling system has a short expected life due to fast technological development.

The railway network is sensitive to climate factors such as intensive precipitation, high flows, long-duration precipitation, large snow quantities, higher temperatures, increased air humidity, increased number of zero crossings, as well as increased wind speeds and changes in the frequency of lightning storms.

Already, without extreme weather events, the disruption tolerance of the railway system is relatively low. The reserve capacity of the system consists of re-routing to other tracks, double tracks and minimised distance between stations where traffic regulation can take place. About 70 per cent of the network is single-track, mainly in northern Sweden. There is insufficient capacity to reroute traffic northwards from Västerbotten.

Consequences

Increased quantities of precipitation bring an increased risk of infiltration and erosion of filling material and track foundations, which means reduced load-bearing capacity. Sudden high flows mean a risk of the formation level and the foundation bed being washed through with consequent landslides and collapse. On slopes in mountain areas, the risk of turbidity currents will increase.

Higher flows bring a considerably increased risk of erosion of bridge supports, foundation beds, abutments and linking embankments. The conditions for erosion, collapse, landslides and turbidity currents are judged to increase in several parts of the country. During high flows or large quantities of precipitation, there can be a risk of leaching of dangerous substances or the expansion of areas contaminated by landslides.

The increased precipitation in the form of snow during the winter months will bring a greater need of clearance.

Increased winter temperatures, closer to 0°, can affect the mobility of points, since ice from vehicles falls loose more easily, blocking the points. Ice accretion on aerial lines in combination with stronger winds can mean a greater risk of destroyed facilities and subsequent traffic disruption in northern Sweden.

The higher summertime temperatures increase the risk of heat buckling.

PROPOSED ADAPTATION MEASURES

Mapping risk areas.

Review of dimension requirements regarding recurrence frequency and flow levels in view of climate change.

Erosion protection at bridges, culverts and other places where extreme flows can occur.

Increased resources for inspection, maintenance and track upgrading of existing facilities, for example de-watering facilities.

Set up models for risk-based assessment and identification of risk objects, e.g. objects bearing a higher burden than dimensioned for, and objects exposed to high flows.

In the long term there is a need for increased reserve capacity and possibilities to reroute above all freight traffic and passenger traffic along the coast of northern Sweden.

Continual monitoring of standards for determining dimensions and constructing aerial lines.

Increased collaboration and information sharing between different players, for example between landowners and those responsible for operation and maintenance of the railway network, so that risks that affect vulnerable constructions are reduced.


KRAFT JOHANSSEN

Shipping

Reduced sea ice in The Gulf of Bothnia will facilitate winter shipping. Generally, climate change will not lead to any negative consequences for shipping.

The season during which ships can use the maritime areas will be extended, which in turn means that sea rescue services will be called out during a longer annual period.

Aviation

The increased quantities of precipitation will burden the airports' stormwater systems. During heavy rain, run-off problems may occur. Reduced occurrence of seasonal ground frost, increased precipitation, higher water table and increased water flows can have a negative effect on the load-bearing capacity of airport surfaces. The more frequent occurrence of extrem eweather events can cause power cuts and can disrupt air traffic. Changed precipitation and temperature patterns in northern Sweden can result in an increased need for de-icing.

Luleå Airport is vulnerable, since its northerly location makes it difficult to transfer traffic and transport to other airports and transport modes.

PROPOSED ADAPTATION MEASURES

Complement airport surfaces with thicker pavement structure.

Renovate the stormwater system at airports.

Vulnerability analysis of the changed load-bearing capacity of tracks with regard to seasonal ground frost and groundwater.

Telecommunications

Sensitivity to climate and weather conditions

Fixed-line network overhead lines and mobile network masts and antennas are sensitive above all to strong winds, ice accretion, lightning, heavy precipitation and high flows due to flooding. Reliable electricity supplies are prerequisite to functioning telecommunications.

Consequences

Gradual adaptation to prevailing climate conditions will be carried out through replacing equipment in the system within the space of 10 to 12 years. In cases where overhead lines are retained, they may be affected by continued disruption. High flows can have consequences for facilities near water.

PROPOSED ADAPTATION MEASURES

Further analysis of the vulnerability of the telecom sector (PTS).

To secure the resilience of the telecom network there is a need to create clearer operator and management responsibility through contract wording (PTS).

Network proprietors should ensure that there are agreements with landowners to ensure trafficable routes to facilities.

Radio and TV broadcasting

Sensitive climate factors

In the event of extreme weather events, there may arise difficulties in distributing repair and maintenance materials to stations in isolated locations. Broadcasting requires an electricity supply.

Consequences of climate change

Strong winds and ice accretion affect masts and antennas. In mountain areas, ice accretion may occur on high ground.

PROPOSED ADAPTATION MEASURES

Ensure that there is reserve power at the facilities, as well as agreements with land-owners to secure a trafficable route to the facilities.

Technical supply systems

Electricity systems and power sources

The system of hydropower plants has a very long expected technical life. The expected life of the main grid is estimated at between 80 and 100-years. The expected life of the plants varies between 15 and 50 years.

The expected life of wind power plants is estimated at 20 to 30 years.

Risks and sensitive climate factors

In mountain areas, the risks are great during snowfall and storms. For inland areas in northern Sweden the same applies to snowfall. Power lines for the main grid are severely affected by ice storms, extreme ice and snow burdens in moderate winds, and extreme high winds without ice. The same applies to the rest of the grid. Here, water in the ground is an additional factor affecting stability. In the event of extreme weather events, difficulties may arise in distributing repair and maintenance materials to facilities in isolated locations.

PROPOSED ADAPTATION MEASURES

- Reconstruction work on local electricity networks in the form of underground installations.
- Reconstruction and extension of power plants and transmission capacity.
- Studies to identify facilities at risk of landslide, collapse and flooding.
- Clearance and widening of power line swaths for regional and local grids.
- Renewed corrosion protection for powerline pylons in areas with increased precipitation.
- Ensure access routes to facilities in isolated locations.

Consequences of climate change

As regards conditions for grid operations in Norrbotten, it is the mountain regions that are most vulnerable. Changes in precipitation and temperature conditions can result in disruptions to transmission. Increased vegetation growth can also cause problems affecting aerial lines. Extended periods of waterlogged ground can cause settlement damage.

Dams

The expected life is long and in all probability extends beyond 2100.

Consequences of climate change

Climate change can lead to a changed inflow cycle: greater inflow in the cold months and less in the warm months. When precipitation increases, and occurs at different times from today, it can mean greater sensitivity and therefore a greater risk when reservoirs are well filled.

When precipitation increases, and occurs at different times from today, it can mean greater sensitivity and therefore a greater risk when reservoirs are well filled. If the capacity of mountain reservoirs is used to 80-90 per cent then a situation arises where there is increased sensitivity to large quantities of precipitation over wide areas. There is a risk that water will need to be spilled from these reservoirs, at the same time as high discharge from tributaries will need to be managed. The biggest increases will occur in the northernmost rivers. The pressure on spillways will increase and they will need to be used more often during the winters.

Increased run-off, particularly when reservoirs are filled near capacity, can lead to increasing flooding problems, among other things affecting buildings, when watercourses act as if undeveloped. This can lead to increased demands from the public for flow attenuation, for which Swedish hydropower dams are not constructed. Attenuation can increase the risk to the dam if the attenuation capacity of the reservoir is used before the inflow has culminated. For flow attenuation to be effective and secure makes far-reaching demands on among other things margins and knowledge, on the hydrology of the watercourse and on the capacity of dams to resist and accommodate high flows. Dam safety must be given priority over interests wanting to reduce flows to reduce flood problems. As regards dam safety, extreme flows are the overriding climate factor. Increased quantities of precipitation and increased flows may change the conditions upon which earlier water-rights court rulings have been based.

There is considerable uncertainty over the future climate, but this should not prevent necessary measures to increase dam safety. Due to this uncertainty, flexibility and margins should in addition be created where appropriate.

It is difficult to draw any general conclusions about how the sized/ estimated flows will be affected by climate change. There is a risk that the increase in today's 100-year floods in the mountains can spread through the entire watercourse as far as the estuary. There will be an increased risk of breaches at small dams and embankments.

PROPOSED ADAPTATION MEASURES

Development of analyses of high flows and risks in regulated linked to climate change. Studies and comparisons of past flow situations and flow dimension estimates.

Review of dam safety regarding whether the current system meets the requirements that today's and tomorrow's climate will call for.

Make an inventory of all dams in the county and investigate aspects of ownership and responsibility.

Dam owners should ensure that trafficable access routes are available.

Analysis of inflow patterns.

Spread knowledge of climate change to responsible dam owners.

With regard to tailings reservoirs, the consequences of dam breaches and ownership matters need to be investigated.

To reduce the degree of uncertainty, calculation data should be regularly reviewed. Uncertainty must not be allowed to impede the introduction of safety improvement measures.

Follow-up and analysis of climate events that occur.

Heating and cooling needs

Consequences of climate change

The rising winter temperature in northern Sweden and reduced incoming solar radiation in the summer mean that future energy needs for heating buildings will probably diminish in northernmost Sweden.

For northern Sweden, energy needs for heating buildings is expected to decrease as follows:

Period	Reduction in heating energy needs
2011-2040	12 per cent
2041-2070	18 per cent
2071-2100	28 per cent

The need for comfort cooling is judged to apply mostly to premises in southern and central Sweden. No corresponding assessment has been made for dwellings. In the long term, it is judged that comfort cooling will be in use in 50 per cent of the premises in northern Sweden. It is judged that the demand for comfort cooling is only to a small extent dependent on the climate. Some premises where there is a good deal of apparatus or processes generating heat may also have cooling needs in the winter.

PROPOSED ADAPTATION MEASURES

To utilise the positive effects of the warmer climate, the possibility to raise the efficiency of energy use should be investigated, since there is major potential to increase efficiency, both in existing and new buildings.

District heating

Expected life

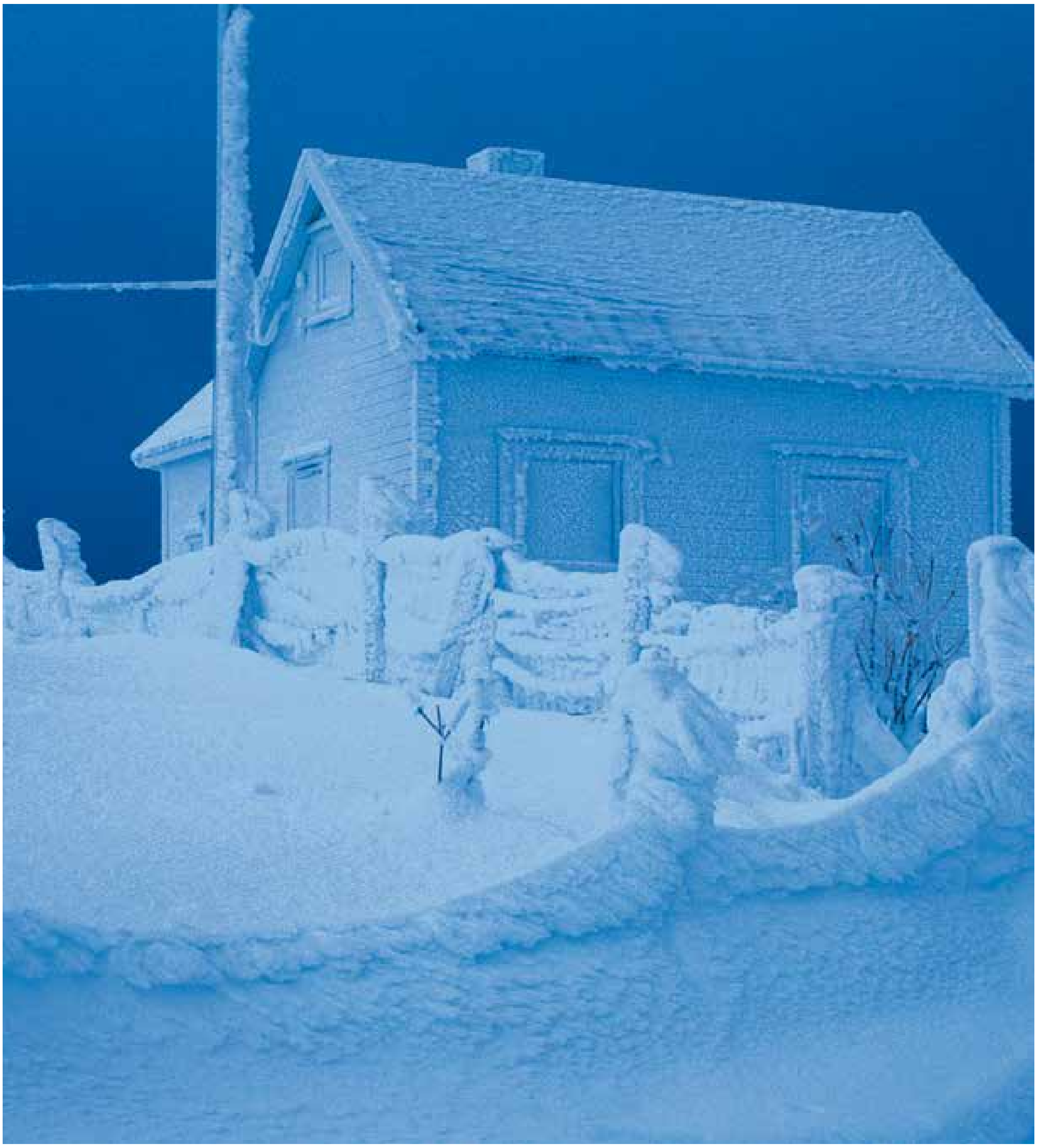
The expected economic life is normally 30 years, but can be shorter or longer, depending on quality. The earliest assembled district heating pipes probably need to be replaced fairly soon.

Sensitive climate factors

Above all, district heating distribution is sensitive to heavy precipitation, flooding and high water tables.

Consequences of climate change

With increased quantities of precipitation and the consequent water table rise, district heating



pipe lines can be exposed to water to such an extent that the expected life is shortened. It is probable that the increased amount of water will also lead to ground displacement, which can lead to serious stress on district heating pipe lines. Flooding in electric supply mains routed through tunnel systems can lead to disruptions in district heating. With increased quantities of rain and water coming into contact with power lines, there is an increased risk of disruption, above all in the case of older power lines near production facilities. District heating production is dependent on functioning infrastructure, and if it is affected by disruptions, the capacity to deliver is affected.

PROPOSED ADAPTATION MEASURES

It is recommended that trade organisations update instructions on how to build district heating and cooling systems, so that they provide knowledge of how to adapt to a changing climate.

Identify the district heating sections that are particularly sensitive to climate change.

Replace weak points in today's distribution systems with products of the right construction and quality.

Drinking water

Consequences

Climate change will probably lead to increased quantities of precipitation, possibly consequent flooding and higher levels of both the water table and surface water. This increases the risk of contaminants entering reservoirs and catchment areas.

Contaminants can come from roads carrying traffic (increased road salt), polluted areas of land, overfilled tanks, sewage systems, grazing land, landfills, industries and industrial land, polluted sediment in lakes and watercourses, water treatment plants, surface run-off, filling stations, etc. Varying water tables mean that chemical conditions in the ground are severely impacted and most ground contaminants become considerably more mobile.

The contaminants can cause acute problems of a microbiological nature and waterborne infections through single-cell parasites and viruses. They can also be of an "environmental toxin" character that can cause more or less permanent damage to a reservoir. In particular groundwater reservoirs with slow flows with contaminant sorption to the ground can be damaged for a very long time.

The relatively simple preparation of drinking water which takes place today at waterworks will probably be inadequate in the future and the doses of chloride used currently will be inefficacious against parasites, and will have little effect on viruses. In addition, many Swedish waterworks for surface water are sensitive to microbial contamination of reservoirs, which in combination with the lack of monitoring systems increases the risk of contamination and the outbreak of waterborne disease.

Higher temperatures, longer ice free periods on lakes and watercourses, and increased runoff mean that both eutrophication and humus content can increase. In cases where an increase occurs of humus substances in water, there is also the possibility of increased particle-bound spread of contaminants. In combination with ion-depleted water, there is an added risk of diminished virus reduction in the water.

PROPOSED ADAPTATION MEASURES

To secure water supplies in Sweden against major negative effects of climate change, the protection of reservoirs and drinking water reserves is probably the most important single factor. Further protection can be put in place through municipal and regional spatial planning, by issuing ordinances and through supervisory and licensing procedures.

Reservoir catchment areas should be protected against increased risk of both chemical and microbiological contamination. It is recommended that reservoirs supplying 50 or more persons or produce more than 10 cubic metres should be the object of water security regulations. Protection, measures and routines should above all target preventive measures such as counteracting the deterioration of raw water quality and supply during normal conditions, as well as during extreme weather and under the effects of climate change.

The risk of polluted water reservoirs should be addressed in spatial planning at local and regional level. In assigning priorities, preference should be given to measures that in the most suitable way promote long-term stewardship of land and water.

Plan for diversion and collection of stormwater to prevent it being discharged untreated into watercourses connected with drinking water supplies.

Review and analyse vulnerabilities and risks in the setup of local water supply systems.

For both municipal water supplies and the owners of private reservoirs, there is a need of educational and information campaigns on the significance and risks of climate change to water supplies.

Concerning private water supplies: the need for purification will increase. The proposed measures are information drives and preventive measures, and increased sampling of water quality.

Where needs exist, microbiological safety measures should be increased in treating drinking water at waterworks.

Draft strategies to enable handling disruptions caused by extreme weather events, or other effects of climate change which can affect reservoirs, waterworks and distribution facilities.

Surface water - consequences

- Increasing humus content, turbidity, nutrients, growth of blue-green algae and increased risk of oxygen depletion.
- Flooding increases the risk that microbial and chemical compounds can be mobilised and spread in the surface water reservoir.
- High raw water temperatures mean that the risk of microbial growth increases. Chloride and other disinfectants lose their effect at high water temperatures.

Groundwater - consequences

- A low turnover rate in groundwater reservoirs means higher sensitivity to contaminants. Small and frequent contaminants can be accumulated and in the long term can cause serious problems.
- A higher water table can mean an increased risk of virus infection through the facilities that have an unsaturated zone of only a few metres.
- During high surface water levels or during flooding, infiltration increases. This leads to considerably shorter retention times and consequently an increased risk of virus infection.

Water mains - consequences

- During torrential rain, overburdened daywater and sewage pipes can cause landslides and collapse, as well as damage to drinking water mains, since they are usually in the same supply network.
- Heavy rain and downpours can cause landslides and collapse which can damage the mains.
- In the event of simultaneous power cuts and flooding, contaminants can leak into drinking water mains.

Consequences to private water supplies

1.2 million inhabitants in Sweden have private water supplies. Privately owned wells will be affected in the same way as other wells and reservoirs. One problem in this context is that monitoring of private wells is generally considerably poorer than for drinking water from larger plants. Already today, many wells need to be remedied or replaced due to quality problems. This situation can deteriorate further as a consequence of climate change.

Spread of contaminants due to landslides and collapse

Consequences

Changes in precipitation patterns, surface water levels and the water table increase the risk of erosion, landslides and collapse, which can free chemical substances and sources of infection. Ground contaminants which are today relatively immobile in the ground can due to landslides and collapse and erosion reach the ground surface, where they can present a threat to people and wildlife in the area or downstream. The spread of contaminants risks affecting ecosystems, drinking water quality, farmland, fishing, etc.

The areas and activities that can contribute to the spread of contaminants during flooding or collapse, landslides and erosion include contaminated ground, landfills, industries and industrial land, sewage treatment plants, petrol stations, storage of hazardous substances, etc. Polluted ground can include rubbish tips, landfills, mining waste, former petrol stations, impregnation facilities, contaminants bound to sediment in lakes and watercourses, etc.

Mines and mining waste contain large quantities of metal which if spread in the environment could have a major impact on the environment and could contaminate reservoirs, etc. In general, mines are not considered a contamination risk in the event of flooding. The greatest risk associated with former or ongoing mining operations arises if tailing dams are breached or other accidents occur, affecting mining waste.

PROPOSED ADAPTATION MEASURES

To be able to determine whether contamination sources and drinking water reservoirs lie within flood-prone areas, there is a need for documentation in the form of updated flood maps.

Within the framework of extended responsibilities for climate adaptation, county administrative boards should map known landfills, industrial ground and anthrax graves etc. in view of the increased flood risks. In particular the risks of the contamination of drinking water reservoirs and pasture should be addressed.

Built-up areas and buildings

Flooding of waterside buildings

Consequences near rivers and watercourses

Flows caused by local extreme precipitation are expected to become more common in the whole country due to climate change. Since the beginning of the 1990s, high flows and flooding have occurred several times due to long periods of intensive rain which have occurred at other times of year than the spring floods.

The increased 100-year floods in mountainous regions can continue along watercourses, leading to flooding, but there is uncertainty factor in the assessment of regulated watercourses. Regulated watercourses can behave as if unregulated in the case of e.g. extended rainfall occurs after a large spring flood and the reservoir is already filled to near capacity.

Consequences for sea levels

Glacial rebound along the coast of Norrbotten is expected to compensate for the rise in sea levels. Due to the flat topography of the Norrbotten coast, the consequences of rising sea level will be more extensive than on high coastlines.

Choice of measures

The choice of measures is governed by how early flow can be predicted and how quickly the water rises. Flash floods and quickly rising water call for more permanent solutions. Digging drainage ditches on wetlands reduces the buffering capacity during high flows. If areas alongside watercourses have been enclosed by embankments further upstream, it can lead to flooding downstream.

Collapse, landslides and erosion

Consequences

It is judged that as a consequence of climate change, large areas of Sweden will be increasingly

PROPOSED ADAPTATION MEASURES

SPATIAL PLANNING. One sure and effective way to prevent flood damage is to avoid building in areas that risk flooding. Since buildings have a long expected life, it is important at an early stage to address the changed hydrological conditions and the uncertainty surrounding climate development and the consequences to the suitability of land for building.

In structure and development plans, municipalities and property owners should consider the effects of changing climate, and in cases of uncertainty should ensure broad safety margins. When the risk of natural disasters can be predicted, preventive measures should be considered and planned.

Take measures to reduce flows by changing management of regulation, or diverting to other areas.

Increase the discharge capacity by increasing the cross-section of the watercourse, by rebuilding dams, creating alternative channels.

Building embankments.

Filling/ raising properties.

Adapting buildings and use.

Existing, low-lying built-up areas may in future need to be protected by embankments and by pumping day water and drainage water.

prone to landslides and collapse. Landslides and collapse are the earth movements which can have the severest consequences for the built-up environment. A landslide can affect the built-up environment to different degrees, from constituting a minimal hazard to affecting large areas, buildings, infrastructure, and perhaps even causing the loss of human lives.

Landslides and collapse occur on sloping ground and can in many cases be a consequence of earlier erosion, when transported sediment has accumulated and formed slopes adjacent to water. Constructing buildings in such areas can be dangerous, since the consequences of increased precipitation and changed water flows can be considerable in such areas. The sediment that is transported can also cause blockage of culverts and can in that way cause flooding.

In slopes with heavy types of ground, such as above all moraine, landslides can occur when the ground is waterlogged after heavy precipitation or in connection with snow-melt. Moraine slides are frequent in mountainous regions and in sparsely populated areas.

Ravine development is common above all in areas with silt soil but can also occur in moraine, sand or clay ground. Ravines are formed by erosion and can appear either quickly or slowly. Ravine formation usually occurs in areas where there is no threat to built-up environments.

In the mountain areas of northernmost Sweden the tendency towards moraine slides and turbidity currents will increase due to increased summertime precipitation and a higher frequency of intensive rain, thereby increasing erosion.

The County Administrative Board has commissioned the Swedish Geotechnical Institute (SGI) to identify areas in the county where climate change may lead to increased risk of natural disasters. Information about climate change is based on the separate climate analysis for Norrbotten County carried out on behalf of the County Administrative Board by SMHI.

Based on existing information, areas in Norrbotten County have been identified in

PROPOSED ADAPTATION MEASURES

Limit future risks to built-up areas which can be caused by climate change through municipal spatial planning in accordance with the Planning and Building Act PBL.

Increase safety margins to enable more secure localisation of built-up areas.

Provide the municipal sector with skills acquisition, support from authorities and information dissemination.

Carry out in-depth analyses of the areas where there is a risk of landslides and collapse to provide documentation that can be used in planning built-up areas and potential exploitation areas.

Initiate reinforcing measures in built-up areas where heavy and light soils where risks are present. Examples of reinforcing measures: stability filling, earth-moving, flattening, strengthening with concrete pilings, lowering of water table, soil nailing, drainage systems, introduction of vegetation, dams, erosion ladders, settling ponds, alternative channelling of watercourses.

Do not build in areas that are or will be under threat.

In cases where it becomes evident that existing buildings are located in a risk area, it may be necessary to relocate or demolished threatened buildings.

In general and development planning, municipalities must take the necessary steps in view of risks to ensure that exploitation is only permitted within appropriate areas, and safety margins are satisfactory.

Raise quality, compile and make available planning and decision-making documentation for spatial planning. This applies to general flood mapping and stability mapping.

In their work with general, development and infrastructure planning, county administrative boards should pay increased attention to the consequences of climate change.

Municipalities should identify, prioritise and analyse areas at risk of flooding, landslides, collapse and erosion and the need for measures.

Municipalities and involved property owners should within risk areas carry out preparedness measures and adaptation of built-up environments to prevent damage and to reduce the consequences of floods, landslides, collapse and erosion.

general. The areas in question are susceptible to erosion, landslides, collapse, turbidity currents and flooding, which can lead to structural and infrastructural damage and can affect areas where there are environmentally hazardous activity and contaminated ground. The results are presented in *Norrbottens län, Översiktlig klimat- och sårbarhetsanalys – naturolyckor (dnr 2-1006-0454).*

It is intended for the report to be used as a basis for climate adaptation work by the County Administrative Board, in work with municipalities' risk and vulnerability planning, and for players in the county with responsibility for activities critical for the community.

The County Administrative Board has also commissioned SGI (the Swedish Geotechnical Institute) to further elaborate previously produced stability surveys.

The results for the municipalities in the County are available in the report *Sammanställning av utförda förstudier och översiktliga stabilitetskarteringar för bebyggda områden (2011-10-10).* The results have also been made available in GIS.

Stormwater systems and overflow of wastewater

Expected life

The expected life of water mains is dependent on ground conditions, construction method and quality. Regulation is often carried out successively. The median age of sewage systems is around 35 years. In extending water mains, the technical life expectancy has been judged at around 50 years. Carefully constructed mains are estimated to have an expected life of at least 100 years.

Consequences

In a changed climate, sewage systems will be heavily burdened due to increased quantities of rain and a redistribution of precipitation to autumn, winter and spring, when evaporation is negligible and the ground is waterlogged. In addition, there is a risk that pipes will be of insufficient capacity during extreme downpours. There is an increased risk of backflow, causing cellars to flood, and for overflowing wastewater with subsequent health risks.

In mains systems where spill water, day water and drainage water are transported in the same pipes, there is a risk of flooding when systems are overfilled.

Short-term precipitation is of major significance to the functioning of sewage systems since intensive short-term rain gives increased volumes to be drained, with a risk of flooding and overflow. The diversion of stormwater is impeded if the recipient becomes blocked further inside the system. The capacity to drain stormwater and drain built-up urban areas is affected.

Increased run-off and the addition of surplus water to sewage systems bring major consequences to sewage treatment plants which must handle

PROPOSED ADAPTATION MEASURES

Sewage treatment must be secured at an early stage in municipalities' planning processes by considering the consequences of future climate change, in particular with regard to the requirements land elevation and highest permitted levels for water and sewage. In this, a principle of prudence is applied.

When climate change takes place slowly, there are possibilities to adapt today's water and sewage systems through ongoing improvement measures. It is probable that an increase in the intensity of precipitation will not only affect parts of the existing sewage systems, and possible that new critical areas will appear. Adaptation measures will probably only be necessary in parts of the water and sewage system.

Stormwater systems should be adapted so that existing buildings are not flooded by backflow water from recipients. Properties can be protected by providing pipes with check valves or pumps.

Stormwater management should be locally planned with elements of open solutions. Together with well-planned elevation of the entire built-up area, the risk of flooding can thereby be reduced.

In newly built-up areas and also in some existing areas, it is important to try to reduce the amount of stormwater in the mains system when overloaded. This can be done by diverting water to less sensitive areas or surface diverting in a secure way, and retaining the groundwater balance and making built-up areas resistant to heavy precipitation.

Investigate possibilities to carry out improvements of privately-owned water and sewage pipes in view of the consequences of climate change.

peak flow volumes for an extended period. Other units in the sewage system will also be burdened.

In a changed climate, with increased precipitation and above all increased frequency of intensive downpours, the transport capacity can occasionally be exceeded. This can mean more frequent and extensive overflows with the surplus flow passing untreated, but diluted by rainwater, to the recipient via overflows. If this occurs at a sewage treatment plant it can result in an increased microbiological load with consequent health risks with regard to raw water.

Building constructions

Expected life

The framework of a building normally has an expected life of more than 50 years, although surfaces need to be replaced far earlier.

Consequences to buildings

The increased intensity and changed frequency of precipitation, the increased number of zero crossings in the winter period and the increased air humidity in the north are judged to cause an increase in frost shattering, an increase in damp, corrosion and rot damage, as well as increased wear. The combination of higher air humidity and increased temperature give an increased risk of mould, rot and insect attack. Higher air humidity means that damage can occur in suspended foundations.

An increase in intensive precipitation increases the probability of damp damage. If the façade consists of brick, plaster or calcium silicate masonry and becomes damp, there is a risk of the damp being transferred on to wooden materials and plasterboard, increasing the risk of mould and rot. Subsequent zero crossings can cause frost shattering.

Wooden façades normally need maintenance at 10-year intervals. With increased solar radiation and precipitation it is probable that maintenance will be required more often.

Windows are affected by intensive precipitation, where any leaks around the window mean that water can seep into the wall or into the

PROPOSED ADAPTATION MEASURES

Choice of materials and surface treatment of façades and roots must take into consideration expected climate change.

High air humidity combined with high temperatures can increase the problems of mould, bacteria, rot, corrosion and insect attack. changed constructions and materials may become necessary.

When locating new buildings, it is important to be aware of the water levels that can be expected.

Drainage systems must be adapted to changed quantities of precipitation.

To counteract rot, mould and other damp damage in buildings and building materials, damp protection projects must be carried out.

To reduce the impact of rain on windows, the windows should be set back as far as possible from the front edge of the façade. When projecting windows, it is important that drainage is planned generously with correctly design of seals, choice of material and surface treatment.

Eaves should be designed so that water from the roof does not run on to the façades and windows.

To reduce the risk of mould damage in suspended foundations, the foundations can be heated or the air can be dehumidified.

In new constructions, the outside of the spandrel beam should be insulated, insulation should be placed on the ground and they foundations ventilated with indoor air (so-called warm foundation). Even in cold suspended foundations, ground insulation is an advantage.

Installing check valves can protect properties from backflow from floor drains.

Run-off and sewage systems need to be of the right dimension and adapted to handle the expected increased precipitation quantities.

Pay attention to the snow burden when setting dimensions.

joint between frame and wall. Other parts of the window construction too, such as putty grooves and joins are sensitive to intensive rain. Painted wooden windows require the same maintenance interval as façades. If condensation arises, there is a risk of damp damage.

In a situation where large quantities of snow accumulate in cold conditions with a wind from an ice-free sea in winter time, "snow cannon" effects can occur (as in Gävle in the 1990s and Kalmar in 2006, when large quantities of snow fell in cold weather with a sea breeze).

The durability of the roofing material is affected by temperature and precipitation. Felt roofs are sensitive to pools of water and high temperatures. As regards sheet metal roofs, it is important to consider movements caused by temperature change.

Older and culturally valuable buildings

Culturally and historically valuable buildings can be affected by the same climate change problems as any other buildings. It is a question of damage caused by increased water flows and flooding, mould, rot and frost shattering. Interiors can also be affected.

A precondition for older buildings being preserved relatively well is that they have been adapted to current climate conditions. If these change, there is a risk of faster decay unless maintenance measures are taken.

Increased temperatures and higher air humidity naturally affect the interior environment too, not least in buildings completely or partially unheated, e.g. churches and castles. This can increase the growth of mould on building materials and inventories stored in the buildings.

To summarise, the need of maintenance of cultural and historically valuable buildings is judged to increase.

Comment by the County Administrative Board: much of the older buildings in rural areas are close to lakes and watercourses. Rising water levels may therefore have a negative impact on a large number of cultural settings.

Land-based industries and tourism

Forestry

Consequences

The generally warmer climate, longer vegetation period and increased carbon dioxide content in the atmosphere is expected to lead to a gradual increase in the growth of pine, spruce and birch so that by the end of the century it can be c. 20-40 per cent greater than today. The relative increase is expected to be greatest in northern parts of Sweden.

Spruce and birch will become stronger rivals to pine in northern Sweden and most deciduous species will expand northward as the climate changes. One risk associated with fast growth is that the quality of coniferous timber will deteriorate.

The increased precipitation on ground with coarse sediment and moraine is expected to mean that the supply of water will possibly become somewhat less growth-impeding on average in northern Sweden.

The changed climate does not lead to increased growth without exception, the precipitation increase means a certain amount of waterlogging in parts of northern Sweden, which in turn will have a negative effect on forest growth conditions. Wetter conditions in winter in combination with reduced seasonal ground frost can also mean an increased risk of windthrow. An increased production shortfall can also be caused by a warmer climate where damage from rot, fire, fungi, insects and wildlife is expected to increase.

The risk of forest fire will probably increase in the whole country as a result of an increased frequency of hot summer periods with a considerable water deficit.

Snow breakage will affect both coniferous and deciduous trees when their branches are burdened with large quantities of heavy, wet snow. The risk of snow breakage damage is greatest when snow is falling at near zero temperatures. Since the temperature rise in the north is greater, it is possible that the risk of snow breakage in coming decades will increase in these areas.

Warm and wet winters with shorter periods of seasonal ground frost will probably impede logging and timber transfer to metalled roads as the ground and logging roads become unstable. Vehicles crossing wet ground also cause increased problems with wheel damage in forest areas with running water and increased leaching of organic substances, sediment and mercury in run-off water.

The changed seasonal ground frost period also means an increased burden on road culverts and the stability of road foundations, and a reduction in road accessibility.

PROPOSED ADAPTATION MEASURES

To reduce the risk of windthrow, forests can be thinned in such a way that conditions are created for more storm-resilient forests in places exposed to high winds. Collaboration here can take place between neighbouring forest owners in planning felling.

Since forest fires will probably become more frequent, preventive measures will become increasingly important.

In order to counteract the negative consequences to the road network of the reduced occurrence of seasonal ground frost, it may be necessary to raise the standard of logging roads, as well as building new logging roads.

To reduce the burden on logging roads during periods of reduced load-bearing capacity, it may be necessary for forestry companies to increase the size of their stocks.

Prevent transport damage to running water in the planning stage by building environment-friendly crossings over watercourses, and practise less harmful driving by avoiding transport near surface water or in outflow areas.

Carry out recurring, extensive information drives targeting private forest owners about climate change and its effects on the forest. The regional branch of the Swedish Forest Agency in collaboration with forestry organisations forms an important channel for this work.

Increase development of cost effective, environment-friendly methods to counteract the effects and attacks of root rot and the pine weevil.

Reduce the risk of major economic loss by increased variation in forestry to spread risks. This can mean:

- planting more trees species in the forest
- retaining or increasing areas of mixed forest
- managing the forest for increased storm resilience in exposed places
- increase the variety of seed provenance (origin) when planting/ seeding
- vary thinning routines, rotation periods and felling schedules (for example via continuity forestry) beyond the customary procedures (but within the law)
- review insurance policies

Protection for forest biodiversity should be increased, in particular the following aspects:

- protection/ consideration that continues to enable the conservation of forest species, and which facilitates shifting their habitat range
- develop planning and techniques for driving in forest land and for protection at crossings over watercourses

Farming

Sensitivity

Heavy short-term precipitation or excessive quantities of water can damage crops or seriously impede growth. Much livestock production is highly dependent on reliable electricity supplies for ventilation, feeding, milking, etc.

Consequences

Increased precipitation and temperature lengthen the vegetation period and mean new conditions for growing. The competitiveness of Swedish arable land in food and fodder production may be strengthened by more favourable climate conditions and presumed increase in demand. This can mean that farmland acreage will increase in Sweden.

Increased temperature means that springtime growing will begin in the middle of April in northernmost Sweden, and springtime operations can begin during the second half of April. The harvest of crops sown in spring is judged to be possible about 3 weeks earlier than today. For spring barley this would mean the second half of August. Autumn sowing could be delayed by the same margin.

The increased quantities of precipitation and changed periodicity mean a risk that the capacity of ground drainage facilities will be inadequate. This can result in delayed spring sowing, increased the risk of vermin attack, weed problems and damage to autumn-sown crops. Extreme weather conditions such as floods and droughts can lead to a shortage of pasture.

Since the winter climate is expected to become milder, insects will be favoured and consequently more numerous in springtime. Insects cause direct damage to crops by feeding on them, and indirect damage by spreading virus diseases. The problem will affect the whole country, but is expected to be greater in drier areas and in southern Sweden.

Fungus diseases are favoured both by rising temperatures and humidity. Big regional differences are expected as regards the future humidity situation. Autumn grain will be especially vulnerable since it has a long infection period in the autumn. In areas where early summer is relatively dry, the effects on spring sowing will be less than today. As regards northern Sweden, the development and spread of fungal diseases will become of increased significance due to a generally more humid and warmer climate.

The occurrence of downy mildew on potato plants and problems in growing seed potatoes are expected to increase in northern Sweden.

In extreme weather and flooding, there is a risk of disruption to electricity supplies. This in turn can have serious consequences to livestock farming.

Fisheries

Consequences

Major changes in fish populations can be expected in different coastal areas due to climate change at a temperature increase of 2.5 to 4.5 degrees. Depending on depths in the environment in question, the size of the habitat of warm water species (perch, pike, perchpike and carp fish) in the North is expected to grow considerably at the expense of the cold water species (char, burbot, smelt, vendace, lavaret, grayling, salmon and trout).

Freshwater and cold water species like lavaret, vendace and trout spawn in autumn. Milder autumns and winters mean a shorter period with ice cover, resulting in deteriorating conditions for spawn development. In addition, fish spawn may hatch early in the spring before animal plankton development is sufficient.

Higher summer temperatures will mean that temperature stratification will be more pronounced and long-term. In combination with an increased inflow of nutrients and increase production, the risk will increase of oxygen depletion and hydrogen sulphide formation in the benthic water.

Several of the species adapted to cold water, charr, burbot, smelt, vendace, common white-

PROPOSED ADAPTATION MEASURES

Changed precipitation as regards quantity and periodicity will mean new demands on drainage and irrigation. In some cases it may be a question of building embankments to protect areas.

Protective measures such as land drainage, changes in embankment constructions or water withdrawal require changed licensing, or in some cases new water court decisions. To change licensing and water court decisions can in many cases be a complex process. The function originally intended to be secured when licensing or in water court deliberations will in many cases be unable to be upheld in a changed climate.

The warmer climate means that conditions for livestock rearing will improve in general. The buildings used above all for pig and poultry rearing should be adapted to facilitate good ventilation.

Many farms are small enterprises or sole proprietorships, which in many cases have limited possibilities and resources to collect information. There is therefore reason to carry out information drives about climate change and the effects on farming of a changed climate.

Further examples of adaptation measures to enable farming to benefit from the changed conditions brought by climate change:

- Weather-controlled, needs-adapted fertilisation and pest control
- Climate governed planning of crop growing
- Climate-adapted quality models
- New species
- Alternative growing systems and pest control methods
- Alternative soil treatment and land use

fish, grayling, salmon and trout, or all economic importance. Returns from fishing are estimated to decrease by about 10 % in inland areas of northern Sweden, as a decline in trout and child is not compensated by an increase in warm water species.

The reduced salt content in the Baltic Sea favours species such as for example vendace, which is a very important species for fishing in the Bothnian Sea. Even though it is disadvantaged by rising temperatures, its southward distribution will be favoured.

A mean temperature increase of 2.5–4.5 degrees and reduced seasonal variation but greater combined total outflow into larger watercourses mean that significant changes can be expected in the Bothnian Sea ecosystem in a long-term perspective. This is considerably affected by the major rivers and other freshwater flows and will among other things mean radical changes in conditions for the species migrating between fresh water and the sea.

Spawning and the growth of fry in fish species that undertake seasonal migrations are adapted to the increased plankton production that arises in connection with spring and early summer flow peaks in both watercourses themselves and rivermouth areas. The survival of fish fry in early stages of life is strongly affected by variations in the supply of food in the form of animal plankton. Climate change is expected to bring increased run-off with increased transport of humus out into the sea, which can lead to reduced production of animal plankton.

Due to high water temperatures, the growth period of salmon in the Baltic Sea may be extended. This can result in the salmon sexually maturing and returning to their home river at an earlier age.

It is also worthy of attention that a species such as the salmon in North Swedish rivers has about 14–20 generations in 100 years. That is an extremely short time for adaptation to new life conditions. Since the ice season is expected to decrease by on average two months in the Gulf of Bothnia, and since the spread of ice is decreasing, this will affect life conditions for the ringed seal and grey seal.

PROPOSED ADAPTATION MEASURES

Negative economic effects of climate change can be countered by eliminating migration obstacles in the water landscape to encourage species to colonise suitable freshwater bodies.

Comment from the County Administrative Board: should only take place in cases where it is anthropogenic migration obstacles that prevent dissemination. Possible measures should be weighed against other interests.

Watercourses should be restored so that they regain their function of slowing and storing water to counteract the negative effects of extreme flows. In the short term: continued work to limit fish catches. Retain or increase migratory options between and within water systems. Alternatively, artificial dissemination of fish can be considered

Comment from County Administrative Board: should only take place in cases where it is anthropogenic migration obstacles that prevent dissemination.

The reindeer industry

Consequences

Warmer, wetter winters can mean increased problems with ice and snow crust, which affect reindeers' ability to reach forage. Supplementary feed increases the risk of disease and mortality caused by enforced change of diet.

Increased precipitation and higher temperatures can also have negative consequences for possibilities to relocate reindeer, since migratory routes often cross ice-covered bodies of water.

Higher temperatures caused problems for the reindeer, as they do not thrive in warm weather.

Different types of insects and parasites that attack reindeer can become more numerous due to higher temperatures and increased air humidity.

The vegetation period is extended and plant production during the summer foraging period is expected to increase, which is advantageous for reindeer, since snow-free forage is more nutritious than winter forage and during the summer, the reindeer build up their reserves for winter. In the coastal region of northern Sweden, the longer snow- free period can result in longer foraging period and thereby higher forage pressure in the region.

Forage pressure can increase in the mountain regions as a result of the suspected reduction in the acreage of unforested land.

In a future climate where vegetation zones move farther north and growth increases, it can be a question of pursuing forestry in areas which are not interesting today. A conflict of interest can arise between the reindeer industry and forestry. Methods that are used today in forestry are sometimes in conflict with the interests of the reindeer industry. Scarification and fertilisation often reduce the stock of reindeer lichen.

Other forms of land use in the shrinking mountain and forest areas can lead to conflicts with the reindeer industry. This applies to the tourist industry, infrastructure build-out, mining, military operations, the space industry, farming, etc.

PROPOSED ADAPTATION MEASURES

Adaptation of tourist activities

When planning infrastructure, attention should be paid to the needs of the reindeer industry for alternative migratory routes due to climate change

The length of time during which coastal forage can be used may change

Increased economic assistance for supplementary feeding

Proposal for adapting forestry to the reindeer industry

Re-sowing with pine

Increased shrubbery clearance

More conservative scarification

Increased prudence when felling in reindeer lichen areas

Tourism and outdoor recreation

Consequences

Increasing attention is being given to the link between the climate issue and tourism. Studies show that a warmer climate can lead to considerable changes as regards the activities offered and to activity and travel patterns.

Climate change in Continental Europe, especially in the Mediterranean regions, can result in an increased influx of tourists to northern Europe. The influx can mean a growing visitor pressure which will exceed the limits of the capacity in Northern areas, for example as regards water supply.

A warmer climate means that the summer season is longer, which can favour bathing tourism and recreation linked to the sea and lakes. To retain the attraction for tourists, good water quality in Swedish waters is a prerequisite.

Climate change can affect the conditions for tourism in northern Sweden both directly, for example through reduced occurrence of snow, and indirectly, for example through changes in mountain and forest landscapes. Mountain hikers, anglers and others pursuing outdoor activities in the mountain regions will in future experience wetter summers, as well as fewer their mountain settings as the tree line rises. Large continuous bare mountain areas will then be found only in the northern Lapland mountains.

Reduced acreage due to vegetation changes with the simultaneous expansion of tourism through an increased offering of year-round activities can mean that the visitor pressure increases in certain areas and an increasing risk of conflicts over land use.

Higher temperatures, changed precipitation patterns and snow conditions mean that winters can change considerably, as will the conditions for winter tourism.

Of the European alpine skiing areas, 87 per cent are in Alp countries. If the temperature rises by 2°, the number of skiing areas with a relia-

PROPOSED ADAPTATION MEASURES

Create strategies to manage the negative effects of increased visitor pressure.

Give consideration to effects which can mean reduced attractiveness, for example environmental impact and deteriorated water quality.

Climate change affects the competitive position of the tourist industry at regional, national, and international level, and successful adaptation requires that management strategies can be adapted to new conditions.

Ski resorts may need to carry out technical adaptation measures, such as for example earthmoving and felling, relocation of pistes to north-facing locations and higher altitudes, manufacture of snow.

Develop alternatives to the primary reason for travel if climate and weather situations impede participation in activities.

Information drives about the effects, threats, opportunities that changed climate brings, to secure the competitiveness and development of the industry.

ble snow season will be reduced by 30 per cent. If the temperature rise is 4°, then the decrease will be by 75 per cent. This would affect the conditions for winter tourism in the whole of Europe. In a European perspective, the Swedish alpine skiing resorts will be less affected than many others, and this could contribute to the continued competitiveness of many Swedish alpine ski resorts.

Skiing areas in low-lying and/ or southern areas could be eliminated. Remaining skiing resorts can be subjected to high visitor pressure, which could negatively affect their attraction.

The negative effects can be handled in the short-term by manufacturing snow and through other adaptation measures such as earthmoving, felling and relocation of pistes. However measures of that type can affect snow-free tourism since there is a risk that the environment is made less attractive, biodiversity is reduced and the risk of earth movements will increase.

It is possible that in the period 2071-2100 winter tourism can only be pursued in northern Lapland. A continuous snow cover for more than a month may be found only in the inland areas of northern Sweden.

The reduced supply of snow and shortened season will have a drastic effect on snowmobile driving. It is possible that there will be a certain changeover period to the use of off-road quad bikes.

Natural environment*

Terrestrial ecosystems, biodiversity and environmental goals

Consequences

When assessing the effect of climate change on biodiversity, it is necessary to also consider the effects of other factors, above all human use of nature and natural resources.

It is possible that the total number of species will increase in a warmer climate, and that this would mean an increase in biodiversity. In this context is important to point out that boreal species can disappear due to the lack of retreat routes north of Scandinavia. The most threatened species are in intermediate alpine and high alpine zones and species with big spatial requirements.

Climate conditions largely decide the extent to which a species can remain in a given habitat, and relatively small temperature changes can affect this possibility. As regards capacity for adaptation, species and habitats in mountain areas, natural pine forest and on wetlands are judged to be the most vulnerable. Particularly vulnerable ecosystems are found in northern Scandinavia.

In the mountains, the effects of climate change are more evident than in many other ecosystems. The tree line has risen 100-150 m in the last 100-years, and tree colonisation is occurring in the biologically rich forest transition zone. Calculations indicate that the tree line can shift upwards by 233-667 m depending on which climate scenario is used, and on the geographical location in the mountain range.

The consequences of climate change to the ecosystems will affect the possibility to reach several of the current environmental goals, and will also affect their relevance. This applies to the diverse flora and fauna, the grandeur of the mountain environment, teeming wetlands and the prevention of eutrophication. As regards the eutrophication goal, it applies to the assumed increased use of nutrient additives in forestry.

It is judged that due to climate change, permafrost areas will be drastically reduces, which can lead to an expansion of bush- and forest-covered land. The thermokarst mounds that exist in northern Sweden (permafrost structures in peat ground) will be affected negatively. Thermokarst areas are designated a priority habitat type in the EU Habitats Directive. This applies to other marshy areas too, and their biodiversity can be affected in a changed climate.

Within forest ecosystems, relocations of species are expected as a consequence of climate change. Such relocations could lead to the extinction of many species unable to manage the changed living conditions.

Farming will be favoured by climate change, which could increase biodiversity. However, an increased need for pesticides and fertilisers is expected.

Increased winter precipitation can make low-lying areas more difficult to cultivate. Improved drainage can ease the problems, but will probably increase the migration of nutrients into watercourses.

In areas where glacial rebound is considerable, major effects are expected since the raised sea level in combination with glacial rebound will mean no creation of new shore grasslands. Zones with shore ecosystems will thereby be affected.

* See also the County Administrative Board publication "Naturmiljö and klimatförändringar i Norrbotten", County Administrative Board report series number 14/2015 .

Example of how the area of land above the tree line could shrink in future climate conditions. The left-hand picture shows the areas of Sweden that are today above the tree line, while the right-hand picture shows the areas after a temperature rise of 3-4 degrees.

(Source: Environmental Protection Agency & SMHI, 2003)

PROPOSED ADAPTATION MEASURES

Map ecosystems/species strongly dependent on climate conditions to classify nature types by different climate zones and there distinguish the significance of climate factors to the survival of the system/species.

Efforts to address the effects on biodiversity of climate change should be integrated in social planning, in construction projects and infrastructure planning. It is suitable to use EIA (Environmental Impact Assessments) and SEA (Strategic Environmental Assessments).

One possible consequence of climate change is that there can arise among species an increased need of northward dispersal pathways and retreat routes. Pathways and fragments of natural forest should be preserved so that the desired colonisation and dispersal can take place. Current strategies for protection and management should therefore be reviewed.

In general there is a significant sparsity of knowledge regarding how different ecosystems will be changed due to climate change. Here are two examples of study suggestions:

1. Go through Swedish nature types, for example the classifications in Natura 2000. Identify the crucial processes and circumstances, and judge their relation to climate and climate change, for example by formulating questions to ask climate researchers. Judge also the interdependence of biotopes and identify needs for new knowledge, qualitative and quantitative. It is recommended that the analysis be carried out by combining biotope science with knowledge of the requirements of species typical for the biotopes.

2. Indicate, on the basis of species expertise (for example through the expert panels of The Swedish Species Information Centre), species strongly dependent on climate conditions, for example species dependent on ice; state how they can be assumed to be affected by climate change and propose actions.

Freshwater environment

Consequences

The following consequences apply to all surface water occurrences in the country and are to be seen in light of the fact that the present status of water quality is considerably inferior in southern Sweden compared to the northern parts of the country.

Water chemical changes take place primarily due to deposition and climate change. Examples of changes linked to climate change: changed water colour due to increased contents of humus, increased overall nitrogen content, increased algae growth, reduced biodiversity, changed flora of fish species, development of cyanobacteria. All simulations of the future climate show that ground leaching will increase in a warmer and wetter climate. It is feared that nitrogen and phosphorus content in water will increase.

The humus content in water affects the conditions for the water in a number of different ways: transport of environmental toxins, occurrence of algae, drinking water quality, microbiological growths in the drinking water mains.

The consequences to surface water of gradually increased air temperatures:

PHYSICAL PROCESSES

Winter/spring: Less snow on ice, earlier ice-out, earlier and reduced spring flow, better light conditions below water, higher water level.

Summer/autumn: Higher water level, stronger and longer turnover period for water.

BIOLOGICAL PROCESSES

Winter/spring: Earlier spring bloom, changed algae composition, earlier occurrence of animal plankton and cyanobacteria, predominance of warm water fish species, spread of alien species.

Summer/autumn: Increased algal bloom, reduced biodiversity, predominance of warm water fish species, increased bacterial growth, spread of alien species.

CHEMICAL PROCESSES

Winter/spring: More nutritive salts below the ice, increased water colour, earlier decrease in

bioavailable nutrients in spring, reduced outflow of nutritive salts in spring.

Summer/autumn: Nutritive salt shortage, oxygen shortage.

Consequences to water quality of increased run-off:

BIOLOGICAL PROCESSES
Reduced biodiversity due to eutrophication and deteriorating light climate, increased bacterial growth.

CHEMICAL PROCESSES
Increased turbidity, water colour, dilution, input of harmful substances, e.g. pesticides and mercury.

PROPOSED ADAPTATION MEASURES

Reduce emissions of nitrogen and phosphorus from farming, airborne deposition and point sources.

Sea environment

The sea and coastal water environment of The Gulf of Bothnia may be affected by temperature change and the change in water quality consequent to changed discharge in watercourses.

PROPOSED ADAPTATION MEASURES

Research into and investigate the effects of climate change at regional level (The Gulf of Bothnia).

Measures to limit the input of nutrients, organic load and contaminants.

People's health

Extreme temperatures

Consequences

Different groups of people have different sensitivity to higher temperatures. Elderly people in particular are vulnerable. People in certain regions with a specific climate are adapted to the prevailing conditions inasmuch as there is an optimum temperature which is different for people in different parts of the world (e.g. the optimum temperature in Finland is judged to be 14°, in London 20°).

One consequence of climate change is that periods of high temperature and occasions with higher temperatures than today will be more frequent.

As a consequence of this, increased mortality is expected, above all for vulnerable groups.

The number of tropical nights – 24-hour periods when the temperature never falls below 20° – is expected to increase in the southern and central parts of Sweden, and on the coast of northern Sweden.

The milder winter climate can mean reduced episodes with deteriorated health conditions for people with angina, chronic heart and lung diseases and rheumatic conditions. Cold related deaths and frostbite are expected to decrease.

PROPOSED ADAPTATION MEASURES

In social planning and the design of buildings and new premises, attention should be paid to the fact that summer temperatures may rise and that extreme heat waves can occur. Buildings in general have a long expected life and planning should therefore be started at an early stage to enable adaptation.

Changed air quality

Consequences

Climate change will affect wind directions and precipitation patterns, as well as many other processes dependent on weather. The total quantity of particles in the atmosphere can increase as dust from drought-hit areas in southern and central Europe is dispersed by winds.

A longer vegetation season can cause a change and increase in the spread of species producing pollen and the start, length, and intensity of the pollen season can change.

Since dwellings in northern Sweden are draught-free and well-insulated, a climate with higher temperatures and more precipitation will increase the risk of mould and mite allergies.

PROPOSED ADAPTATION MEASURES

Address climate when plans and strategies for work with air quality are drafted.

Health effects of climate change

Consequences

The health consequences of climate change are highly dependent on the vulnerability of the population, and the capacity of the ecosystem to recover, as well as the capacity of society to handle disruptions and to adapt. The positive health consequences brought by a warmer climate can lead to a decrease in the occurrence of frostbite, angina and rheumatic conditions. The population is also expected to enjoy improved health due to increased periods spent outdoors and more outdoor activities.

Transmission of infections

Through climate change, patterns of disease transmission through different animal species will change. The milder winters mean that the dispersal of species bearing infections can increase, and that they will survive to a greater degree. Examples include the tick, which can spread the disease borrelia and the sandfly, which can spread the serious disease visceral leichmaniasis. Borrelia is expected to spread to large parts of northern Sweden, with the exception only of mountain regions.

Due to a warmer climate, the grazing period for livestock herds can be extended, where on the one hand less time indoors reduces the risk of infections, but on the other hand the time outdoors exposed to parasitic infections and bacteria increases.

Fish and shellfish are adapted to the prevailing climate with a relatively low water temperature and will therefore be unfavourably affected by higher temperatures, at the same time as aquatic parasites and bacteria are favoured by higher temperatures.

High temperatures

The optimum temperature for people varies depending on climate and the adaptations individuals have made to their current living environment. Studies indicate that an increased number of heat related deaths as a rule appears immediately and over a short period, while the consequences of a cold period can appear over several weeks. As regards heat, the risk groups identified are the elderly and functionally disabled, who can have increased sensitivity and reduced ability to identify the risks.

Low temperatures

A milder winter climate will bring several positive health effects. Above all, this means a decrease in problems relating to cardiovascular and lung disease. It is also probable that the milder winters will lead to a decrease in the number of frostbite injuries.

Air quality

Climate change will affect wind directions, precipitation patterns and other processes that govern the content of air contaminants. Northern Scandinavia can expect a reduced content of ground level ozone and non-organic particles (sulphates, nitrates, ammonia) in the air.

Regarding the dispersal of pollen producing species and the start and length of the pollen season, an increase in pollen content in northern Sweden can apply above all to birch, but also to other alien species. However, certain scenarios have mapped out a decline in birch and grass in mountain areas, where an increase would have appeared more likely. In cases where precipitation increases, the risks associated with pollen exposure will decrease.

Indoor air

Increased outdoor temperatures and increased precipitation can cause damp and mould damage indoors, as well as a more favourable climate for mites. Increased indoor temperatures in combination with increased air humidity can increase the risk of emissions from building materials.

Floods, storms, landslides and collapse can become more frequent as a consequence of climate change. This in turn can lead to anything from personal injuries to serious disruptions in electricity and water supplies.

As regards major flooding, this can have serious consequences to important community functions by affecting the care sector, electricity and water supplies, sewage, and can hinder rescue services and traffic. Power cuts can affect many functions, from heating and drinking water supplies to food handling and livestock farming.

After flooding, problems generally remain in the form of surface water and drinking water becoming contaminated by sewage water, harmful micro-organisms, fertiliser, sludge and stormwater or chemical toxic substances released by the flooding. Polluted water can cause among other things skin infections and intestinal diseases in people and animals. Also different vector-borne diseases spread by rodents and insects tend to increase as a result of flooding.

Water supply and water quality

Increased temperatures in water favour the growth of micro-organisms, which in combination with a longer bathing season can mean increased risks to people at outdoor bathing facilities. Also the occurrence of toxic algal bloom is favoured by higher water temperatures. The supply of phosphorus regulates growth.

Infectious matter spread through water can be calicivirus which causes intestinal infections.

Salmonella and campylobacter are examples of other infectious matter. Mountain regions can also be affected through increased risk of the spread of giardia and campylobacter.

Food

In a warmer climate it is increasingly important that food cooling can be maintained and that food management is adequate, since increased temperatures and air humidity can lead to an increase in attacks from harmful micro-organisms.

Changed habits with regard to production and handling of food can cause an increased risk of the spread of food-borne disease. The explanation for this can be increased consumption of ready-prepared food that is reheated, and the increased import of food.

Impact on ecosystems

As a consequence of temperature increases and changed seasonal and precipitation patterns, existing ecosystems are expected to be affected both favourably and unfavourably. The dispersal of plant and animal species can be changed, which in turn will affect the spread of different diseases (for example, pollen allergies and vector-borne diseases).

Early signs of change are most evident in northerly areas and at high altitude. The diversity of Arctic animal species, the dispersal and their occurrence is judged to be threatened by climate change. New plant and animal species may outcompete the boreal species, increasing the risk of introduction and establishment of new animal diseases.

Changed land use due to climate change also affects ecosystems and this in turn can have consequences to the spread of disease. Also changed recreational activities can change the risk of the onset of disease through people's change behavioural patterns.

Nephropathia epidemica, spread by voles, is an example of a disease whose distribution can be affected by climate change. A reduced snow cover can result in voles approaching closer than normal to built-up areas. In that way, they approach closer to people and the risk of infection spreading will increase.

The natural areas in the Scandinavian countryside provide relatively good space for wildlife which in turn can serve as blood hosts and infection reservoirs for vectors (diseases spread by insects, ticks and rodents). Overall, vectors and reservoir animals must be favoured in an area visited by people in order for the disease to become more frequent.

Tick- and insect-borne infectious matter that causes borrelia and Tick Borne Encephalitis (TBE) is expected to spread in northern Sweden. Increased temperatures, air humidity and the expected increase in standing water due to increased precipitation create favourable conditions for mosquitoes.

In changes to biotopes, for example if mountain birch forest becomes established in areas presently above the tree line, the dispersal of mosquitoes can increase. More frequent floods can result in colonisation by shrubbery and waterlogging, which favour bloodsucking insects and mites. Short and milder winters, as well as longer vegetation periods, mean that many host and reservoir animals improve their ability to survive, which in turn favours vectors.

Glossary:

Host animals – species that bloodsucking insects and ticks feed on.
Vector – animal that spreads infectious matter via urine, faeces, etc.
Reservoir for infectious matter – animal that causes infection in bloodsucking insects and ticks.

Wildlife

Climate change can mean that organisms causing disease have better living conditions. Through changed climatic conditions, vectors have new dispersal patterns. Examples of such species include European hare, mountain hare, roe deer, fallow deer and boar.

PROPOSED ADAPTATION MEASURES

Plan for food handling adapted to conditions where higher temperatures are more frequent.

More effective purification of drinking water.

In planning and operating bathing sites, the risk of spreading infection should be considered.

Spread of information to the public regarding risks of infection when handling food, bathing and other risk situations.

Continual updates of routines to reduce the risk of infection.

Mapping of contamination risks in flooding, collapse, landslides and erosion.

Set strategies to enable providing support to vulnerable groups.

Changes in the world and their impact on Sweden

Consequences

Climate change is expected to cause considerable changes in migratory patterns. The relocation of people will probably take place within a relatively limited area.

It is feared that migratory movements will cause a certain destabilisation in and economic strain on the affected regions. This will affect the security situation both nationally and internationally. In regions with well-developed intranational and international cooperation forms, the probability of conflicts is less than in regions with less developed cooperation.

In the short term, the effects of climate change are expected to bring stresses in southern Europe to a greater extent than in northern Europe.

The energy supply and farming sectors, which are of interest to security policies, will meet problems in all or part of Europe.

It may be necessary that the areas in Europe where conditions for farming are expected to improve will also be used to a greater extent to guarantee the self-sufficiency of the EU.

Northern Europe belongs to the part of the world which will not be economically affected particularly severely, at least in the short term. The Swedish economy can however be indirectly affected by the feared reduction in demand at international level.

The increased frequency of extreme weather events can bring considerable damage to nations' infrastructure, and this in turn can cause disruptions in global financial systems. The international insurance sector too will be severely hit through increased claims for compensation.

EFFECTS IN SWEDEN OF CLIMATE CHANGE IN OTHER PARTS OF THE WORLD – OVERVIEW

Effects in Sweden	Expected effect
Farming and food	Reduced supply of food on world markets, depending on the extent production of climate change. Can mean increased demand for Swedish foodstuffs.
Forestry	Big regional differences in the supply of commercial wood products may affect Swedish forestry.
Water supply	Increased demand for water on the world markets. Possible future Swedish export.
Tourism	Regional climate effects in e.g. the Mediterranean and the Alps can lead to increased tourism in Scandinavia.
Energy	Increased European demand for electricity. Risk of disruptions in import of certain energy forms, e.g. oil.
Insurance sector	Reinsurance system can be affected, with more expensive premiums as a result.
Health	Deterioration in global health, among other things due to an increased number of conflicts, which can lead to increased risk of spread of infectious diseases.
Swedish industry	Changed global conditions require that countries have a high rate of structural transition to maintain competitiveness.
National security	Renewed focus on EU agricultural policy. Increased integration with aid policy. Increased focus on water. Increased focus on energy.
Aid policy	Increased focus on climate adaptation issues.
Refugee migration	Increased need for coordination at European level and preparedness for increased refugee migration.

SMHI Klimatologi, issue 32, 2015. Future Climate in Norrbotten – according to RCP scenarios

Mean annual temperatures

Mean temperatures winter, spring, summer, autumn.

Heat wave mean annual precipitation – mean precipitation winter, spring, summer, autumn

Number of days with more than 10 mm precipitation

Maximum 24-hour precipitation

Change in short-term precipitation

Number of days with snow cover with over 5 mm water content

Number of days with snow, with over 20 mm water content

Changed maximum snow, changed total mean inflow for year and seasons

Changed total ten-year inflow. Changed total 100-year flood

Changed local mean annual inflow

Changed local main inflow winter, spring, summer, autumn

Changed local ten-year inflow

Changed local 100-year inflow

Annual inflow dynamics

Length of vegetation period

Starting point of vegetation period

Soil moisture

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