Climate change in Norrbotten County

– consequences and adaptation

County Administrative
Board of Norrbotten

IN CONNECTION with parliamentary adoption of the government bill 2008/09:162 An Integrated Climate and Energy Policy – Climate, the County Administrative Board in Norrbotten County was commissioned, as were the other the county administrative boards in Sweden, to coordinate work at regional level to adapt to a changed climate.

THE WORK IS TO BE CARRIED during 2009-2011 and involves coordination, consultation and support for municipalities and regional players in their climate adaptation work. One express goal is to create strategies for adaptation to a changed climate at both local and regional levels.

There is no longer any doubt that global warming will lead to major changes to the climate. For the part of Norrbotten, the changes will among other things lead to much milder and shorter winters, and we shall have more rainfall.

However, the consequences to the County will be less dramatic than to the rest of Sweden, although there is a big possibility that by the end of this century our children and grandchildren will experience extensive changes in living conditions as the climate changes.

Change is often associated with risks and threats, but the warmer climate also creates new opportunities. The growth season in forestry and agriculture will become longer and the ice-free period for shipping will grow longer. Perhaps ski tourism in our county will benefit.

For at the same time as there is cause for a degree of concern, we must be creative and try to turn the threats into hope – like the children.

It is our children and grandchildren who are to live with the new climate. Today it is we adults who must plan and adapt society to the new circumstances.

Per-Ola Eriksson, *County Governor*

Our children are going to live in a new climate

“Maybe you can swim and sunbathe more in the summertime”, says five-year-old Lova Ejneborn (left), at Bergsprängaren nursery in Luleå. Her friend Bo Lindberg (right), also aged 5, calls the new season in November “Winterautumn” - when he goes sledding one day and gets his bike out of the store the next. “If it doesn’t snow, we can play on the slide instead, and when it rains you can slide on your tummy even faster”, says five-year-old Ebba Tjärnberg, not pictured.

Photo: Johan Baggström

CONTENTS

Introduction

BECAUSE OF global climate change, Sweden can experience changed quantities of precipitation, increasing daily temperatures, higher water levels and a more frequent occurrence of extreme weather. Such developments can have consequences that affect buildings, infrastructure and other important social activities. We can count on increasing stresses and thereby the occurrence of new risk situations.

The duties of the County Administrative Board include matters to do with sustainable social planning, management of peacetime emergencies, and running rescue services.[1] Together with other authorities, the County Administrative Board has “special responsibility for planning and implementing preparations to create the capability to manage a crisis, to prevent vulnerability and counteract threats and risks.” [2]

With this publication, the County Administrative Board wishes to disseminate the results of the Commission on Climate and Vulnerability (SOU 2007:60) that have a bearing on Norrbotten. In the continuing work of the County Administrative Board with the government remit to “adapt to a changed climate” a compilation becomes at the same time a starting point for future dialogue on how climate change will affect Norrbotten the and how we ourselves can adapt to reduce vulnerability in the county. Through dialogue, the County Administrative Board aims together with municipalities and other players in the county to be able to identify:

- Further areas that may be affected
- Areas where there is a need for more in-depth analysis and planning documentation
- Adaptation measures
- Skills acquisition needs

Once implemented, the measures will form the basis for setting strategies for adaptation work by the county.

The remit is to be seen as a complement to the ongoing work to reduce greenhouse gas emissions and increase the efficiency of energy use. See the County Administrative Board’s “Climate energy strategy Norrbotten County”.

[1] Ordinance (2007:825) with County Administrative Board instructions 3 §

[2] Ordinance (2006:942) on disaster preparedness and heightened alert 11§

Climate change in Norrbotten County and its consequences

On the following pages the consequences of climate change in Norrbotten County are described for these three areas: coastal land, inland areas and mountain areas. Here we present climate indices based on the results of calculations using climate models for the period 1961-2100. The factors dealt with are temperature, precipitation, snowfall, snow cover, ice conditions, run-off, the vegetation period, winds and land conditions. Unless otherwise stated, the details have been provided by the Swedish meteorological institute SMHI[3] and the calculations cover the period 1961-2100. In all, Sweden is divided into 19 districts. (District 16, which extends all the way from the coast of Uppland to The Gulf of Bothnia coast, is not presented here, since the data for District 13 corresponds better to conditions in the Norrbotten coastal area.)

The UN climate panel, IPCC, has processed assumptions on future greenhouse gas emissions in the world. These assumptions have resulted in a number of varied emission scenarios.

The assumptions upon which the scenarios are based concern the development of world economy in the future, population growth, globalisation, etc. The Commission on Climate and Vulnerability (SOU 2007:60) has chosen to focus on emission scenarios A2 and B2.

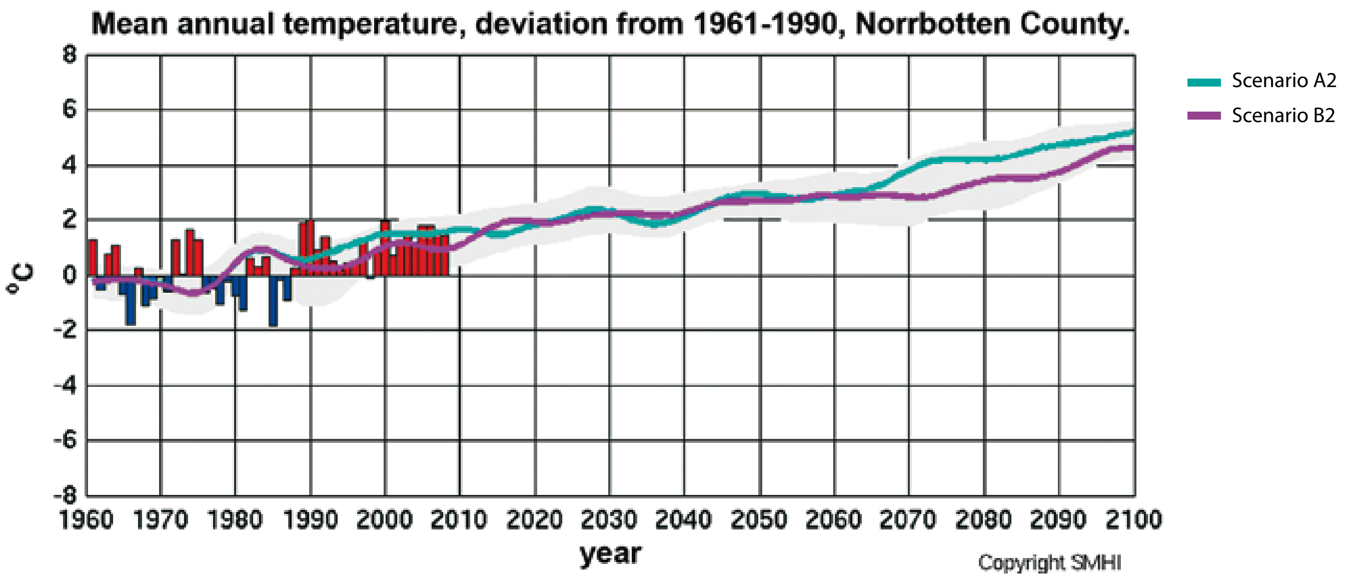
As a basis for illustrating the consequences of climate change in Norrbotten, scenario A2 has been chosen, which causes the greatest changes to A2 and B2. The reason for this choice is that our emergency capability should be geared to a worst-case scenario.

Rapid temperature increase

IN THE COURSE OF the 20th century, the global mean temperature increased by 0.6°C, which in a climate context may be regarded as a large and rapid increase. Other signs of change include the retreat of glaciers, the reduction in the Arctic ice cover, rising sea levels and changes in precipitation patterns.

Today there is a growing consensus that the earth's climate is changing due to human activities. In all probability our children and grandchildren will by the end of the century be experiencing extensive changes in the living conditions of both large groups of people and other living creatures on earth.

In an international perspective, including for example low-lying cities under threat of flooding due to rising sea levels, Sweden is considered to be relatively fortunate. As regards Norrbotten County, climate change is estimated to give milder, shorter winters. The consequences to the county are thus expected to be less dramatic than in the rest of the country, among other things because coastal regions in the north may be able to benefit from the considerable glacial rebound.



Calculated change (°C) in the mean annual temperature for the years 1961-2100 compared to the normal (mean value for 1961-1990). The bars show historical data acquired from observations; the red bars show temperatures higher than normal and blue bars show temperatures lower than normal. The graphs show running mean 10-year values from the scenarios. The cerise line corresponds to changes in the annual mean temperature for emission scenario B2 and the turquoise line corresponds to emissions scenario A2. The grey field shows the variation in temperature between years (calculated from the scenarios).

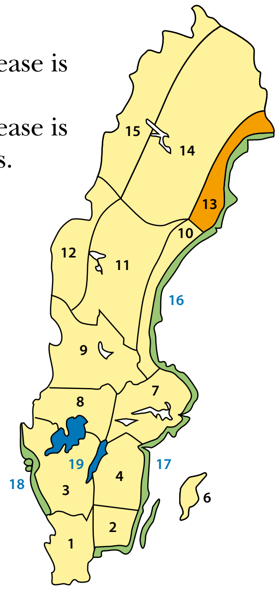
[3] http://www.smhi.se/cmp/jsp/polopoly.jsp?d=8785&l=sv (2009-07-16)

COASTLAND

(Data from SMHI unless otherwise stated.)[4]

Temperature

Mean annual temperature
By the year 2050, the increase is estimated at c. 3° Celsius.
By the year 2100, the increase is estimated at c. 5.5° Celsius.



Seasons, temperature increase by 2050
Spring 3°
Summer 2°
Autumn 3°
Winter 4°

Seasons, temperature increase by 2100
Spring 5°
Summer 3.5°
Autumn 5°
Winter 7°

Precipitation

Annual precipitation will increase by 10-15 per cent to 2050 and just under 30 per cent by 2100.

Seasons, changes in precipitation by 2050

Spring:	no increase
Summer:	no increase
Autumn:	increase by 20 per cent
Winter:	increase by 30 per cent

Seasons, changes in precipitation by 2100

Spring:	increase by 20 per cent
Summer:	no increase
Autumn:	increase by 30 per cent
Winter:	increase by 50 per cent

Extreme 7-day precipitation and extreme daily precipitation
The maximum precipitation in a period of 7 consecutive days is estimated to increase by 2-3 per cent up to the year 2050 and by the year 2100 just over 15 per cent. The estimated number of days with extreme daily precipitation is estimated to increase by 5-9 days.

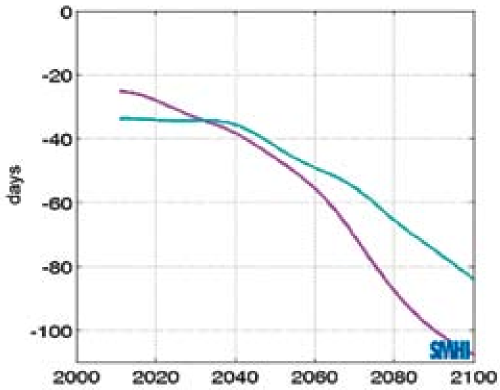
Estimated number of days per year with precipitation exceeding 10 mm

Period	Days
2011-2040	18
2041-2070	20
2071-2100	25

Dry periods
The longest continuous dry period per year is estimated to change little on average, but will become shorter compared to 1961-1990.

Snowfall, snow cover

Number of days with snow cover



Estimated change in the number of days with snow cover for 2011-2100 compared to the estimated mean values for 1961-1990. The curve shows the mean 30-year value for A2 (cerise) and B2 (turquoise).

The period with snow cover is estimated on average to become almost 50 days shorter by the year 2050 and more than 100 days shorter by 2100. The estimated maximum water content in the snow is considerably reduced.

Details for Norrbotten County as a whole
For the period 2071-2100 there will be an increase in snowfall (mm) during the months December-March.[5]

Ice conditions

Estimated day number (mean value) when the ice break-up/ ice-out takes place

Period	Day
1961-1990	124
2011-2040	116
2041-2070	114
2071-2100	100

The ice break-up/ ice-out on lakes is estimated to occur on average 15-25 days earlier.

[4] http://www.smhi.se/cmp/jsp/polopoly.jsp?d=8785&l=sv (2009-07-16)
[5] Norrland - Klimatet förändras och förändrar. SWECO 2008 s. 16

Run-off

Data for Norrbotten as a whole

Run-off will increase, above all in the mountain range.[6]

The time/ periods of run-off will also be affected. The spring flood can decrease and wintertime run-off can increase.[7]

Vegetation period and last spring frost date

The duration of the vegetation period is estimated to increase by more than 50 days by 2100.

Duration of the vegetation period

Period	Vegetation period mean value no. days
1961-1990	155
2011-2040	171
2041-2070	183
2071-2100	209

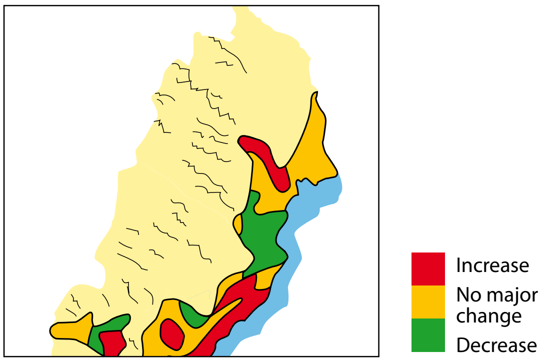
The last spring frost is estimated to occur around 10 days earlier by around 2050 compared to 1961-1990 and 20-30 days earlier by 2100.

Winds

The maximum wind gust is estimated to increase by around 1 m/s.

Land conditions [8]

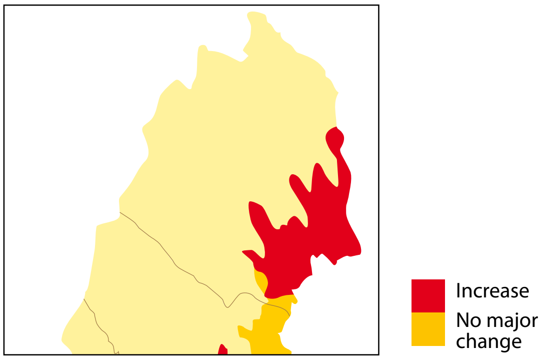
Erosion



Change in erosion tendency due to climate change up to 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.

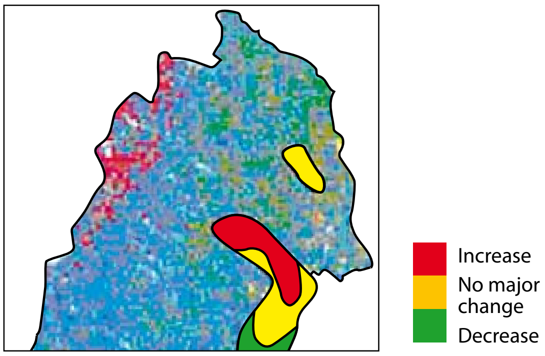
Landslides and collapse



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

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

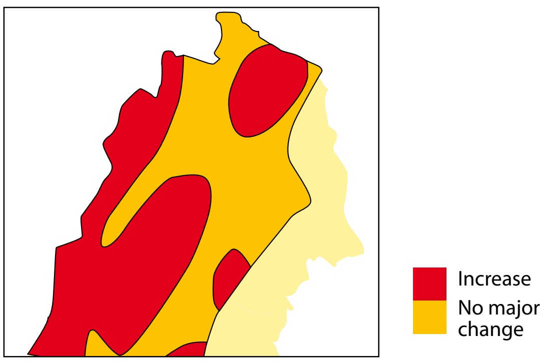
Ravine development



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

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

Moraine slides and turbidity currents



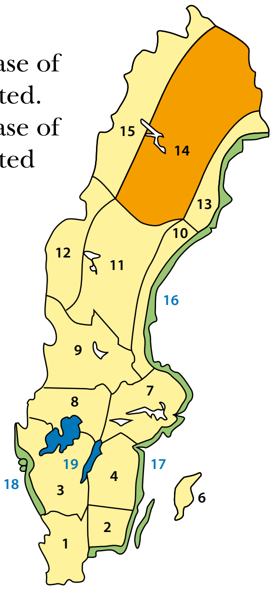
In the mountain regions of northernmost Sweden the tendency towards moraine slides and turbidity currents will increase due to increased summertime precipitation and a higher frequency of intensive rain and thereby increased erosion.

6 SOU 2007:60 s.175 ff
7 Future flood risks SMHI 2006 s. 61
8 SGI Varia 571 broad assessment of earth movements due to climate change.

INLAND

Temperature

Annual mean temperature
By the year 2050, an increase of approximately 3° is estimated. By the year 2100, an increase of approximately 5° is estimated



Seasons, increased temperature by 2050
Spring 2.5°
Summer 2°
Autumn 3°
Winter 4°

Seasons, increased temperature by 2100
Spring 5°
Summer 3°
Autumn 5°
Winter 7°

Precipitation

Annual precipitation will increase by approximately 12 per cent by 2050 and 30 per cent by 2100.

Seasons, change in precipitation by 2050

Spring:	no increase
Summer:	no increase
Autumn:	increase by 20 per cent
Winter:	increase by 35 per cent

Seasons, change in precipitation by 2100

Spring:	increase by 20 per cent
Summer:	no increase
Autumn:	increase by 35 per cent
Winter:	increase by 60 per cent

Extreme 7-day precipitation and extreme daily precipitation
The maximum precipitation in 7 successive days is estimated to increase by c. 4 per cent by the year 2050 and c. 11 per cent by the year 2100 The estimated number of days with extreme daily precipitation is expected to increase by 5-8 days.

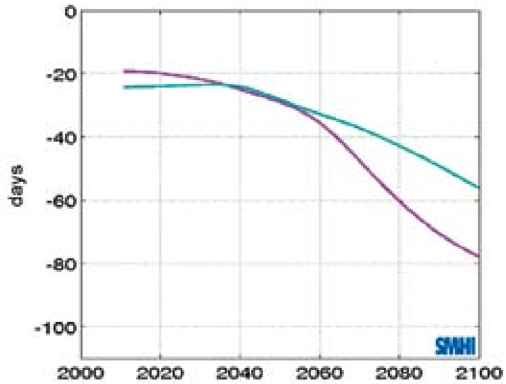
Estimated number of days per years with precipitation exceeding 10 mm

Period	Days
2011-2040	17
2041-2070	20
2071-2100	24

Dry periods
The longest continuous dry period per year will on average is estimated to change little, but will become shorter compared to 1961-1990.

Snowfall, snow cover

Number of days with snow cover



Estimated change in the number of days with snow cover for 2011-2100 compared to the estimated mean values for 1961-1990. The curve shows the 30-year mean value for A2 (cerise) and B2 (turquoise).

The period with snow cover is estimated on average to become almost 30 days shorter by the year 2050 and more than 80 days shorter by 2100. The estimated maximum water content in the snow is considerably reduced.

Details for Norrbotten County as a whole
For the period 2071-2100 there will be an increase in snowfall (mm) during the months December-March.[10]

Ice conditions

Estimated day number (mean value) when the ice break-up/ ice-out takes place

Period	Day
1961-1990	131
2011-2040	124
2041-2070	122
2071-2100	112

The ice break-up/ ice-out in lakes is estimated to occur on average 17 days earlier.

Data for Norrbotten as a whole
Run-off will increase, above in the mountain range.[11]
The time/ periods of run-off will also be affected. The spring flood may decrease and wintertime run-off may increase.[12]

[9] http://www.smhi.se/cmp/jsp/polopoly.jsp?d=8785&l=sv (2009-07-16)
[10] northern Sweden - Klimatet förändras och förändrar. SWECO 2008 s. 16
[11] SOU 2007:60 s.175 ff
[12] Future flood risks SMHI 2006 s. 61

Vegetation period and date of last spring frost

The duration of the vegetation period is estimated to increase by nearly 50 days by 2100.

Duration of the vegetation period

Period	Vegetation period mean value no. days
1961-1990	135
2011-2040	152
2041-2070	161
2071-2100	181

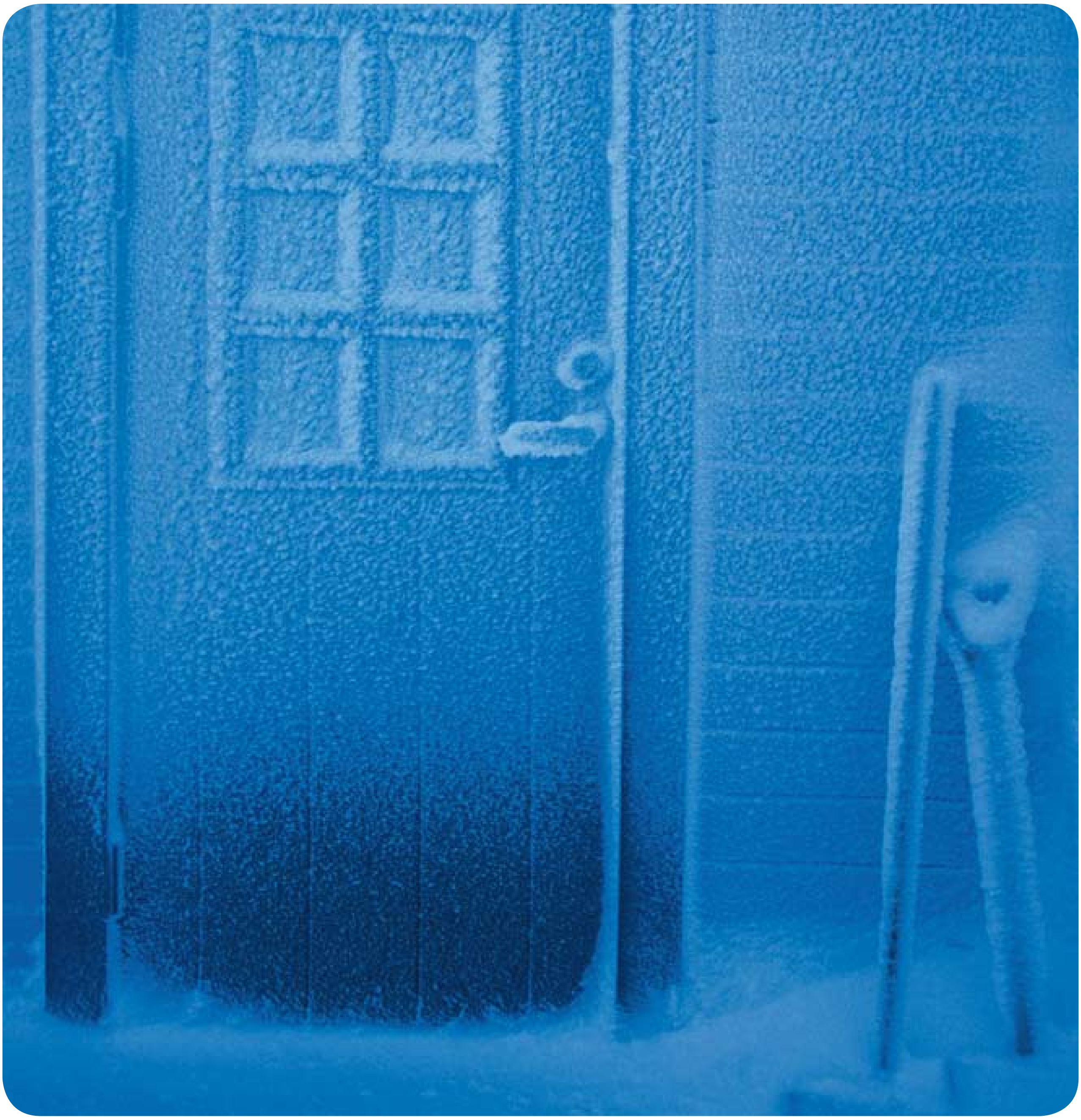
The last spring frost is estimated to occur nearly 10 days earlier by around 2050 compared to 1961-1990 and 20 days earlier by the end of the century.

Winds

The maximum wind gust is estimated to increase by about 1 m/s.

Land conditions

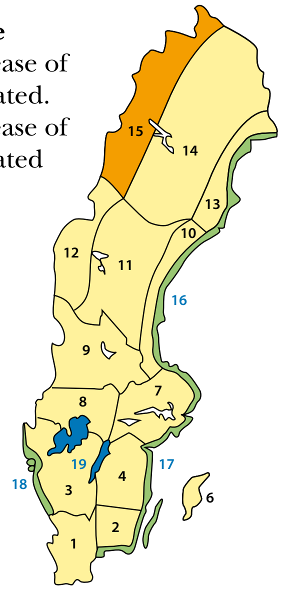
See previous section regarding the coastland.



MOUNTAIN REGIONS

Temperature

Annual mean temperature
By the year 2050, an increase of approximately 3° is estimated. By the year 2100, an increase of approximately 5° is estimated



Seasons, increased temperature by 2050
Spring 2.5°
Summer 2°
Autumn 3°
Winter 4°

Seasons, increased temperature by 2100
Spring 5°
Summer 3°
Autumn 5°
Winter 7°

Precipitation

Annual precipitation is estimated to increase by c. 17 per cent by 2050 and 35 per cent by 2100.

Seasons, change in precipitation by 2050

Spring:	increase by 15 per cent
Summer:	decrease by 8-10 per cent
Autumn:	increase by 25 per cent
Winter:	increase by 40-45 per cent

Seasons, change in precipitation by 2100

Spring:	increase by 50 per cent
Summer:	no increase
Autumn:	increase by 35 per cent
Winter:	increase by 70 per cent

Extreme 7-day precipitation and extreme daily precipitation
The maximum precipitation in a 7-day period is estimated to increase by c. 7 per cent by the year 2050 and 15 per cent by the year 2100. The estimated number of days with extreme daily precipitation is estimated to increase by 10-20 days.

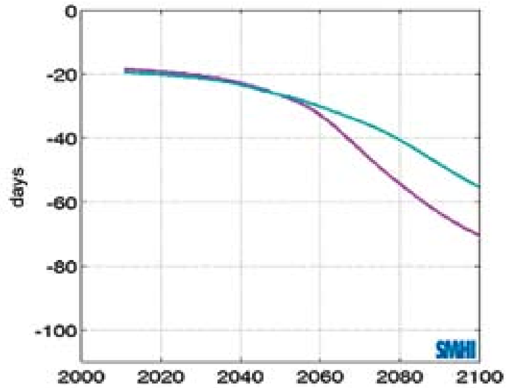
Estimated number days per year with over 10 mm precipitation

Period	Days
2011-2040	42
2041-2070	47
2071-2100	55

Dry periods
The longest continuous dry period per year is estimated to change little on average, but will become shorter compared to 1961-1990.

Snowfall, snow cover

Number of days with snow cover



Estimated change in the number of days with snow cover for 2011-2100 compared to the estimated mean values for 1961-1990. The curve shows the 30-year mean value for A2 (cerise) and B2 (turquoise).

The period with snow cover is estimated on average to become c. 25 days shorter by the year 2050 and c. 70 days shorter by 2100.
The estimated maximum water content in the snow is considerably reduced.

Details for Norrbotten County as a whole
For the period 2071-2100 there will be an increase in snowfall (mm) during the months December-March.[14]

Ice conditions

Estimated day number (mean value) when the ice break-up/ ice-out takes place

Period	Day
1961-1990	142
2011-2040	135
2041-2070	131
2071-2100	121

The ice break-up/ ice-out in lakes is estimated to occur on average 15-20 days earlier.

[13] http://www.smhi.se/cmp/jsp/polopoly.jsp?d=8785&l=sv (2009-07-16)
[14] Norrland - Klimatet förändras och förändrar. SWECO 2008 s. 16
[15] SOU 2007:60 s.175 ff
[16] Future flood risks SMHI 2006 s. 61

Run-off

Data for Norrbotten as a whole

Run-off will increase, above all in the mountain range.[15]

The time/ periods of run-off will be affected. The spring flood may decrease and the wintertime run-off may increase.[16]

Vegetation period and date of last spring frost

The duration of the vegetation period is estimated to increase by just under 50 days.

Duration of the vegetation period

Period	Vegetation period mean value no. days
1961-1990	111
2011-2040	130
2041-2070	138
2071-2100	158

The last spring frost is estimated to occur just under 10 days earlier around the year 2050 compared to 1961-1990 and about 20 days earlier by the end of the century.

Winds

The maximum wind gust is estimated to increase by about1-2 m/s.

Land conditions

See earlier section regarding coastland.

It is not solely a matter of technical measures

The goal of the research programme is to facilitate future adaptation measures in different sectors and regions in Sweden in view of the ongoing long-term climate change.

Annika Carlsson-Kanyama, researcher at the defence research Institute FOI, and associate professor at the Royal Institute of technology KTH, leads Climatools which includes other researchers from KTH, the National Institute of Economic Research and Umeå University.

Adaptation is not solely about technical measures, but also about changing behaviour, changed decision-making processes and new regulations, she says and gives a number of examples.

- The increase in rain quantities means we should not to the same extent lay asphalt on our private land, and for example should not pave the entire yard.
- Perhaps we must change our holiday habits and travel to the Mediterranean in autumn and spring instead of summer.
- We must get used to the idea of not having snow in winter, and skiing in ski tunnels, or cutting back on activities that require snow.

In the future then, it will be largely about doing without?
"No, we will also be able to benefit from new possibilities. Growing fruit, vegetables and garden plants on allotments."

Perhaps we will dare to try new varieties. If the average global temperature rises moderately, a maximum of 2°, there will be both advantages and disadvantages for the Nordic countries. But if it turns out to be 4 to 60 days, it will be harder to predict what will happen, she says.

"One advantage is a reduction in energy costs for heating. Other advantages are that growth will increase in forestry and agriculture. On the other hand fans and cooling facilities will be needed in the summer."

You also mention changed decision-making. How?
"Previously, it was assumed in planning that the climate was stable. Today there is major uncertainty about how our climate will develop. So it is good that decision-makers do not enter long-term undertakings. And we should bear in mind the worst case scenarios."

The project also includes a gender perspective. Can you give an example?
"In the Mediterranean heat wave in 2003, it was seen that the effects were different for men and women. There were far more women who died. One theory is that women take more diuretic medicines, and another is that women's work duties in the household in general have to be carried out under all circumstances, while men who work with for example house alterations can postpone such work. A third factor may be that public transport is often poorly adapted to heat waves, and that women use public transport to a greater degree than men."

Is adaptation solely the responsibility of society? Do we individuals have responsibility?
"Yes, actually. But it is something we have hardly begun to talk about so far. We must encourage individuals too to adapt. What responsibilities do people living in waterside locations have, for example? If I bought a house by the sea, where I have heard the sea level is estimated to rise by 0.8 to 2 m by the year 2100, I would not expect to be protected against damage costs."

How are the costs to be distributed?
"That's a very interesting question. People who are well-off and have a house by the sea in Skåne where the water is rising – should society pay their costs or should they themselves pay? No one has solved that problem."

What do you do personally do to be climate smart?
"We have three children who've grown up without us having a car. But I'm not good at taking fast showers."

Why should people in Norrbotten do?
"I think it's with car trips you can do most, by reducing trips, among other things by car sharing. Many people in Norrbotten have large houses, and it's worth thinking about the indoor temperature or whether certain spaces can be cooler."

Local councils' responsibility – but also our own

Sten Bergström, professor at SMHI, is something of a nestor in climate issues and hydrology. How does he judge the consequences of climate change for Norrbotten?

"It's a complex matter. I prefer to talk about changes in Norrbotten, rather than worsening. Some things will improve, for example the vegetation period will be longer."

If you compare with other parts of Sweden, Norrbotten will not be hit so hard by the consequences of climate change.

"For Sweden, the really big problems will mostly arise in southern and western Götaland, and in the Stockholm area", says Sten Bergström, who also reminds us of the global perspective; low-lying cities in the world's poor countries will be hit first, while we in the cold regions of Norrbotten, Siberia and northern Canada will manage relatively well."

One factor that favours the Norrbotten coastal zone compared to the southern parts of the country is the fairly rapid glacial rebound.

"We all tend to want to live near water. But in Norrbotten, glacial rebound will probably stay at the same rate as the general rise in the sea level for the foreseeable future."

Calculations by SMHI show that winters in the North will be increasingly mild with less snow. Winters will be more slushy, like we have in the South today. Since the snow limit is moving northwards, tourism could do it too. It can be both an advantage and disadvantage for tourism in the North.

What risks are associated with the big rivers in Norrbotten?

"A lot of work is going on in this area, and SMHI maintains a frequent dialogue with the power industry. I'd say we are at the forefront of adaptation work in Sweden. There is also a dialogue with the mining industry about tailings reservoirs."

"It is not certain that river flows will increase in the future. The spring floods will probably diminish in the long run, at the same time as the flow of rainwater will increase, above all up in the mountain areas."

When it comes to the developed rivers, Sten Bergström stresses that there are a series of factors alongside the climate issue which can play an important role, for example the development of the electrical power industry.

"And the link to the development of wind power. It is difficult today to see what it will mean to the dynamics of rivers. In the future, perhaps we will be using more electricity for cars than for warming our houses. And when there is a heat wave in Europe, perhaps we will need to produce electricity to run air conditioning plants."

Society has a responsibility for adaptations. Does that apply to us individuals too?

"It's a very good question. If we have something built ourselves, for example a cottage, it is clear that we have a responsibility. Nevertheless the main responsibility is still with the municipalities who have the last word in planning issues. There is a special situation in Sweden, with fairly decentralised regulation of planning permission. It puts considerable pressure on the municipalities. Their competence and understanding of issues are therefore extremely important, and it is good that the County Administrative Boards are now assembling the municipalities."

If winters grow milder, can we then carry out adaptations which in a way are positive – for example, changed recommendations on the frost free depth for pipes and cables?

"No, in the future we will be shifting through several different climates. And the predictions are uncertain. In carrying out adaptation work, one must quite simply accept increasing uncertainty, I think."

What will be difficult to adapt?

"That would be alterations to existing buildings, for example waterside sites."

Finally: what do you do personally to be climate smart?

"I'm like most people. I usually cycle to work and try and avoid flying. My family think I'm a bore for not wanting to fly to Thailand. The trip there corresponds to a whole year's car driving..."

Consequences and adaptation proposals

The following compilation shows how society can be hit by increased vulnerability due to climate change. The emphasis is on the consequences estimated to occur in the long term. The material is based on data from the Commission on Climate and Vulnerability. The selection includes factors of relevance 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 description of the consequences and the Proposed adaptation measures have been divided into the following seven areas:

- Transport and communications
- Technical supply systems
- Buildings
- Land-based industries and tourism
- The natural environment and environmental goals
- Public health
- The impact of a changing world

Transport and communications

INCREASED PRECIPITATION LEVELS are expected during the winter months. In combination with increased run-off and reduced occurrence of seasonal ground frost, this can lead to considerable increases in groundwater formation during the winter months. There is also concern over a possible cumulative effect with a gradually rising water table. In parts of northern Sweden and along the coast of northern Sweden, calculations show that 100-year floods with extreme local inflow can be changed to 20-year floods.

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 load-bearing 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.
- Measures regarding bridges: an investigation should be carried out of hydrological conditions and the vulnerability of bridges with a clearance height of less than 0.3 metres above the maximum high water mark. Preliminary number: 12 in Norrbotten.

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.

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 extreme

weather events can cause power cuts and can disrupt 21 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 landowners 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 power-line 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.

For example, forecasts for the Suorva dam show a relatively large increase in inflow during September, October and November. Also for the winter months of January, February and March, forecasts indicate an increased inflow, although to a lesser extent than during the autumn months. The changed inflow cycle can mean problems for among other things the filling period from the spring flood until autumn.

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.

On the basis of the studies that have been carried out, no clear decision can be given as to whether climate change will result in increased or decreased flows for class 1 dams. At present (2007) there is too little data to judge whether, and if so how, dams need to be adapted in view of the expected climate change. It is judged that the climate issue will bring added uncertainty which needs to be addressed when planning dam safety levels.

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 run-off 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. The surplus would then need to be spilled past the reservoir. In the rivers Kalix and Pite the recurrence frequency of 100-year floods is judged to be the same as during the period 1961-1990.

Consequences for sea levels

Glacial rebound along the coast of Norrbotten is expected to compensate for the rise in sea levels. The mean sea level at the end of the century is estimated to be 15 cm higher in the northern Gulf of Bothnia. The 100-year water level is estimated to be up to 196 cm above the mean sea level. 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.

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.
- In-depth studies should be carried out of certain rivers in northern Sweden, since today’s 100-year floods may become more frequent in parts of mountain regions.
- Existing, low-lying built-up areas may in future need to be protected by embankments and by pumping day water and drainage water.

Collapse, landslides and erosion

Consequences

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

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 constitute a risk. 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.
- Carry out in-depth studies of watercourses where climate calculations indicate that today's 100-year floods can occur much more often.
- In their own 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.

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 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.

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.

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 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

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.

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

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

increased addition of nutrients and increase production, the risk increases of oxygen deficiency in the formation of hydrogen sulphide in the bottom water.

Several of the cold water species char, burbot, smelt, vendace, lavaret, grayling, salmon and trout are of economic importance. Revenue from fishing is expected to decrease by about 10 per cent in the inland areas of northern Sweden, since the decrease in trout and char cannot be compensated by an increase in warm water species.

The reduced salt content in the Baltic Sea favours species such as vendace, which is a very important fish species in the Gulf of Bothnia. Even though it is disadvantaged by the temperature increase, its southward expansion will be favoured.

PROPOSED ADAPTATION MEASURES

- Negative economic effects of climate change can be countered by eliminating obstacles to migration in water areas to stimulate species to colonise suitable bodies of freshwater. (Comment by the County Administrative Board: should only be attempted where it is anthropogenic migratory obstacles that are preventing the spread. Possible measures should be weighed against other interests.)
- Watercourses should be restored to their original function of slowing and storing water to counter the negative effects of extreme flows.
- In the short-term: continue work to limit fishing catches.
- Retain or increase migratory options between and within water systems. Alternatively, one can consider artificial distribution of fish. (Comment by the County Administrative Board: should only be attempted in cases where it is anthropogenic migratory obstacles that are hindering spread.)

A mean temperature increase of 2.5 to 4.5° and less seasonal variation, but a greater total discharge from large watercourses, mean that considerable changes can be expected in the ecosystems of The Gulf of Bothnia in a long-term perspective. This is strongly affected by the big rivers and other freshwater flows, and will mean among other things comprehensive changes to the conditions for the species that migrate between fresh water and the sea.

Spawning and smolt growth among fish species that undertake seasonal migrations are adapted to the increase in plankton production that occurs in connection with spring and early summer peak flows, both in the watercourses themselves and in river estuaries. Its early stages of life are strongly affected by variations in the supply of food in the form of animal plankton. Climate change is expected to mean increased run-off with increased transport of humus 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 can be extended. This can result in the salmon maturing and returning to their natal rivers at an earlier age.

Attention should be given to the fact that a species like the salmon in northern Sweden rivers goes through about 14 to 20 generations in a century. This is a very short time for adapting to new life conditions.

Since the ice season is expected to become on average two months shorter in the Gulf of Bothnia, and the shortening of the ice season will affect the life conditions of the ringed seal and the grey seal.

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
- Consultation requirements should be extended to all reindeer forest forage 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 reliable 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 af-

fected 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.

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.

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.

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 bio-

available 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 production	Reduced supply of food on world markets, depending on the extent 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 i nfectious 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.

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Text: Micael Bredefeldt, The County Administrative Board in Norrbotten County
Address: Länsstyrelsen i Norrbottens län, 971 86 Luleå, Sweden
Tel: +46 920-96000
E-Mail: norrbotten@lansstyrelsen.se
Web: www.lansstyrelsen.se/norrbotten
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