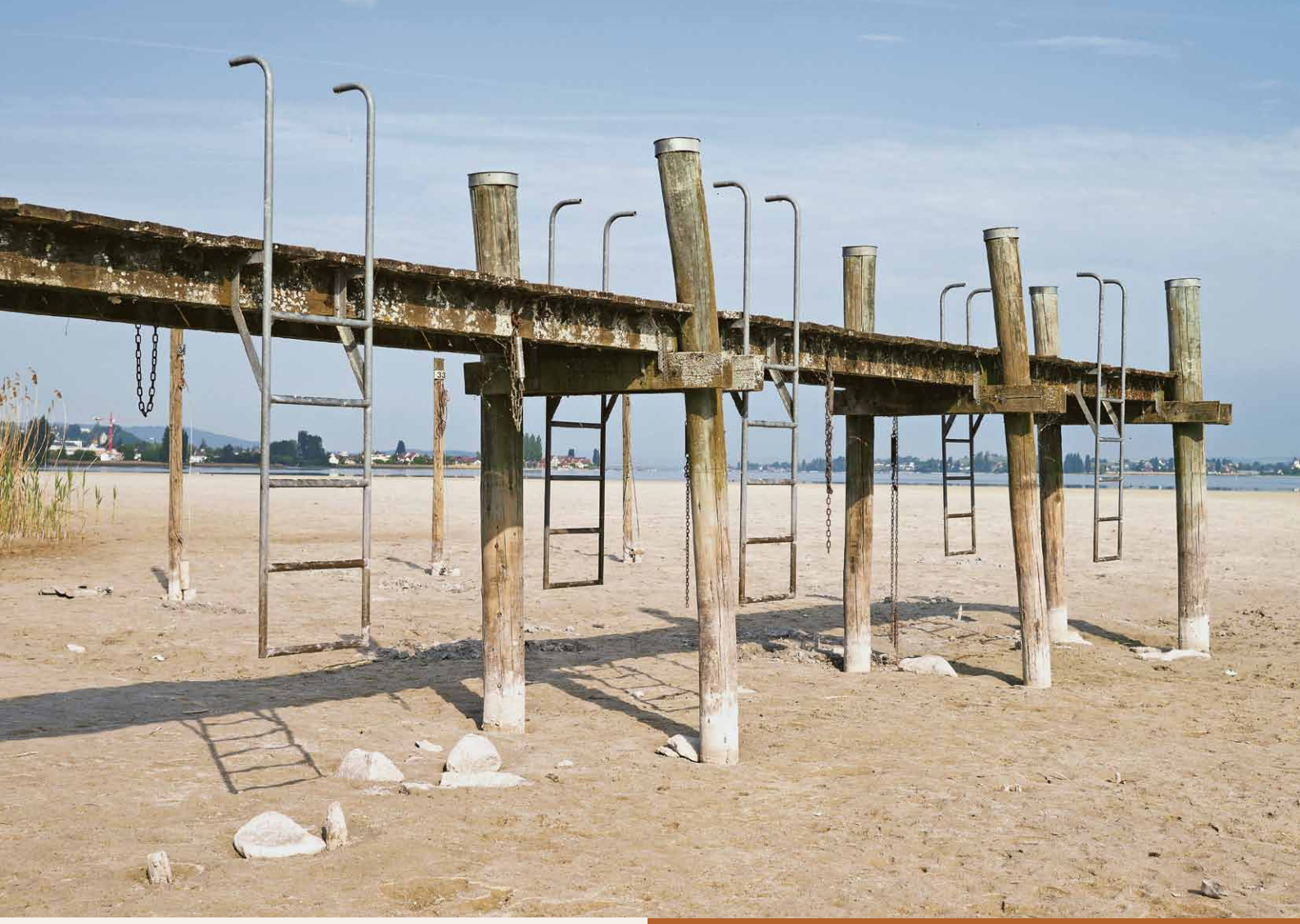

Adaptation to climate change in Switzerland

Goals, challenges and fields of action

First part of the Federal Council's strategy
Adopted on 2 March 2012

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

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Low water at Untersee near Triboltingen (Canton Thurgau) on 10 May 2011: The lack of rainfall during the winter months led to an above-average drop in the water levels of rivers and lakes in Switzerland. Climate change is likely to cause extended dry periods in summer.
Source: KEYSTONE / Rene Ruis

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Adaptation to climate change in Switzerland

Goals, challenges and fields of action

First part of the Federal Council's strategy
Adopted on 2 March 2012

The Federal Council's strategy "Adaptation to climate change in Switzerland – Goals, challenges and fields of action. First part of the Federal Council's strategy. Adopted on 2 March 2012" was published on 2 April 2012 in the Federal Gazette and is the legally binding version. This publication is the version of the strategy that was designed for better readability.

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
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Summary

The climate in Switzerland is changing and will continue to change. The extent of change depends to a large extent on future levels of global greenhouse gas emissions. The higher the new emissions, the greater the extent of climate change will be. If emissions rise as projected by a moderate emissions scenario, temperatures will increase in the coming decades in all parts of the country and in all seasons of the year. In particular, we can expect a marked decrease in levels of summer rainfall in the second half of the 21st century. Climatic changes have an impact on environment, economy and society. We need to start adapting to climate change now, and the urgency of the situation will become more acute with time. The Federal Council's adaptation strategy creates the framework at federal level for a coordinated course of action in adjusting to climate change.

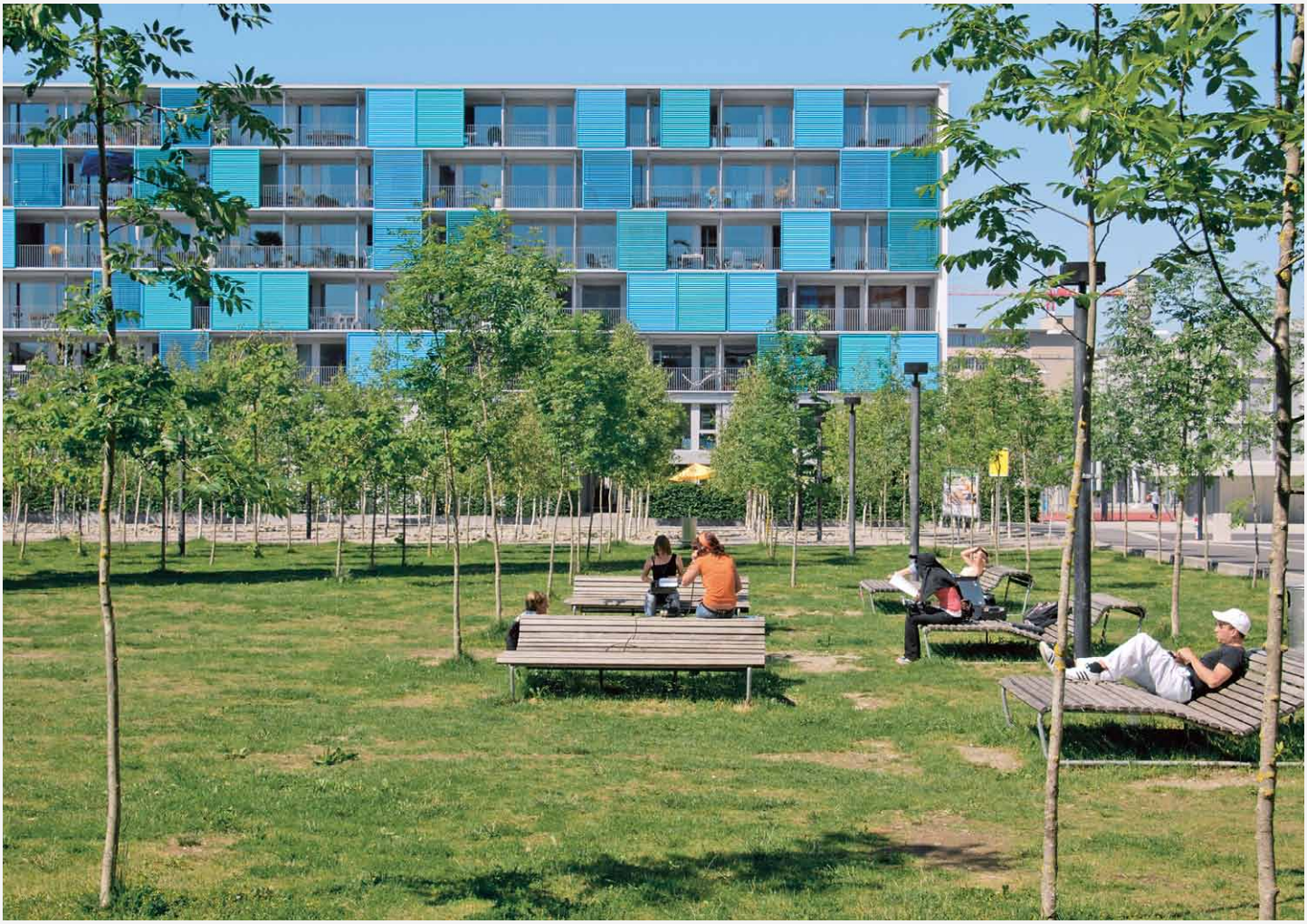
The adaptation strategy is divided into two parts. The first part, presented here, describes the goals, challenges and fields of action in adapting to climate change. The adaptation strategy should enable Switzerland to take advantage of the opportunities provided by climate change, minimise the risks and increase the adaptive capacity of its natural and socio-economic systems. The most important challenges arising directly from the effects of climate change in Switzerland and to which the country must adapt are:

– greater heat stress in agglomerations and cities,
– increasing levels of summer drought,
– greater risk of flooding,
– decreasing slope stability and more frequent mass wasting,
– rising snowline,
– impaired water, soil and air quality,
– change in habitats, species composition and landscapes,
– spread of harmful organisms, disease and alien species.

The need to improve the bases upon which adaptation measures are planned and implemented poses further challenges. In particular, the monitoring and recognising of climate-related changes at an early stage need to be better coordinated and improved and the knowledge base expanded. There needs to be increased awareness, information and coordination, and better assessment of what resources are required and how costs will be met. In order to overcome the challenges posed by the impact of climate change and the need to improve the way in which we react to the changes, we need to work more closely across sectors and coordinate efforts on a national scale.

Besides looking at these challenges, the first part of the strategy considers how we can adapt in a range of areas, from water management, natural hazard management, agriculture and forestry to energy, tourism, biodiversity management, health and spatial development. Fields of action for adapting in these sectors are defined, adaptation goals formulated and possible ways of achieving these goals outlined. The interfaces between ways of adapting to climate change in the different sectors are also described. These should allow us to use existing synergies in adapting to climate change to the full, and avoid and resolve conflicting objectives.

The first part of the adaptation strategy is not a catalogue of measures. Adaptation measures will be developed in a next step by the departments responsible and presented and coordinated in a joint plan of action – the second part the strategy. Cooperation between the Confederation, cantons, communes, associations and individuals is important in this process. The measures will also need to be aligned with other Federal Council cross-sector strategies.



Climate change will lead to heat waves becoming longer, more frequent and more intense. The way in which we design open spaces when adapting to climate change is very important. In a new residential area in Zurich-Oerlikon, expansive green spaces were created to have a positive impact on the local climate. In future, they will provide a recreational area for the heat-stricken urban population.

1 Introduction

Switzerland must adapt to the effects of climate change over the coming decades. The adaptation strategy creates a framework for the federal offices to adopt a coordinated course of action in responding to these changes. Switzerland should exploit the opportunities arising from climate change, applying targeted measures to minimise the risks involved, protect the population, infrastructure and natural landscape, and increase the adaptive capacity of society, the economy and nature.

Confederation, cantons, communes and individuals must work together to adapt to climate change. The strategy presents ways of adapting at federal level, only taking account of effects of climate change in Switzerland. The effects of climate change in other regions of the world on Switzerland, for example the impact of increasing levels of drought in subtropical areas on food imports or the threat to global security due to climate-related resource conflicts, are not dealt with here.

1.1 Adaptation strategy content

The adaptation strategy is divided into two parts. The first part, presented here, describes the goals, challenges and fields of action in adapting to climate change. The second part, due to be available by the end of 2013, will build on this, presenting a plan of action which brings together specific adaptation measures.

The first part of the adaptation strategy is presented as follows: In Chapter 2, a summary of the most significant challenges in adapting to climate change facing the country at federal level is presented. A distinction is made between the challenges arising from the effects of climate change and those involved in improving the bases for adapting to climate change. In Chapter 3, super-ordinate goals and principles for adapting to climate change are formulated. Chapter 4 looks at adapting to climate change in the key sectors most affected. For each of these sectors, it identifies important fields of action, frames adaptation goals for the fields of action and outlines the way in which these goals can be achieved. Chapter 5 gives an overview of the interfaces which exist between the sectors in the adaptation to climate change. Chapter 6 outlines a further course of action. Annex A1 sets out the procedure and methodology adopted in drafting the first part of this strategy. Annex A2 presents a summary of a regional climate scenario for Switzerland and the most significant effects of climate change on Switzerland upon which the adaptation strategy is based.

1.2 Role of federal offices in strategy development

The drafting process for the first part of the adaptation strategy was coordinated by the Interdepartmental Committee on Climate (IDA Climate). The following federal agencies were involved:
- Federal Office for Spatial Development (ARE)
- Federal Office for Civil Protection (FOCP)
- Federal Office for the Environment (FOEN)
- Federal Office of Public Health (FOPH)
- Swiss Federal Office of Energy (SFOE)
- Federal Office for Agriculture (FOAG)
- Federal Veterinary Office (FVO)
- Federal Finance Administration (FFA)
- Federal Office for Meteorology and Climatology (MeteoSwiss)
- State Secretariat for Economic Affairs (SECO)

The FOEN had the overall responsibility for developing the present first part of the strategy. It moderated the procedure, ensured that a uniform approach was adopted and coordinated work between sectors. The individual federal offices were responsible for adaptation in their sectors. MeteoSwiss provided the climatological data on observed changes in the climate and future climate scenarios.

1.3 Interfaces between adaptation strategy and other strategies and policies

With the revised CO_2 Act[1] passed by the Federal Assembly on 23 December 2011, adapting to the effects of climate change from 2013 became the second, complementary element of Swiss climate policy in addition to the urgent need to reduce greenhouse gas emissions. In accordance with Article 8 (Coordination of adaptation measures), the Confederation is required to coordinate climate change adaptation measures and to create the necessary framework within which these measures can be implemented. The adaptation strategy plays an important role in meeting this statutory mandate.

Establishing the need to adapt in the CO_2 Act accords with the UN Climate Change Convention, which in Article 4, paragraph 1 requires the contracting states to assess their need to adapt to climate change and to implement appropriate measures accordingly. In the Bali Action Plan, adapting to climate change is one of the four central categories of global climate policy[a].

The adaptation strategy will be coordinated with the Federal Council's "Sustainable Development Strategy" action plan for the legislative period 2012–15. There are numerous interfaces and overlaps with the sectoral programmes, strategies and policies. In the water management sector, adapting to climate change is a response to the Walter postulate (parliamentary procedural request) entitled "Wasser und Landwirtschaft. Zukünftige Herausforderungen"[2] (Water and agriculture. Future challenges). This calls on the Federal Council to draw up a water strategy which, among other things, sets out how water will be distributed in times of scarcity and how to deal with conflicting interests regarding conservation and use. In the field of natural hazards, adaptation to climate change is explicitly dealt with in the "Strategie Naturgefahren Schweiz"[3] (Natural hazards strategy for Switzerland) drawn up by PLANAT. In a further study[4], the significance of climate change for civil protection is examined in detail. In the agricultural sector, adapting to climate change is discussed in the "Klimastrategie Landwirtschaft"[5] (Climate strategy for agriculture) and in the consultation document "Land- und Ernährungswirtschaft 2025"[6] (Agriculture and food production). In the field of forestry, adaptation is dealt with in the "Waldprogramm Schweiz"[7] (Swiss forestry programme). "Energieperspektiven 2035"[8,9] (Energy Outlook 2035) looks at the effects of climate change on the energy industry in the form of sensitivity analyses. The "Wachstumsstrategie für den Tourismusstandort Schweiz"[10] (growth strategy for Switzerland as a tourist location) defines climate change as one of the five most significant challenges facing the Swiss tourist industry; adaptation is discussed in the context of the 2012–15 implementation programme. The Federal Council has submitted a "Strategie Biodiversität Schweiz"[11] (Swiss biodiversity strategy) for consultation, which does not examine the issue of adapting to climate change, instead making reference to the adaptation strategy.

At an international level, Switzerland takes part in the dialogue on adaptation to climate change in the network of European environmental agencies. In 2009, the European Commission published a white paper on adapting to climate change. In contrast to the tightly coordinated measures within the European Union (EU) to mitigate climate change, efforts to adapt to climate change even within the EU are still based on national and regional strategies. As a result, when placing its strategy in an international context, Switzerland concentrates on observing national strategies in Europe and exchanging information with its neighbouring countries on experiences of strategy development and implementation.

a The four main categories of the Bali Action Plan are: (1.) emissions reduction, (2.) adaptation, (3.) technology transfer and (4.) financial support (capacity building).

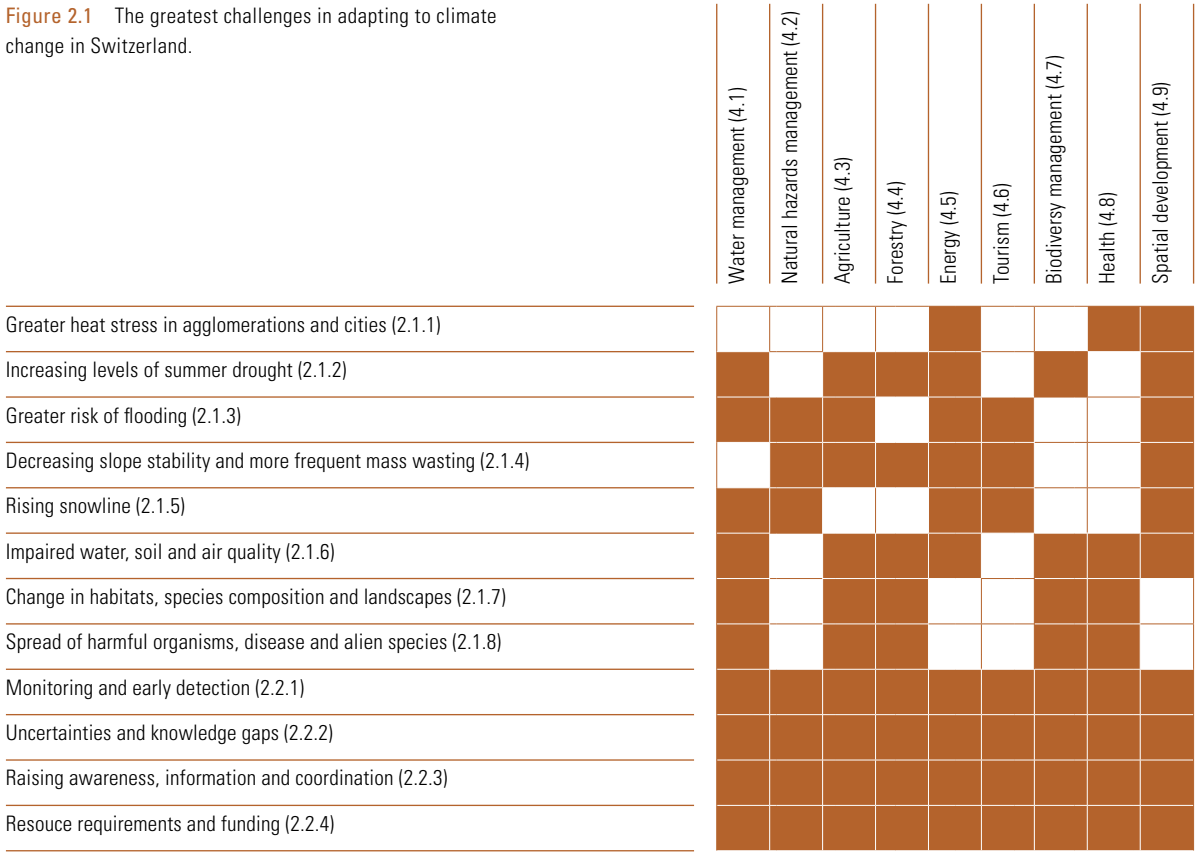
2 The main challenges in adapting to climate change

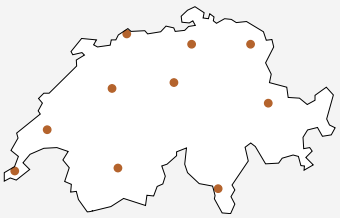
The main challenges facing Switzerland in adapting to climate change at federal level are described below. The selection is based on a cross-sector analysis and is advocated by all specialist bodies involved. It is based on statements on adaptation to climate change in the main sectors affected by the phenomenon (Chapter 4) and on an analysis of the interfaces between these sectors (Chapter 5).

The main challenges and the various sectors affected in each case are depicted in Figure 2.1. They are given in no particular order of priority. Some of the challenges result directly from the effects of climate change on the sectors (cf. 2.1). The other challenges are intended to improve the basis for implementing adaptation measures (cf. 2.2).

At the beginning of the each description of the different challenges, there is a brief depiction of their regional impact, which is also presented in graphic form. There are also references to the affected sectors and fields of action (Chapter 4).

Figure 2.1 The greatest challenges in adapting to climate change in Switzerland.





Greater heat stress in agglomerations and cities

Regions affected:
Agglomerations and cities

Sectors affected:
Spatial development (S1)[b], health (H2, H3), energy (E1)

b The abbreviations in brackets indicate the areas of adaptation in the different sectors (Chapter 4).

2.1 Challenges posed by effects of climate change

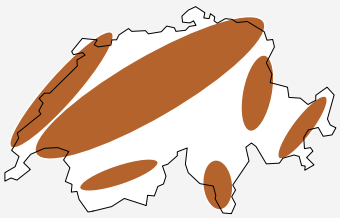
2.1.1 Greater heat stress in agglomerations and cities

As the average temperature increases, heatwaves are likely to become longer, more frequent and more intensive. For urban populations in particular, this will lead to greater health problems. In cities the effect of higher temperatures may be intensified locally: limited wind circulation in densely built areas, the lack of shade and green areas, absorption of the solar irradiation by the large amount of sealed surface and waste heat from industry, buildings and transport create an urban heat island, where daytime temperatures increase and night-time cooling is restricted. Maximum temperature differences of up to 10 °C between the inner-city areas and the surrounding rural area have already been measured.

Heatwaves can be life-threatening to the elderly and infirm, those in need of care and to babies. In the heatwave of summer 2003, a marked link was established between the high temperatures and the above-average number of deaths. High temperatures reduce the shelf life of food and there is a greater risk of incidences of food poisoning. Finally, high temperatures affect people's performance, reducing productivity and concentration levels in the workplace.

There must be closer cooperation between the spatial development, health and energy sectors in order to address the issue of how to adapt to greater levels of heat stress in our cities. The development of open spaces in urban areas is of particular significance in this respect; spatial planning can ensure that there are sufficient open spaces with a multifunctional purpose (cooling, air circulation, recreation etc.). The ecological infrastructure is a key factor here – trees and green areas break up sealed surfaces, enhance open spaces, create shade and have a cooling function for the local climate (evaporation). But the general public can also adapt its behaviour to help reduce the risk to health.

Targeted information on how best to act during a heatwave needs to be disseminated promptly. In the energy sector, steps must be taken to counteract the growing demand for power for cooling purposes in order to safeguard the interests of super-ordinate political targets (efficient energy use, low-carbon energy coverage). In particular, incentives must be created for installing solar energy systems on roofs (carbon-free energy generation and reduced heat radiation), green roofs and facades, minimum requirements for cooling, air conditioning and ventilation installations and appliances and greater awareness among owners, architects and planners.



Increasing levels of summer drought

Regions affected:
Jura, Southern Alps, inner-alpine dry valleys, small and medium-sized catchment areas in Mittelland[c], Rhine Valley

Sectors affected:
Water management (W1, W4, W5, W9, W12), agriculture (A3), forestry (F3), energy (E2), biodiversity management (B2), spatial development (S4)

c The Swiss plateau

2.1.2 Increasing levels of summer drought

Overall, Switzerland has considerable available water reserves, and we can assume that there are sufficient amounts of water for the various users. Depending on the region, season and sector, there are however already bottlenecks in water supplies. Climate models predict a marked reduction in summer precipitation levels for the whole of Switzerland, in particular for the second half of the 21st century. Extended periods of drought are to be expected to occur more frequently. At the same time, evaporation from plants and soils, water bodies and glaciers will increase as temperatures rise.

Declining levels of summer precipitation affect all water users: agriculture, which increasingly needs to water crops to keep up production; forestry, which has numerous drought-sensitive areas affected by the spread of insect populations and a greater risk of forest fires; electricity production, in which less water can be extracted from watercourses to generate power; biodiversity, for which a minimum water flow and good water quality in rivers are essential, and residential water regimes, which require sufficient water flow in receiving watercourses for the treatment of wastewater. There may also be local and periodic restrictions to the supply of drinking water.

As climate change increases the pressure on available water reserves, competition between the various water users in small and medium catchment areas may arise during long periods of drought. In finding ways to adapt to increasing drought, attention must be paid to reducing the water requirements of the affected sectors and to using the available water reserves in an optimum manner. These are two central elements of integrated catchment area management, which aims to affect a paradigm change from demand-oriented to supply-oriented water management.

In agriculture, water requirements can be reduced by increasing the water retention and storage capacities of soils, selecting suitable plant breeds and optimising irrigation systems. In forestry, the focus is on eliminating existing risks and regenerating forest areas with adaptable species. In residential water management, possibilities include waste water treatment on a more regional level and discharging treated water into large receiving watercourses when water levels are low. The energy sector can counter restrictions in hydroelectric power generation by efficiently exploiting the remaining potential and making use of additional renewable energy sources to a greater extent.

Water supply can be optimised. However, for this to happen we need new water storage and water distribution models. In particular we need to look at ways of exploiting natural water storage facilities, using reservoirs in a variety of ways, adapting lake regulation, constructing water storage facilities for irrigation purposes and optimising distribution systems. In this, the needs of the neighbouring countries must be taken into account.

Furthermore, a clear set of rules and procedures regarding water distribution in times of water shortage are required. At federal level, these are developed in the reply to the Walter postulate[2].

Due to the greater risk of forest fires, the fire-fighting services of the civil protection forces will be required more frequently. It needs to be assessed how best to prepare them for this task.

Greater risk of flooding

Regions affected:
Whole of Switzerland

Sectors affected:
Water management (W2, W6, W7, W8), natural hazards management (N1, N2), agriculture (A1), energy (E2), tourism (T2), spatial development (S3)

2.1.3 Greater risk of flooding

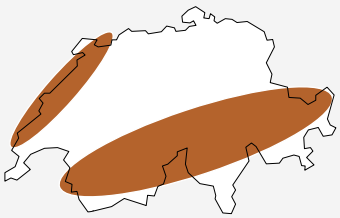
As a consequence of climate change there are likely to be more frequent incidents of winter flooding throughout Switzerland. The reason for this lies in the predicted increase in total winter precipitation plus a rise in the snowline. Spring and early summer could also see a greater risk of flooding as a result of combined extensive snowmelt and intensive precipitation. These projections are, however, relatively uncertain.

The likely increase in flood events affects built-up areas, buildings, transport routes, infrastructure and agricultural areas to differing degrees. Built-up areas with large sealed surfaces preventing infiltration will be particularly vulnerable.

A comprehensive approach to flood protection has already been developed in Switzerland. In addition to organisational and structural safety measures, this includes spatial planning measures. Adapting to the increasing risk of flooding involves above all the sectors natural hazards management, spatial development and water management.

Spatial planning plays a key role. Firstly, it must ensure that areas at risk are not built over. Hazard maps are an important instrument which allows spatial planners to take account of natural hazards and draft comprehensive conservation models. Once completed, these are regularly updated and applied in the planning process. Secondly, watercourses must be allowed sufficient space, including in an overload situation, and altered as required. Water can be stored naturally in the soil and floods controlled naturally by ensuring some areas remain unbuilt and by suitably adapting agricultural management. Water management must also look at new flood prevention models, in particular the multipurpose use of reservoirs and lake regulation. The interests of our neighbouring countries must be taken into account in this.

When new flood control structures are built or existing ones renovated, the influence of climate change on flood discharge should be taken into account. Finally, the civil protection forces, for which flooding already poses a huge challenge, must be prepared for the more frequent occurrence of such events.



Decreasing slope stability and more frequent mass wasting

Regions affected:
Alpine region, Jura

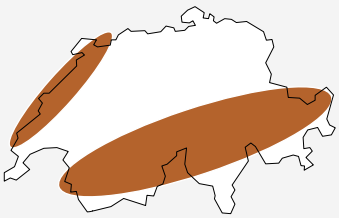
Sectors affected:
Natural hazards management (N3), agriculture (A1), forestry (F1), energy (E4), tourism (T2), spatial development (S3)

2.1.4 Decreasing slope stability and more frequent mass wasting

As a consequence of climate change, landslides, rockfalls and mass wasting will probably become more frequent in the coming decades due to the increasing rate at which glaciers are melting and the slow thawing of the permafrost. Both these phenomena are causing a reduction in slope stability in the steep areas in the Alpine valleys. There will also be a greater risk of landslides if the incidences of heavy precipitation increase and the snowline rises.

The increase in mass wasting may pose a threat to residential areas and passenger and freight transport on rail and road and to gas and power cables in Alpine areas. Tourist installations, river barrages, agriculture and important transport links in the Mittelland may also be affected.

Adapting to the climate-related increase in mass wasting involves primarily the sectors natural hazards management, spatial development and forestry. We must first of all observe developments in glacier melt and thawing of the permafrost and monitor areas at risk (cf. 2.2.1). Once completed, the hazard maps must be regularly updated and used in spatial planning processes. Furthermore, this instrument should be developed further so that integral hazard mapping and risk mapping is possible. In view of the changing hazard situation, the existing protection models must be reassessed and adapted as necessary. Forestry is a further area facing specific challenges; storms, pests, drought stress and forest fires may adversely affect the protective function of the forest to a considerable degree. Protection forests must be adapted both to the changing climate and to the changing hazard situation. This will involve additional management intervention in areas with insufficient rejuvenation and reduced stability. In some cases, more protective structures may be necessary. Transport and energy infrastructure will also need to be considered in the adaptation measures, and operators made aware of the altered risk situation. In agriculture, suitable methods can be employed in specific situations to help prevent hazards and reduce damage.



Rising snowline

Regions affected:
Alpine region, Jura

Sectors affected:
Water management (W2, W5, W12), natural hazards management (N1, N2), energy (E2), tourism (T1), spatial development (S2)

2.1.5 Rising snowline

As our climate warms up, the average height of the snowline will rise. At low and medium altitudes, we must expect more rain instead of snow in winter. It is unclear how snow cover will develop at high altitudes in the future; this depends on local climatic factors.

A rising snowline has an impact on the water cycle: flow rates increase in winter, as less precipitation is stored as snow. The risk of flooding increases (cf. 2.1.3), and more water is available for electricity production. In the early summer flow rates are likely to drop due to the lower levels of snow melt. This increases the risk of periods of drought, (cf. 2.1.2), and so less hydroelectric power can be generated. Moreover, a rise in the snowline affects winter tourism. Whereas the guarantee of snow provides a competitive advantage for Alpine winter resorts at high altitudes, low-lying snow-sport resorts, in particular in the Alpine foothills, may be adversely affected due to uncertain snow conditions.

Hydroelectric power generation must react to changes in flow rates resulting from the rising snowline by adapting the way in which reservoirs are managed. In winter tourism, artificial measures such as snow-making are at present principally employed in reaction to the rising snowline. However, such measures will only be temporarily effective due to increasing temperatures in lower-lying regions. Therefore, it is more and more vital to diversify the tourism supply, developing alternatives to winter snow sports and increasing the profile of summer tourism.

Impaired water, soil and air quality

Regions affected:
Whole of Switzerland

Sectors affected:
Water management (W1, W3, W9, W10, W11, W13), agriculture (A1, A2), forestry (F2, F4), energy (E3), biodiversity management (B2), health (H2), spatial development (S2)

2.1.6 Impaired water, soil and air quality

Climate change may well impair water, soil and air quality. The temperature of surface waters will continue to rise as air temperatures increase. As the temperature of water rises, its oxygen content decreases. The concentration of pollutants may increase in shallow water. The quality of groundwater and spring water may be adversely affected when infiltrated by surface water of impaired quality. More frequent and heavier rain in some areas will result in greater soil erosion, the associated loss of topsoil and leaching of nutrients. Air quality could be impaired by a possible increase in stable areas of high pressure, which cause higher concentrations of pollutants. Higher temperatures may lead to greater amounts of plant matter, but also cause organic matter to decompose at a faster rate.

The changes outlined above have an impact on the use of resources. Higher water temperatures compromise the production of energy in thermal power stations (nuclear, gas) and mean that water can be less effectively used in other cooling processes. Higher water temperatures and poorer water quality also have a negative impact on fish stocks. Drinking water supplies could also be affected by the possible reduction in groundwater quality. In agriculture, the processes described above will pose a huge challenge to maintaining humus levels and nutrient supply to plants – thus endangering production. Poorer air quality may have a serious effect on health. High pollutant concentrations in the air during heatwaves exacerbate cardiovascular diseases.

The adaptation strategy concentrates on the sustainable use and management of resources. In the field of energy production, cooling systems need to be improved or other cooling mediums used. Statutory regulations relating to the introduction of cooling water may need to be revised. In the case of drinking water, improving the network and using several independent water resources are possible solutions. In agriculture, methods must be employed which counteract the loss of topsoil and plant nutrients.

Furthermore, it will be necessary to reduce the threat to resources from non-climatic influencing factors and prevent developments which reduce the systems' resilience. For example, human activities which result in the warming of water in rivers must be restricted. In the case of air quality, we must continue to restrict ozone precursors and emissions of other pollutants.

Change in habitats, species composition and landscape

Regions affected:
Whole of Switzerland

Sectors affected:
Water management (W13), agriculture (A1), forestry (F2, F4), biodiversity management (B2, B4), health (H1)

2.1.7 Change in habitats, species composition and landscape

Changes in temperature and precipitation have an effect on the distribution of animal and plant species and on natural habitats. The range of particular species which rely on specific climatic conditions will adapt to the changing climate as far as possible. There will be changes in the combination of species present on a localised level; new species will arrive; some will become more abundant, others rarer, and some may even disappear. It is expected that local plant diversity will decline. Changes in local conditions may lead to a loss of habitat for individual species and species composition and to changes in the character of the landscape in the longer term.

Changes in biodiversity will most likely affect ecosystem services negatively, at least initially, whilst positive effects might only be expected after some time. More frequent drought in the inner Alpine valleys threatens the stability of forests and negatively affects their protective function. Furthermore, forests, wet meadows and moorland will be unable to act as effectively as carbon sinks, and the rise in the tree line resulting from climate change will probably be able to compensate for this only partially. A change in species composition in pastureland will have an impact on the quality of and returns from fodder cultivation. In general, the suitability of land to grow particular crops may alter. Warmer rivers will mean that habitats for cold water fish will shrink and warm water fish will have a larger natural environment. Species at lower and warmer altitudes will be able to spread, whilst the range of species in higher, cooler and wetter areas will decline. Many species will be affected by this; Switzerland has a special responsibility to protect them.

Barriers to the migration of animal and plant species need to be removed if the latter are to be able to adapt their habitats to climate change. In particular, we need to establish a clearly defined geographical system of conservation areas and habitat corridors in cooperation with the principal land users and with international affiliation. The possibility of resettlement must also be investigated for selected climate-sensitive species. In agriculture, growing suitable crop breeds will allow production potential to be exploited. In forestry, woodland needs to be continually regenerated with trees which are able to adapt to changes in their environment. In this way, the level of ecosystem services can be maintained, even though habitats may change.

Spread of harmful organisms, disease and alien species

Regions affected:
Whole of Switzerland below around 2000 m

Sectors affected:
Water management (W13), agriculture (A5), forestry (F1, F2), biodiversity management (B3), health (H1)

2.1.8 Spread of harmful organisms, disease and alien species

The warmer climate and milder winters will mean that in future more potential harmful organisms overwinter in Switzerland and their populations will be able to develop and spread more rapidly than before. The longer periods of warmth will allow insects to form additional generations. New, thermophilic animal and plant species may appear and spread in this country. These may include invasive organisms which have negative effects on human health and natural ecosystems.

Mobility and climate change favour the spread of and increase in the number of harmful organisms, and this may cause enormous loss or damage to landscapes and forests. Several such harmful organisms have already appeared in Switzerland, making special action by the Federal Plant Protection Service necessary. Human and animal health may be adversely affected by the appearance of new pathogens and their hosts and vectors. In some parts of the country, the tiger mosquito and the Asian bush mosquito have already become established as potential disease carriers. For people who suffer from a pollen allergy, the spread of the highly allergenic ambrosia species is an additional burden. The invasive behaviour of alien species also has an impact on biodiversity. Habitats such as wetlands and watercourses are already adversely affected by the presence of certain invasive species.

There are numerous ways in which the affected sectors, including biodiversity management, forestry, agriculture and health, can cooperate in dealing with alien species and the spread of harmful organisms and new diseases:

- There is still much to learn about how such organisms appear, become established and spread, and about how to control them. We are often dealing with the same or similar species and processes in the case of these harmful organisms, disease and invasive alien species; it is therefore important to build up a network of skills, coordinate research activities and exchange information between research, administration and practice (cf. 2.2.2 and 2.2.3).
- In order to become aware of these species and their impact at an early stage, existing monitoring systems must be coordinated and linked across sectors, and should focus on measuring the consequences of climate change (cf. 2.2.1).
- These organisms do not respect borders between countries; activities therefore need to be intensified at an international level.

2.2 Bases for implementation

2.2.1 Monitoring and early detection

In the human concept of time, climate change is a slow process. Some climatic changes can only be established after a considerable period of time (e.g. climate-related changes in the frequency and intensity of extreme events, or shifts in habitats). Serious changes may be detected too late or may be interpreted incorrectly. As a result, adaptation measures may be introduced too late, prove unsuitable or be incorrectly designed and so avoidable loss or damage and unnecessary costs may arise.

Ways of adapting to climate change are based on findings from climate observation and on climate scenarios that have to be regularly updated and made available. In order to better detect climate-related changes early on, existing monitoring systems must be extended and adjusted to the challenges that climate change presents. Almost all sectors are affected; in water management, existing monitoring networks must be maintained and supra-regional water management models established (cf. 2.1.2). In natural hazard management and the energy sector, we require a better system for monitoring changes in permafrost, snow levels, glaciers and soil movements (cf. 2.1.4). In the field of agriculture, a system of environment monitoring is currently being developed which involves a range of indicators also impacted by climate change (e.g. nutrient balance, application of production inputs, risk of erosion, quality of ecological buffer zones). Moreover, it will become increasingly important to detect drought and harmful organisms at an early stage. In forestry, early detection of harmful organisms and the broad monitoring of forest dynamics are of key importance (cf. 2.1.8). In the health sector, early detection and monitoring of climate-sensitive pathogens and vectors is essential (cf. 2.1.8). In biodiversity management, the central issue is to recognise climate-related changes by means of long-term monitoring programmes (cf. 2.1.7).

Monitoring and early detection are indispensable if we are to react to changes on time. In this area, there are numerous ways in which the different sectors can cooperate, for example in monitoring harmful organisms, pathogens, vectors and invasive alien species or with supra-regional water management models. Cross-border cooperation and the exchange of information at an international level are also vital.

2.2.2 Reducing uncertainties and closing the knowledge gap

There are still huge uncertainties regarding the way in which emissions and the global and regional climate will develop. Current observations suggest, however, that global greenhouse gas emissions are likely to develop according to more pessimistic scenarios. There is also much discrepancy in estimations of the effects of climate change in different sectors, how different systems will adapt and the costs and benefits of adaptation measures. The temporal decoupling of cause and effect makes it difficult to plan ways of adapting. Despite these uncertainties and incomplete knowledge, it is vital that measures are already introduced today. In most sectors, however, we do not have specific models for dealing with the uncertainties resulting from climate change.

In order to be able to react to the challenges of climate change with targeted adaptation measures, we need to lessen the existing uncertainties. Specific, coordinated research efforts are required. At the same time, we need to develop new models for dealing with uncertainties and improve existing ones. Approaches to climate adaptation which have already proved successful (flexible and robust measures, no-regret measures) must be identified and applied in the different sectors.

Adapting to climate change is a long-term process. Only if we improve our knowledge levels, reduce uncertainties and increase our experience will we be able to improve our response to this phenomenon.

2.2.3 Raising awareness and improving information and coordination

In order to adapt to climate change effectively, it is essential for the Confederation, cantons, communes, associations and private individuals to cooperate. Many decision-makers, however, are not yet sufficiently aware of the fact that climate adaptation is necessary and brings benefits. Furthermore, too few people are aware of the information available. This may mean that climate adaptation measures are introduced too late, are badly coordinated and that important information is not taken into account.

In order to raise awareness of the necessity of adapting to climate change among decision-makers in all sectors and at all institutional levels, these key players must receive targeted information about the effects of climate change and the existing ways in which these can be addressed.

Improving communication between players in research, administration and practice means that the information available from observation, early detection and national and international research can be used in the adaptation process. At the same time, it will encourage the flow of information on successes and failures experienced in adaptation projects. In working together in a coordinated manner, all players can ensure that adapting to climate change occurs efficiently. Of utmost importance is the cross-border exchange of information on the impact of climate change on the Alpine region and regarding adaptation strategies and measures and how they are implemented.

2.2.4 Resource requirements and funding

The effects of climate change will involve huge economic costs. The extent of these will depend on how global greenhouse gas emissions and the climate develop. At present, global greenhouse gas emissions are developing in accordance with more pessimistic scenarios, and we must therefore expect more extreme changes in the climate. The regional effects of extreme climate change in Switzerland have not yet been investigated in detail. We only have model calculations for the extent of damage to be expected in Switzerland if the climate warms up to a medium degree. This is set at 0.15 % of gross domestic product in 2050[12]. The damage costs will clearly rise thereafter. Averaged out over the 21st century, expected annual average costs will be around a billion francs (median, at today's prices and at a discount rate of 2 %).

By applying targeted adaptation measures, it will be possible to reduce potential loss or damage, ensure that the public and environment are protected and make the most of potential opportunities. Adaptation measures should be conceived in such a way as to achieve the best possible cost-benefit ratio.

At federal level, measures will be implemented as part of existing sector policies and budget priorities should be set in each policy area so that the task of adapting to climate change can begin. Where new measures require a greater contribution from the Confederation, additional financial and staff requirements should be assessed and funding proposals made by the offices responsible for the measures.

The Federal Council's strategy envisages implementing the measures by means of regulations and standards which help to mitigate the effects of climate change, as well as by creating incentives which encourage innovative adaptation processes. New promotional measures at federal level can be implemented additionally, if required. Account should be taken of the division of responsibilities between Confederation and cantons and the costs-by-cause principle appropriately applied.

Construction work on the Unterer Grindelwald Glacier (Canton Bern) on 7 October 2009: The glacier has retreated to a huge extent in the last 150 years. In 2005 a lake formed for the first time on its surface. In 2009 a drainage tunnel was built in order to avert the danger of a glacial lake outburst flood.

3 Goals and principles of adaptation

When adapting to climate change, the following goals and principles apply:

Adaptation goals

Switzerland makes the most of the opportunities that arise as a result of climate change. It minimises the risks of climate change, protects the population, public assets and natural life support systems and improves the adaptive capacity of society, the economy and the environment.

Principles in adapting to climate change

1. The process of adaptation is based on the principle of *sustainability*: when decisions are made and measures planned and implemented, the interests of current and future generations are considered equally. At the same time, environmental, economic and societal concerns in Switzerland and abroad will be given balanced consideration.

   In relation to future generations:
   - adaptation measures should impair future scope for action as little as possible *(flexibility)*.
   - the *precautionary principle* applies in the adaptation process.

   In relation to the environment:
   - Adaptation measures with a positive effect on the environment and ecosystem services should be promoted and those with a negative effect on the environment and ecosystem services avoided.
   - Emphasis should be placed on adaptation measures which encourage and benefit natural regulating processes.

   In relation to the economy:
   - Emphasis should be placed on adaptation measures whose benefits outweigh the costs, or measures with the best cost-benefit ratio. All monetary and non-monetary costs and benefits are to be considered.
   - Emphasis should be placed on measures which are worthwhile regardless of the extent of climate change *(no-regret measures)* and which have additional positive effects on other areas *(secondary benefits)*.

   In relation to society:
   - Emphasis should be placed on measures which do not disadvantage any social groups, have positive effects on health and encourage social cohesion.
   - The *costs-by-cause principle* shall apply, i.e. those who contribute to climate change will be held responsible for the ensuing costs. The solidarity principle should also be applied; because damage arising as a result of climate change may affect only certain individuals and at certain times, the entire community of causal agents should be required where possible to finance necessary adaptation measures, not only those affected by potential damage events.

2. Adapting to the effects of climate change involves the whole of society. The adaptation strategy makes it possible to coordinate action at federal level and provides a basis for the Confederation, cantons, communes and private individuals to *work in partnership*, taking account of existing responsibilities and competences. Where possible, the adaptation strategy should build on existing strategies.

3. Climate change adaptation is a complementary process to the reduction of *greenhouse gas emissions*. If we do not effectively curb climate change, the extent of the effects will exceed the ability of systems to adapt and adaptation measures will become more complicated and more costly. Adaptation measures should not counteract greenhouse gas reduction targets.

4. Adapting to climate change is based on *scientific findings*. New scientific findings are evaluated and taken account of when measures are planned and implemented. Where knowledge is lacking, questions will be directed at the field of research in order to improve the knowledge base. The precautionary principle should be applied; if uncertainties exist, this is not a reason for inaction.

5. Adapting to climate change is based on a *risk approach*. The opportunities and risks which arise for Switzerland as a result of climate change are analysed, evaluated and compared. The procedure should be transparent and comprehensible. The risk analysis provides a basis for determining the main elements in Switzerland's adaptation strategy and for formulating targets for each of these elements.

6. Existing *uncertainties* regarding the future development of global greenhouse gas emissions, of the global and regional climate and the impacts of climate change must be taken into account. Robust measures must be developed which will be of benefit regardless of how the climate develops.

7. There are differences in response timescales among different systems affected by climate change. In planning and implementing adaptation strategies, these varying timescales must be taken into account.

8. Switzerland takes part in *international exchanges of experience* regarding adaptation to climate change. It benefits from the knowledge and experience of other countries and at the same time makes its own knowledge and experience available to other countries. When cross-border problems occur, Switzerland coordinates its course of action with the neighbouring states.

9. The advances made in adapting to climate change are regularly *evaluated*. The existing systems of indicators (e.g. MONET, Cercle indicateurs) should be considered when identifying appropriate impact indicators.

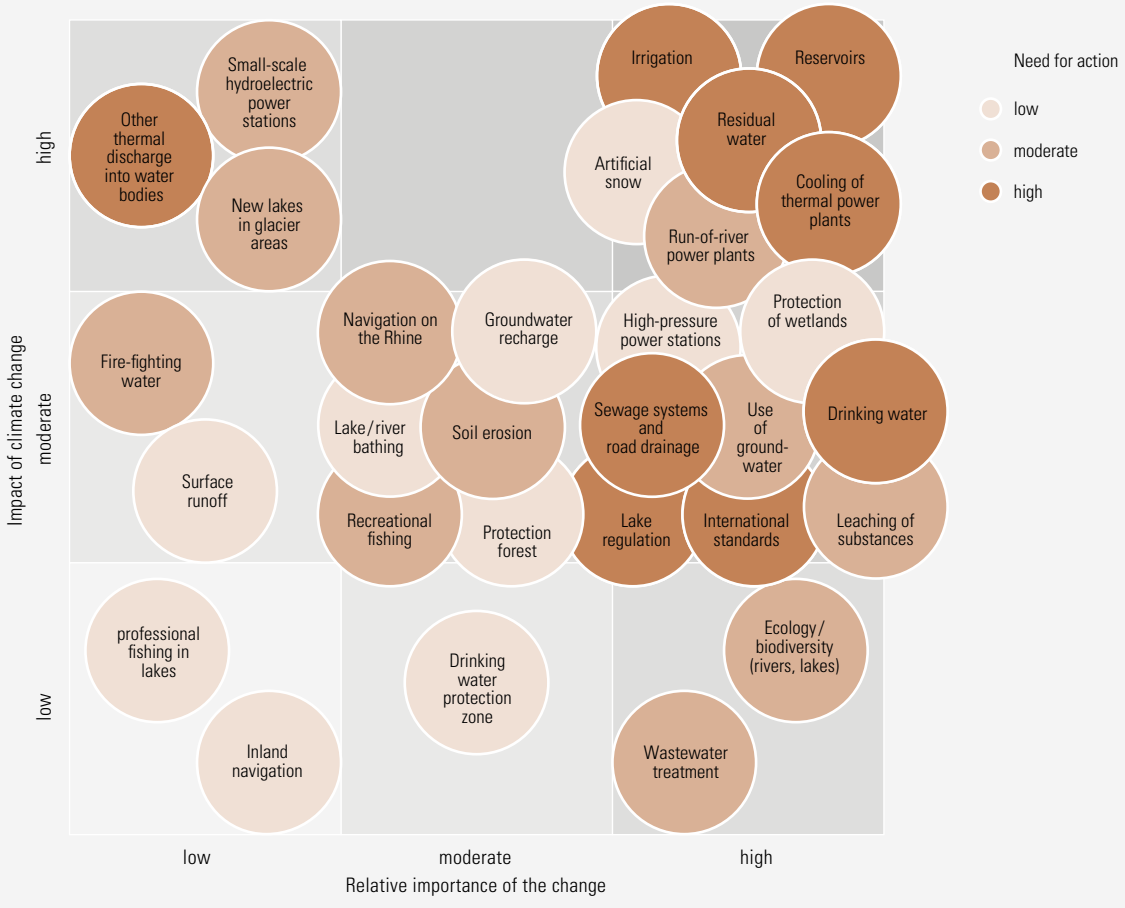
10. Adapting to climate change is a *dynamic process*. The main aim should not be to preserve the conditions that we enjoy today, but to adapt to changes in a controlled fashion, with minimum risks for people and the environment. The adaptation strategy must be periodically revised, taking account of changes in the general conditions and of new scientific findings. This involves documenting changes in climatological variables which impact adaptation and regularly udpating prognoses of how they may develop.

4 Adaptation in the sectors

The following sub-chapters look at adaptation in nine sectors particularly affected by climate change in Switzerland in which the federal government has a number of possibilities for action (Figure A1.2). With one exception, the sectoral sub-strategies are presented in the form of summaries, developed according to the procedures outlined in Annex A1.2: water management (4.1), natural hazards management 4.2), agriculture (4.3), forestry (4.4), energy (4.5), biodiversity management (4.7), health (4.8) and spatial development (4.9). The statements on adaptation in the tourism sector (4.6) are based on the Federal Council's growth strategy for Switzerland as a tourist location[10] and on a scientific study[13] on the impact of climate change and adaptation options.

The following information is provided for all sectors (for methodology see Annex A1.2); firstly, the most important fields of action in adapting to climate change are determined, then the areas affected by climate change in each sector are assessed qualitatively according to a three-level scale (low – moderate – high) for the dimensions "impact of climate change," "relative importance of climate-related change" and "climate-related need for action". Each

Figure 4.1 Assessment of the relevant areas of the water management sector in relation to impact of climate change, relative importance of climate-related change and need for action.



area is assessed from the perspective of its related sector and on the basis of expert knowledge. Since the sectors do not share a standard quantitative basis, it is not possible to make a comparison between them. The same area present in various sectors may be assessed differently. Fields of action in adaptation are those areas that are assessed as either moderate or high in all dimensions, while areas that are categorised as low in one of the dimensions are not dealt with further in the adaptation strategy. The results are plotted on a nine-field matrix for each sector. Adaptation goals are defined for the fields of action, and suggestions are made on how to achieve these goals at federal level. Taking these proposals as a base, specific adaptation measures will be formulated at a later stage in an "Action plan for adapting to climate change" (see Chapter 6).

4.1 Water management

4.1.1 Fields of action requiring adaptation in water management

Thirty relevant areas in the water management substrategy were examined, and 14 of these were identified as fields of action requiring adaptation[d] (Figure 4.1). The need for action is particularly high in the following fields of action:

W1 Drinking water: Regional and temporary bottlenecks in the provision of water can compromise the supply of drinking water. This mainly affects private utility services that are not networked.

W2 Reservoirs: New challenges (higher bedload, suspended sediment) and demands (flood prevention, irrigation water) require the comprehensive management of reservoirs.

W3 Cooling of thermal power plants: Increasing water temperatures and lower discharge during the summer season can lead to reduced efficiency in water-cooled thermal power plants (nuclear power plants, gas) and operational restrictions.

W4 Irrigation: There is an increasing need for irrigation in agriculture. At the same time, the ecological requirements for surface water and groundwater need to be satisfied.

W5 Residual flow: Existing provisions (concessions) and calculation bases (Q347[e]) for residual flow volumes may need to be revised due to modified discharge patterns.

W6 Sewage systems and road drainage: If there is a considerable increase in the intensity and volume of extreme precipitation, sewage networks and detention basins may be insufficient in size.

W7 Lake regulation: Lake regulation serves to ensure flood prevention, tourist interests and balanced downstream flow. Changes in discharge patterns lead to a change in demand, which means that existing regulations may need to be revised.

W8 International demands: Switzerland's neighbouring countries also have an interest in Switzerland's most important international waters[f].

There is a moderate need for action in the following fields of action:

W9 Use of groundwater: Groundwater and springs can be adversely affected by the infiltration of low-quality surface water. Higher water temperatures exacerbate the problem.

W10 Leaching of substances: Intensive precipitation can cause leaching and seeping away of (harmful) substances, which can adversely affect the quality of groundwater and surface water.

W11 Soil erosion: Increasingly heavy precipitation leads to more soil erosion, which calls for locally adapted farming practices.

W12 Run-of-river power plants: Changes in discharge patterns can affect the turbines' overall performance.

W13 Recreational fishing: Rising water temperatures restrict coldwater fish habitats and encourage the immigration of thermophile species.

W14 Navigation (Rhine): Changes in discharge patterns and extended periods of drought during late summer result in a serious deterioration in the Rhine's transport capacity.

d Fields of action include the areas that are categorised as moderate or high in all three dimensions: "Impact of climate change," "Relative importance of the change" and "Need for action" (see Annex A1).

e The Q347 flow rate refers to the flow of a water body which is reached or exceeded on 347 days per year (averaged over 10 years).

f Switzerland's most important international waters are: Rhine, Lake Constance, Rhone, Lake Geneva, Tresa, Lake Lugano, Lake Maggiore, Inn and Doubs.

4.1.2 Adaptation goals in water management

The following eight goals have been defined for water management:

1. Ensure the safety of large-scale dams *(W2, W12)*.
2. Develop water storage and water distribution in such a way as to offset the effects of a change in discharge patterns and to meet the various needs of the economy, society and environment (establish priorities and procedures for water supply shortages and the multipurpose utilisation of existing reservoirs and lakes) *(W2, W4, W5, W7)*.
3. Ensure the required space for revitalisation, flood control and a healthier ecology for watercourses so that they can fulfil their natural functions *(W9, W10, W13)*.
4. Regionalise and network the supply of drinking water and the treatment of wastewater (avoid shortages; avoid excessive discharge into watercourses during low water periods or in the case of extreme events) *(W1, W6)*.
5. Implement new cooling technologies to compensate for the watercourses' reduced cooling capacity and comply with the statutory limit value for cooling water discharge despite increase in warming *(W3, W4)*.
6. Examine legal bases and where necessary take into account changing natural conditions (residual flow, thermal discharge, water restitution, lake regulation, etc.) *(W2, W3, W5, W7, W12)*.
7. Optimise transport capacities during low water periods by implementing specific measures along waterways (removal of local obstacles, deepening of navigable channels); use available technology to the full in shipbuilding and improve 4–5-day water level forecasts *(W14)*.
8. Improve cooperation in transboundary water management to recognise and resolve conflicts of interest early on *(W8)*.

The field of action soil erosion (W11) also appears in the agriculture sector under the goal site suitability (A1) (see Chapter 4.3). Recreational fishing (W13) is also included in the goal for habitats and species (B2) in the biodiversity management sector (see Chapter 4.7).

There has been a lack of overall coordination in water management up until now. Adaptation to climate change is a challenge requiring new, comprehensive concepts. If the above-mentioned goals are to be successfully implemented, several requirements must be met:

– We need to gain a comprehensive understanding of water management. Water management must take account of all human influences on water resources and water bodies and the related infrastructure. It involves all activities targeted at waters protection, use of water and protection from water.
– We must affect a paradigm change in water management from a demand-oriented to a supply-oriented approach. Instead of simply using water, this resource must be managed in a sustainable way in the future.
– We need to create the institutional conditions to enable and promote the integrated management of water bodies. A first step in this effort is the document "Watershed Management. Guiding Principles for Integrated Management of Water in Switzerland."[14].

We still do not know enough about the quantitative impact of climate change on water regimes and discharge. It is therefore essential to continue using and improving measurement networks and climate and climate change modelling for water management.

4.1.3 Guidelines for reaching goals

Fundamentals

– Continue to use/consolidate measurement networks (analyses, trends, early recognition) (general aspect).
– Improve regional modelling of climate and water regime (general aspect).
– Develop new policies for water storage/water distribution (goal 2; W2, W4, W5, W7).
– Develop cooling technologies (goal 5; W3).
– Improve discharge and water level forecasts for the Rhine by intensifying transboundary exchange of information between specialised agencies (goal 7; W14).

Information/awareness-raising

– Climate and water – Findings gained from measurements and modelling (general aspect).
– Watershed management as a management method (requirement for strategy implementation).
– Opportunities and possibilities of integrated water management (paradigm change) (requirement for strategy implementation).

Promoting and implementing measures

- Ensure the safety of large-scale dams (goal 1; W2, W12).
- Safeguard riverine zones (goal 3; W4, W9, W10, W13).
- Create drinking water supply networks (goal 4; W1).
- Regionalise wastewater treatment (goal 4; W1, W6).
- Implement specific structural measures along the navigable channel of the Rhine to remove local obstacles and deepen navigable channel (goal 7; W14).
- Improve transboundary water management (goal 8; W8).
- Create incentives/funding mechanisms for watershed management (requirement for strategy implementation).

Legal framework

- Water shortage: distribution rules and procedures (goal 2; W2, W5, W7).
- Revision of legal provisions on low water, discharges, lake regulation (goal 6; W2, W3, W5, W7, W12).
- Institutional framework for watershed management (requirement for strategy implementation).

4.2 Natural hazards management

4.2.1 Fields of action requiring adaptation in natural hazards management

Natural hazards have always had great significance and far-reaching consequences in Switzerland, because in many parts of the country they pose a major threat to human life, infrastructure and material assets. The increase in the value of infrastructure, settlement expansion in danger areas and the impact of climate change all increase the potential devastating effects of existing hazards. The main climate change factors influencing natural hazards are an increase in hydro-meteorological extreme events (frequency and intensity of heavy rainfall) and the effects of higher temperatures.

The fields of action (hazard processes, Figure 4.2) requiring adaptation to climate change are:

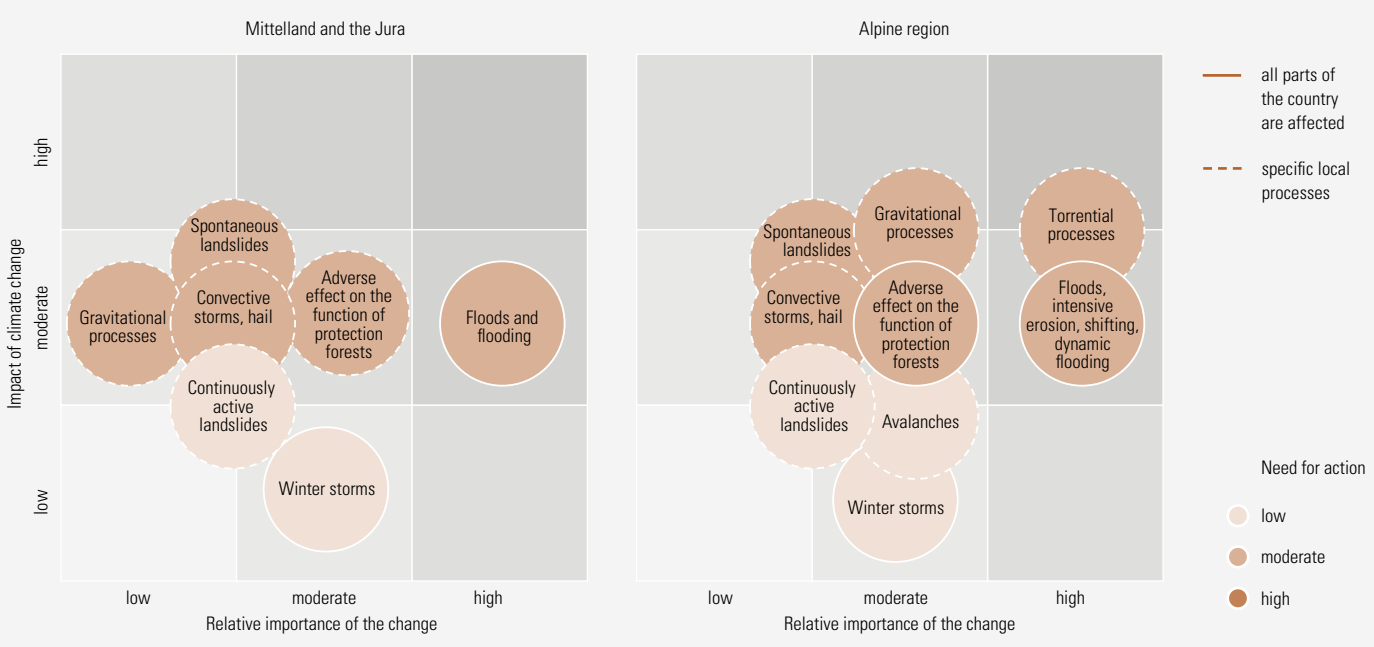
N1 Floods (Alpine region): Particularly in early summer there is a high risk of large areas of snow melting combined with heavy precipitation. This can lead to greater water flow and an increased risk of flooding. Erosion and shifts in material are intensified in mountain streams. Additional bedload from higher-lying catchment areas has a far-reaching impact, affecting even the lower reaches of a river. When a glacier lake overflows or a river bursts its banks, this often causes dynamic flooding and accelerated erosion on steep slopes.

N2 Floods (Mittelland and the Jura): In terms of discharge, the above-mentioned causes play the same role. Due to the low gradient and the lakes near the Alps (sedimentation basins), hazards arise downstream of the lakes, mainly in the form of flooding at low flow rates (water, fine material, but little bedload).

N3 Torrential processes (Alpine region): Mountain torrents are characterised by their capacity for transporting large volumes of loose material in the stream bed. An increase in temperature in the mountains accelerates permafrost degradation, glacier retreat and weathering processes, thus intensifying the mobilisation of loose material. In addition, changing precipitation patterns produce greater and more variable flow and increasingly frequent sudden landslides. This increases the influx of bedload into mountain streams and the risk of mudslides and debris avalanches (debris flow), which can cause damage to buildings and infrastructure.

N4 Gravitational processes (Alpine region): Changes in freeze-thaw cycle frequency, longer lasting heat waves and heavy precipitation have an impact on and tend

Figure 4.2 Assessment of the relevant areas of the natural hazards sector in relation to impact of climate change, relative importance of climate-related change and climate-related need for action.



to increase the intensity of weathering, which can lead to increased rockfall activity in many areas. Greater water-level fluctuations in rock chasms may lead to increased rockslide activity. Glacier retreat and thawing permafrost are conducive to increased gravitational activity.

N5 Protection forest: The effects of temperature rise and increasing drought (e.g. the spread of harmful organisms, drought stress and forest fires) and more frequent storms impair the function of protection forests. The protection forests primarily affected are those with site stability problems and insufficient regeneration, which account for about one eighth of the entire protection forest area (= critical protection forests)[g].

From the perspective of natural hazard prevention, there is less need for additional action in the N5 field of action than in N1 to N4.

In principle, all parts of the country are at risk from flooding, including agglomerations and important infrastructure in the Mittelland. Flooding can be widespread and cause considerable damage to property. Torrential processes and debris flows, on the other hand, affect smaller areas in mountainous and hilly regions. They can, however, cause serious property damage and endanger people's lives on a local scale. Gravitational processes tend to occur locally, but have a serious impact when they affect residential areas, transport facilities and interconnection infrastructure.

4.2.2 Adaptation goals in natural hazards management

The lessons learned and findings from the events of the last decades form the basis for current legislation and PLANAT's "Swiss natural hazards strategy". Resulting core areas such as "strategic controlling" and "development monitoring", which are used to periodically determine costs, risks and loss or damage, explicitly take into account adaptation to climate change and create the basis for a shift in priorities in the future.

It is therefore possible to overcome the additional challenges resulting from climate change by consistently implementing the PLANAT strategy and ensuring integrated risk management. The general strategy goals are also relevant to the fields of action requiring adaptation to climate change and can be summarised as follows:

1. Guarantee a generally accepted safety level on the basis of uniform criteria.
2. Reduce existing risks and prevent new ones.
3. Make efficient use of the means available to reduce existing risks as far as possible and prevent new ones.

An analysis of the floods of 2005 and 2007 showed that prevention, intervention and increasing the degree of self-protection of the population (resilience) have considerable potential for improving the manner in which residual risks are dealt with:

– Promote personal responsibility (training property builders, raising public awareness).
– Support for architects, production engineers, etc. (training on property protection measures and safety standards).
– Promote organisational measures (emergency planning and emergency plans including warning and alert mechanisms) and optimise intervention to deal with residual risks.

4.2.3 Guidelines for reaching goals

Implementing integrated risk management already presents a major challenge. Besides ongoing and introduced measures, measures that reduce the potential for damage created by climate change are becoming increasingly necessary. We need to make additional efforts primarily in the following areas, and ongoing activities in these areas must be intensified and accelerated:

Fundamentals

– *Continually monitor* all relevant developments in relation to hazard processes and hazard events, risks and the effectiveness of measures (e.g. periodical examination of the protective effect of existing installations).
– Continue to develop and improve the *methodology for identifying new natural hazard processes* including changes in known danger areas caused by climate change in coordination with neighbouring countries (e.g. new potential bedsill processes, early detection and monitoring of glacier lakes).
– Optimise existing measurement and observation networks.
– *Assess hazards and risks* including observation of "extraordinary" scenarios.
– Continually *update and implement the hazard maps in spatial planning* (in structural and land use plans).

g The Forestry sub-strategy provides a more detailed examination of the impact of climate change on critical protection forests.

- Expand *research activities* to improve the bases for assessing hazard processes and specifically *evaluate* the effectiveness of climate change adaptation measures in conjunction with countries in the Alpine region (harmonise data and terminology and exchange experiences).
- *Monitor the strategy and its implementation* (including analysis of major incidents): periodically and systematically record risks and the means employed for natural hazard protection; periodically examine goals (strategic controlling).

Information/awareness-raising

- *Raise awareness and educate* the public on the impact of climate change in relation to natural hazards (people know what the hazards are and what they can do, and therefore can take action themselves).
- Involve all the stakeholders in a *risk dialogue*.

Promoting and implementing measures

- Encourage integrated planning of measures that takes account of the impact of climate change in appropriate scenarios.
- Support robust, durable and adaptable solutions with dimensions that take adequate account of existing uncertainties (flow rate, total discharge, amount of bedload and transport rate of bedload).
- Implement spatial planning measures (avoid hazards, use space according to risk and taking climate scenarios into account).
- Maintain and optimise biological and technical measures (taking into account overload scenario).
- Encourage and support personal responsibility (training builders, raising public awareness).
- Encourage and support architects, production engineers, etc. (training on property protection measures and safety standards).
- Encourage organisational measures (emergency planning and warning and alert emergency plans) and optimise intervention to deal with residual risks.

Legal framework

- Improve coordination between the areas of law involved.
- Provide a legal basis to ensure financing of hazard prevention.

Flooding in Lucerne on 25 August 2005: Following torrential rain in the summer of 2005, there was severe flooding in central Switzerland and the Alps. The Schwanenplatz in Lucerne was flooded. There are likely to be more frequent floods in future as a result of climate change.

4.3 Agriculture

4.3.1 Fields of action requiring adaptation in agriculture

The climate strategy for agriculture[5] looks both at reducing agricultural greenhouse gas emissions and adapting to climate change. The fields of action identified are as follows (Figure 4.3):

A1 Site suitability: The features of the natural landscape (topography, soil type and exposure) and climatic conditions are among the factors that determine the suitability of a site for agricultural production. Variations in climate change in different regions therefore lead to a change in site suitability. The direct or indirect impact of climate change on soil properties (humus content, soil moisture, soil depth, etc.) also has an effect on the exploitation potential and the farming opportunities of a site. In addition, the risk of natural hazards (flooding and debris flows) can also change.

A2 Heavy rainfall: Intensive and/or continuing rainfall increases the risk of soil erosion (topsoil loss) and leaching, particularly during periods of low vegetation.

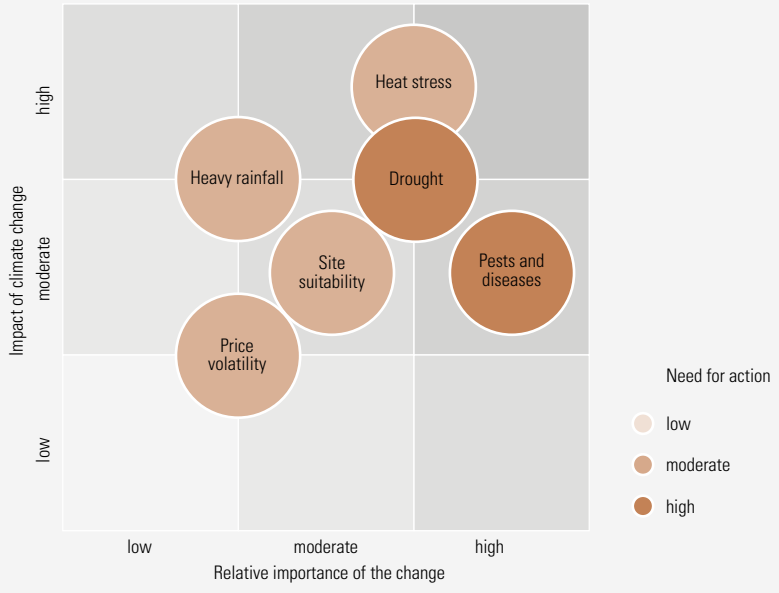
A3 Drought: Rising temperatures increase potential plant and soil surface evaporation. The lack of rainfall reduces the water content in soil available for plants, depending on soil properties. This can lead to increasingly critical situations in soil water status and increases the risk of losses in field, fodder, vegetable and other special crops.

A4 Heat stress: Extended periods of extremely high temperatures can cause heat stress in plants and animals. This can adversely affect yield and earnings and cause health problems in animals.

A5 Pests and diseases: Rising temperatures and the resulting mild winters lead to the occurrence and spread of new harmful organisms (harmful insects, weeds, vectors and disease) in crops and among farm animals.

A6 Price volatility: Climate change may lead to a shift in production areas throughout the world and possibly to an overall decrease in suitable farming areas. It may also increase climate variability (increase in extreme events). This, in turn, leads to fluctuations in crop yields and prices and to a general increase in feed and food prices.

Figure 4.3 Assessment of the relevant areas of the agricultural sector in relation to impact of climate change, relative importance of climate-related change and climate-related need for action.



4.3.2 Adaptation goals in agriculture

The overall goal for agriculture is to adapt pre-emptively in order both to increase production and to improve the general services it provides to society.

A1 Site suitability

– Adapt agricultural production optimally to the changes in site suitability.
– Maximise production potential and reduce risk and hazard exposure.
– Reserve the best soils (crop rotation areas) for agriculture.

A2 Heavy rainfall

– Take pre-emptive measures against erosion and nutrient leaching, and targeted measures to reduce soil compaction.

A3 Drought

– Optimise water management (improve water retention in soil, reduce evaporation losses and prevent critical soil water conditions).
– Base irrigation on water resources and manage irrigation economically and efficiently.
– Cultivate drought-resistant crops and varieties where necessary.

A4 Heat stress

– Develop and apply effective measures to prevent plant and animal heat stress (shade, cooling, breeding, etc.).

A5 Pests and diseases

– Monitor potential pests and diseases that risk spreading to Switzerland.
– Recognise new incidences of pests and diseases with a high potential for damage early on, and take the necessary prevention and control measures.
– Develop and implement alternative control measures and anti-resistance management strategies.

A6 Price volatility

– Cushion the impact of price fluctuations with effective risk management (business and income diversification, warehouse stocks, crop insurance, etc.) and integrated markets.

4.3.3 Guidelines for reaching goals

Fundamentals

– Conduct problem-oriented research into adaptation to climate change in agriculture, in particular into the potential of farming practices which preserve good soil structure and of targeted humus management for water regimes in soil. Also research into the role of biodiversity in increasing the resilience of agro-ecosystems.
– Interpret the results of climate models showing the impact of climate change on agriculture in higher resolution and using improved data.
– Develop and assess adaptation options in agriculture; formulate and identify good climate adaptation practices; monitor implementation in (model) farms.
– Develop systems to further decision-making (instruments); develop and establish analysis, forecasting and early-warning systems providing practical information for making specific decisions in agricultural management (e.g. climate suitability maps, drought and pest forecasts).
– Develop agri-environmental monitoring.

Information/awareness-raising

– Improve specialist consultancy.
– Increase awareness of support instruments.
– Include good climate adaptation practices in agricultural training.

Legal framework

– Verify and if necessary adapt/specify incentives and requirements in agricultural policy instruments and measures to achieve forward-looking climate adaptation practices with the objectives of minimising the risks of loss of earnings and negative environmental impacts and of taking advantage of any opportunities that arise (key concepts: locally adapted and soil conservation farming practices in proof of ecological performance and for direct payments, overall improvements, support for irrigation projects, investment aid for stable construction, preservation of genetic diversity, risk coverage, etc.).
– Create good conditions in other related legal provisions (key words: spatial planning, waters protection, allocation of water usage rights, water tariff structures etc.).

4.4 Forestry

4.4.1 Fields of action requiring adaptation in forestry

Compared with the slow processes in the forest (growth, seed distribution, genetic adaptability etc.), climate change threatens to occur at a rate that overwhelms natural adaptation processes. Important forest products and services such as protection against natural hazards could be reduced or disappear. We can also expect there to be a considerable impact on timber production and the nearly 80,000 jobs in domestic forestry and the timber industry. The first adaptation measures should reduce existing risks, increase adaptability through carefully planned regeneration and reduce future risks. The fields of action identified are as follows (Figure 4.4):

F1 Critical protection forests[h]: Forests with a protective function in which there is a combination of insufficient regeneration and reduced stability are particularly vulnerable to extreme events (these cover an area of around 68,000 ha according to the Swiss National Forest Inventory). As a result of the Lothar winter storm in 1999 and the dry summer in 2003 a major outbreak of bark beetles was a new phenomenon observed in protection forests. Such an outbreak had never occurred at this altitude before.

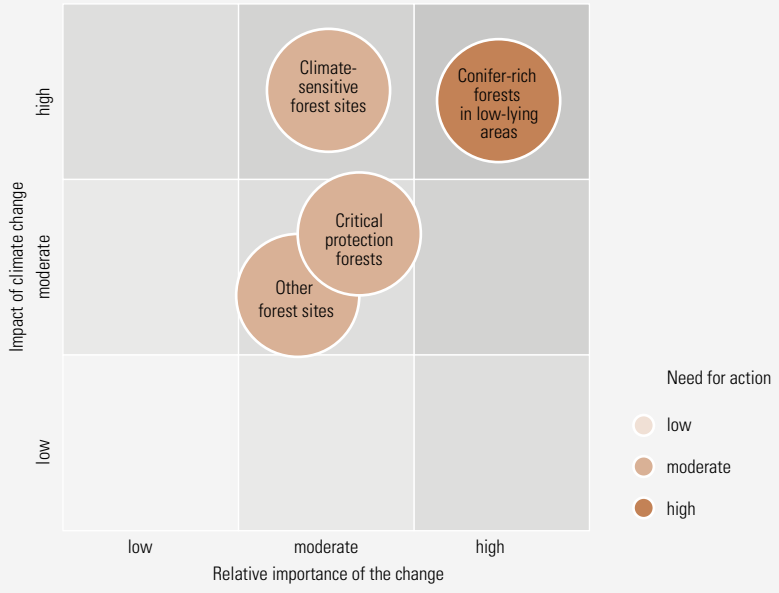
F2 Conifer-rich forests in low-lying areas: These forests, which according to the Swiss National Forest Inventory cover an area of around 50,000 ha, have proven to be sensitive to windthrow, drought and bark beetle infestations in recent years. Between 1995 and 2005, around 4.4 million m^3 of spruce wood fell victim to windthrow in the lowlands and in the Alpine foothills, and an additional 3.7 million m^3 of spruce trees was infested by insects. Against the backdrop of climate change, it makes economic sense to regenerate these forests that are important for the domestic timber industry, and to reduce risks.

F3 Climate-sensitive forest sites: These are drought-prone sites or sites with large amounts of dry wood in areas at risk from forest fires (e.g. Ticino, Valais, Graubünden), which cover approximately 50,000 ha. This residual category will be described in more detail in the Forest and Climate Change research programme.

F4 Other forest sites: Greater resilience and adaptability need to be achieved in other forests, so that currently regenerated forests can also fulfil their functions under changing climate conditions in future.

h The natural hazards management sub-strategy looks at the entire protection forest area, while here only critical protection forests with insufficient regeneration and reduced stability are considered.

Figure 4.4 Assessment of the relevant areas of the forestry sector in relation to impact of climate change, relative importance of climate-related change and climate-related need for action.



4.4.2 Adaptation goals in the forestry sector

F1 Critical protection forests

– Prevent major outbreaks of bark beetles and other harmful organisms and so avoid the resulting damage.
– Appropriately and sufficiently regenerate forests to increase their adaptability and stability.

F2 Conifer-rich forests in low-lying areas

– Prevent major outbreaks of bark beetles and other harmful organisms and so avoid the resulting damage.
– Convert forests to robust mixed forests by introducing an appropriate proportion of adaptable tree species.

F3 Climate-sensitive forest sites

– Remove combustible material (dead trees) from endangered locations (e.g. near built-up areas).
– Regenerate forest sites with adaptable tree species.

F4 Other forest sites

– Regenerate forest sites with resilient/adaptable tree species.

4.4.3 Guidelines for reaching goals

It is aimed to implement the federal government's options for action in Switzerland's 2020 forest policy.

Fundamentals

– Evaluate the first phase of the Forest and Climate Change research programme (2009–2011), launch the second phase 2012–2015, close gaps in knowledge and formulate recommendations for action.
– Develop early warning systems for major outbreaks of bark beetles, invasive organisms and forest fires.
– Close climate-relevant gaps in forest inventories; monitor the development of forest sites.
– Include relevant aspects of adaptation to climate change in incident management strategies (e.g. re-forestation strategy after storm damage).

Information/awareness-raising

– Inform forest owners, forestry practitioners, political authorities and the public of the results of the first phase of the Forest and Climate Change research programme (2009–2011).

Promote and implement measures

– Continue the Forest and Climate Change research programme.
– Promote measures to combat contamination by harmful organisms outside of protection forests.
– Strengthen protection forests by promoting intervention in forests affected by insufficient regeneration and reduced stability.
– Promote the conversion of conifer-rich forests in low-lying areas to more robust mixed forests. Promote forest regeneration and the removal of combustible material in dry, climate-sensitive sites.

Legal framework

– Article 77 of the Federal Constitution[15] and Article 26 of the Federal Act on Forest[16] provide the constitutional and legal foundations for the Federal Council to take legislative action to prevent and repair damage to forests. Legislation needs to be adapted to give the federal government access to the necessary funds to implement measures to prevent and combat harmful organisms outside of protection forests.

4.5 Energy

4.5.1 Fields of action requiring adaptation in the energy sector

In view of Switzerland's specific requirements as a mountainous country without its own fossil resources, four areas of the energy sector were identified as relevant to the adaptation strategy (Figure 4.5). Mobility was excluded, because the impact of climate change needs to be actively monitored first before any adaptation strategies can be developed, for example in the area of recreational traffic.

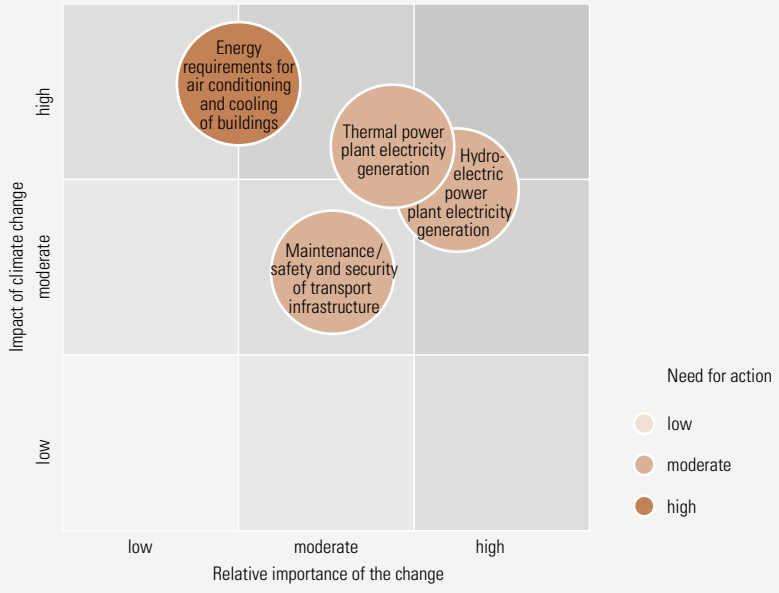
E1 Energy demand for air conditioning and cooling of buildings: Rising average and maximum temperatures have led to an increase in the cooling requirements of buildings. The widespread use of installations and devices for ventilation, cooling and air conditioning is likely to lead to a marked increase in demand for electricity. The challenge lies in providing comfortable living and working conditions while at the same time achieving the energy policy objective of efficient and rational energy use.

E2 Generation of electricity from hydropower: The use of hydroelectric power is closely linked to precipitation and discharge patterns. Periods of extreme weather (drought, floods) as well as temperature-related changes in high mountain regions (glacier retreat, thawing of the permafrost) can affect the production potential, safety and operation of power plants. Furthermore, we must expect greater competition for water resources and additional demands on the management of reservoirs.

E3 Generation of electricity from thermal power plants: Thermal power plants – at present nuclear power plants in particular – play a major role in the production of electricity in Switzerland. There may be a need for action due to rising temperatures on two fronts: on the one hand, higher ambient temperatures reduce power plant efficiency, and on the other, power plant output must be reduced when there are inadequate cooling facilities.

E4 Maintenance and safety of transport infrastructure: Major electricity and gas transit pipelines run through Switzerland. Some sections of these lines run through areas where rising temperatures may lead to bedrock destabilisation and increased mass wasting (debris flows, rockslides). The question arises whether additional precautions need to be taken to ensure the safety and security of the transport infrastructure.

Figure 4.5 Assessment of the relevant areas of the energy sector in relation to impact of climate change, relative importance of climate-related change and climate-related need for action.



4.5.2 Adaptation goals in the energy sector

E1 Energy demand for air conditioning and cooling of buildings

– Implement efficient solutions to deal with rising temperatures (such as building technology and building greening; planning, implementation and operation phases).

E2 Generation of electricity from hydropower

– Secure the contribution of hydropower to maintain security of supply.
– Make optimal use of hydropower potential under changing hydrological and water management conditions.
– Federal-level safety monitoring of new climate-related risks (e.g. due to thawing of the permafrost).

E3 Generation of electricity from thermal power plants

– Ensure the contribution of thermal power plants to maintain security of supply, at the same time guaranteeing power plant safety (in particular during heatwaves) and coordination with other water users.

E4 Maintenance, safety and security of transport infrastructure

– Take adequate account of the impact of climate change in the federal government's supervisory and control activities.

4.5.3 Guidelines for reaching goals

Fundamentals

– Supervise and evaluate research activities relevant to changing the framework conditions for the use of hydropower (E2).
– Review the need for adaptation in the government's supervisory activities of high-voltage power lines, gas pipelines and dams (E2 and E4).

Information/awareness-raising

– Raise awareness among stakeholders in the building sector (E1) and provide them with further education and training.
– Promote awareness of the existing energy label (E1).
– Raise awareness about new risks among transport infrastructure operators (E4).

Promoting and implementing measures

– Create more incentives and directive measures for promoting building greening and planting trees to save energy in residential areas (E1).
– Integrate the topic of "climate-induced increase in the demand for electricity" in the SFOE's activities in the field of energy efficiency/SwissEnergy (E1).

Legal framework

– Lay down minimum standards for facilities and devices for cooling, air conditioning and ventilation (E1).
– Draw up basic principles for the management of water resources and water bodies (E2).
– Review the legal provisions on the discharge of cooling water into watercourses (E3).

4.6 Tourism

4.6.1 Fields of action requiring adaptation in tourism

Tourism involves many aspects of life and the economy, which is why climate change has such a wide range of direct and indirect impacts on the tourism sector. Three central fields of action requiring adaptation to climate change have been identified based on the most important impacts of climate change on Swiss tourism (Figure 4.6)[13]:

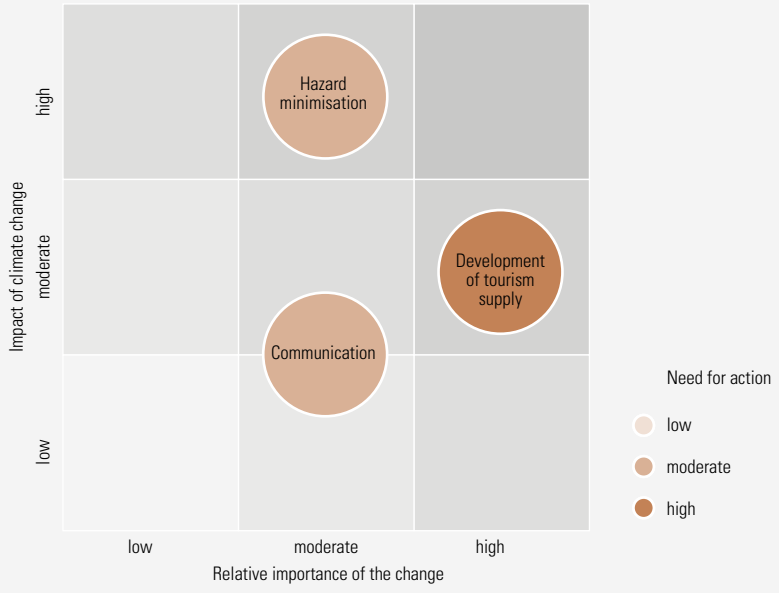
T1 Development of tourism supply: Climate change will lead to a decrease in guaranteed snow, especially in low-lying areas. With a temperature rise of 2 °C, the number of ski resorts with guaranteed snow in Switzerland is estimated to drop by at least a fifth. This loss is below average in comparison with neighbouring Alpine countries, which can be explained by the comparatively large number of high-altitude ski resorts in Switzerland. The loss of a winter atmosphere in the lowlands represents a challenge. It is nonetheless difficult to gauge to what extent this change will actually affect the tourist demand for winter sports. Higher temperatures and generally lower precipitation levels will provide Alpine tourist regions with a pleasant climate in summer.

Climate change will produce significant changes in landscape. Glacier retreat in Alpine regions is expected to have a negative effect on scenic attractiveness. On a more positive note, newly formed glacier lakes may provide new attractions. A Mediterranean atmosphere could make Swiss cities more attractive as tourist destinations. The tourism supply needs to adapt in response to the impact of climate change, seizing the opportunities that arise and mitigating any resulting risks.

T2 Hazard minimisation: The warming of the atmosphere affects the intensity and frequency of weather extremes, which can lead to an increase in natural hazards. The thawing permafrost is expected to cause increased debris flows and destabilisation of basic tourism infrastructure in mountainous regions (cableway installations, hotel and restaurant buildings). Risks arising from calving glaciers and flooding caused by melting glaciers will increase. This field of action is particularly important for tourism infrastructure in the Alpine region.

T3 Communication: Climate change poses major challenges for actors in the tourism industry. Long-term global thinking needs to be combined with short- to medium-term action. It is particularly important for the actors in the tourism industry in individual destinations to join forces, since numerous individual tourist services go towards creating the overall experience of travelling, staying somewhere and holiday-

Figure 4.6 Assessment of the relevant areas of the tourism sector in relation to impact of climate change, relative importance of climate-related change and climate-related need for action.



ing. Destinations need to position themselves more clearly and consider the effects of climate change in their marketing campaigns in order to raise awareness among and regularly inform guests and the general public on climate issues.

4.6.2 Adaptation goals in the tourism sector

Adapting to climate change is one of the most important challenges for Switzerland as a tourist destination.[10] Adaptation efforts should help Switzerland to remain an attractive and successful tourist destination and to exploit its exceptional potential as a travel destination in the long term. Having identified three fields of action, the focus is on the following adaptation goals:

T1 Development of tourism supply

- Promote innovation and diversification (esp. of summer tourism and year-round tourism), intensify research.
- Safeguard and develop winter sports.

T2 Hazard minimisation

- Improve hazard prevention by introducing technical and biological measures.
- Mitigate risks by introducing organisational measures.

T3 Communication

- Clear positioning and targeted marketing.
- Raise public awareness.

4.6.3 Guidelines for reaching goals

The 2012–2015 implementation programme on growth strategy for Switzerland as a tourism destination will focus on adapting tourism to climate change. This will include clarifying the roles of the various private and public stakeholders. The tourism sector itself will have a key role in adapting to climate change. The options of the federal government are based on the newly designed tourism policy, tourism policy goals and the relevant legal bases for tourism policy. Against this background, the main focus is on the following ways to achieve the adaptation goals:

Fundamentals

- Encourage build-up of knowledge on adapting tourism to climate change (strategic *Issue Management* in tourism policy, close research gaps, intensify international exchanges of experience).
- Strengthen cross-sectional tasks in tourism policy (in particular establishing coherence between tourism policy and climate policy).

Information/awareness-raising

- Diffuse knowledge on adapting tourism to climate change, e.g. by publishing information and organising thematic events (Switzerland Tourism Forum).

Promoting and implementing measures

- Promote national Innotour[i] projects for adapting tourism to climate change.
- Top-down and/or bottom-up-promotion of regional and local Innotour pilot projects for adapting tourism to climate change.

Legal framework

- The federal government's redesigned tourism policy provides the necessary legal framework (Federal Act on the Promotion of the Accommodation Sector[17], Federal Act on Switzerland Tourism[18], Federal Act on the Promotion of Innovation, Cooperation and Knowledge Creation in Tourism Innotour[19]).

i Programme of the State Secretariat for Economic Affairs SECO to improve the structure and quality of Swiss tourism.

4.7 Biodiversity management

4.7.1 Fields of action requiring adaptation in biodiversity management

Political decisions made in other sectors on the way in which and degree to which land and resources are used have a direct and indirect impact on biodiversity. It is therefore important for biodiversity management that the impacts on biodiversity are considered when adaptation measures are introduced in other sectors.

In the context of adaptation to climate change, the following fields of action have been identified (Figure 4.7):

B1 Gene pool: Climate change endangers local species and increases the risk of more relict populations. The loss of important genetic expressions jeopardises the long-term survival of species with a low capacity for adaptation and small populations.

B2 Habitats and species[j]: Climate change can have both a positive and a negative impact on species and habitats. While species living in dry habitats can profit from climate change, those in more humid habitats will lose out. We can already foresee a change in the composition of aquatic communities. In the same way, the habitat of alpine species – for which Switzerland bears a particular responsibility – shrinks as the climate warms up. New climatic conditions and changes in species compositions lead to the development of new habitats and communities.

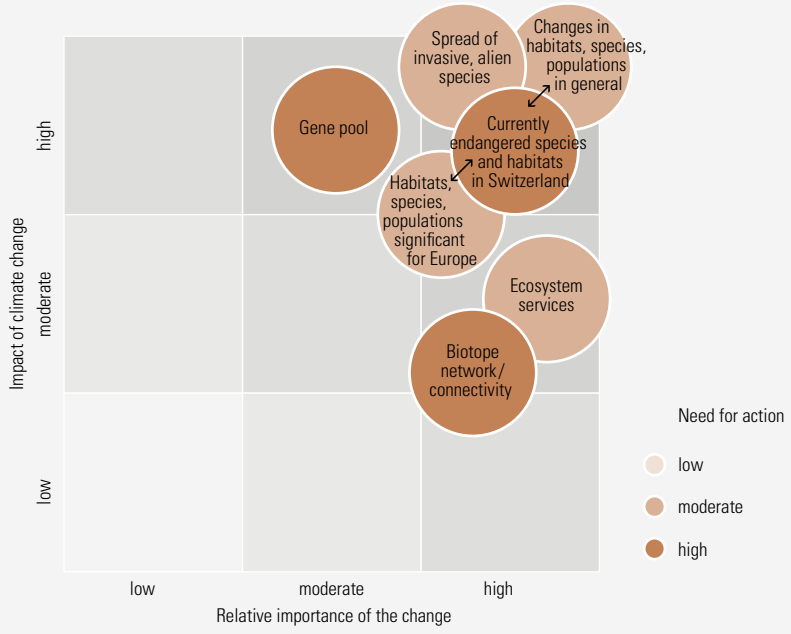
B3 Spread of invasive alien species: Climate change favours the introduction and spread of alien species and causes more of these organisms to exhibit invasive behaviour. The rate and extent of the spread are largely determined by human activities.

B4 Biotope network/connectivity: Climate-induced migration increases the need to connect habitats and make the landscape permeable. Climate-related changes in spatial planning (e.g. more intensive agriculture in the areas surrounding nature reserves) also have an impact on the quality of important habitats and their connectivity.

B5 Ecosystem services: Human wellbeing depends significantly on a large number of ecosystem services. In biodiversity management, priority is given to the regulating ecosystem services that are under pressure

j The areas "Changes in habitats, species, populations in general", "Currently endangered species and habitats in Switzerland", and "Habitats, species, populations significant for Europe" are summarised under one field of action: "Habitats and species".

Figure 4.7 Assessment of the relevant areas of the biodiversity management sector in relation to impact of climate change, relative importance of climate-related change and climate-related need for action.



as a result of climate change. These include carbon storage in peat soils and protection against landslides and debris flows by vegetation (root structures, water retention).

4.7.2 Adaptation goals in the biodiversity management sector

B1 Gene pool

– Identify important (sub-)populations of climate-sensitive species.
– Supervise genetic drift in small (sub-)populations of selected species.
– Reduce the loss of genetic diversity.

B2 Habitats and species

– Identify the habitats and species primarily affected by climate change and requiring protection; continually adjust assessment to changing conditions and communicate these adjustments.
– Coordinate the necessary preservation and support measures with the cantons and other sectors and at international level.
– Promptly introduce initial measures to support habitats and species that are known to be particularly affected (aquatic and wetland habitats, alpine habitats).

B3 Spread of invasive alien species

– Recognise invasive alien species with a high potential for damage at an early stage.
– Coordinate prevention and control measures at international level and implement them across sectors at an early stage to prevent uncontrolled spread.
– Raise awareness and communicate the problem to trading industries and the general public.

B4 Biotope network/connectivity

– Develop an ecological infrastructure in Switzerland for nature reserves and habitat corridors. This covers a wide range of climate-related migration and spreading.
– Integrate this national connectivity system at an international level and in binding national spatial planning provisions (sectoral biodiversity plan).

B5 Ecosystem services

– Recognise multifunctional ecosystem services in all sectors and take account of them in decision-making.
– Monitor ecosystem resilience and any changes in ecosystem services.
– Take account of the impact on global biodiversity and ecosystem services in national decisions on climate-related adaptations in other sector policies.

4.7.3 Guidelines for reaching goals

Fundamentals

– Improve the level of knowledge and exchange of information relating to the impact of climate change on the three levels of biodiversity (genetic, species and habitat diversity) and to the adaptability of these three levels.
– Develop monitoring activities to supervise species, biodiversity and recently, in particular, habitats on a continuous and cross-sector basis.

Information/awareness-raising

– Identify possibilities for preserving habitat diversity characteristic of the landscape when adapting its use in response to climate change.
– Evaluate possible losses of species as a basis for deciding how to further develop priorities for action (national priority species, concepts for the conservation of endangered species, etc.).
– Make recommendations in cooperation with the responsible federal offices to land users and parties concerned to prevent the further spread of existing and new invasive species.

Promoting and implementing measures

– Preserve and promote populations with adequate crossover by providing ecological infrastructure for nature reserves, habitat corridors and permeable landscapes.
– Develop standards for assessing relocation measures for selected climate-sensitive habitats and species.

Legal framework

– In cooperation with the most important land users, establish a national ecological infrastructure for nature reserves and habitat corridors that is binding under spatial planning and has international connections (including coordination with the European Emerald Network of Areas of Special Conservation Interest).
– Offer critical support to the main land users in use adaptation; where required, work towards adapting use in favour of long-term biodiversity conservation and multifunctional ecosystem services.

4.8 Health

4.8.1 Fields of action requiring adaptation in the health sector

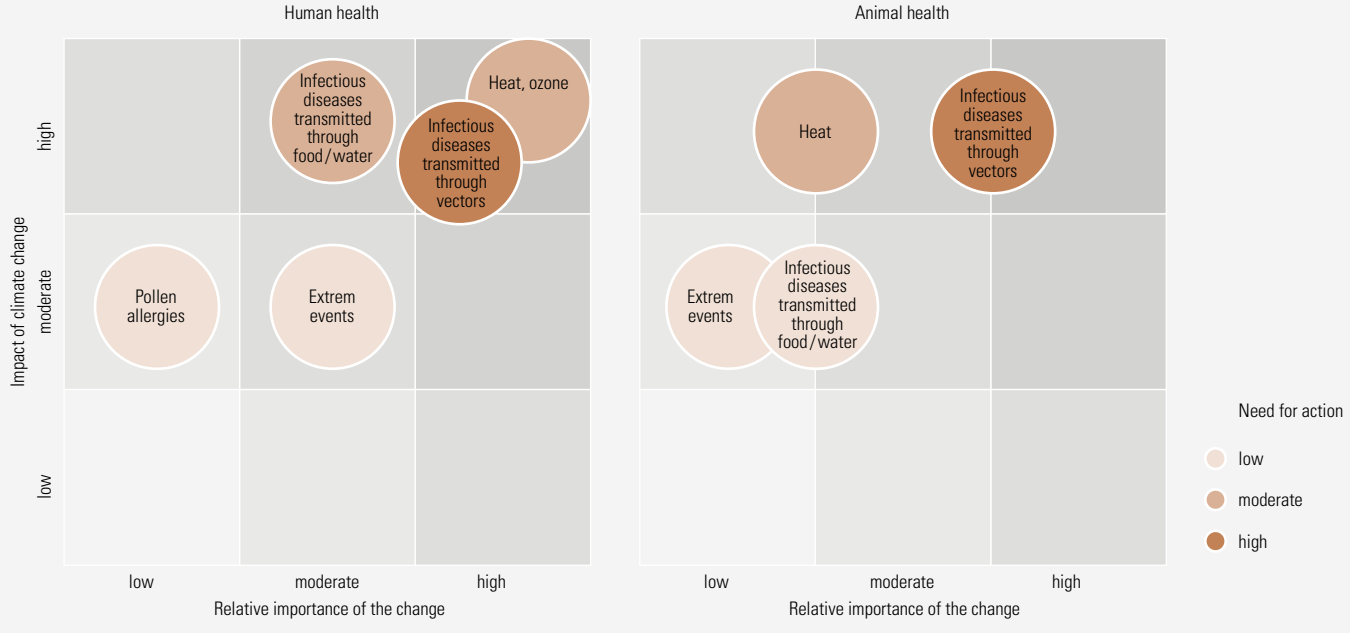
The health sub-strategy deals with the impact of climate change on humans and animals. Three fields of action requiring adaptation to climate change have been identified (Figure 4.8).

H1 Vector-borne diseases (humans and animals): Climate change fosters the emergence of new pathogens as well as their hosts and carriers (vectors). This increases the risk of new infectious diseases in humans and animals, which can spread rapidly and are sometimes difficult to treat.

H2 Effects of heat (humans and animals): Heatwaves can lead to cardiovascular conditions, dehydration, overheating and impaired performance. Summer heat increases ozone levels, which causes respiratory ailments and impairs lung function.

H3 Food- and water-borne diseases (humans): Infectious germs in water and food, in particular in dairy and meat products, thrive at higher temperatures.

Figure 4.8 Assessment of the relevant areas of the health sector in relation to impact of climate change, relative importance of climate-related change and climate-related need for action.



4.8.2 Adaptation goals in the health sector

H1 Vector-borne diseases

– Create excellent networks of professional competencies at national and international level. Make relevant information available to all stakeholders involved.
– Integrate new risks in existing strategies and structures to protect against infectious and epizootic diseases; coordinate action between the FOPH and the FVO.
– Raise awareness among risk groups and the public.

H2 Effects of heat

– Ensure that the whole of Switzerland is adequately prepared for heatwaves according to the degree of risk.
– Provide essential information appropriate to different target groups.
– Raise awareness among the general public, architects/urban planning experts and animal owners.

H3 Food- and water-borne diseases

– Maintain the currently high level of safety.
– Alert potentially affected businesses and the public to new risks.

4.8.3 Guidelines for reaching goals

Fundamentals

– Document the level of knowledge and close major research gaps. Create and consolidate competence centres and networks at national and international level. Provide the necessary capacities in the areas of early recognition and monitoring (H1).
– Clarify the impact of heat on human performance, on the adaptability of farm animals (high-performance animals, fish), and establish the need for adaptation in the area of animal husbandry/livestock farming (H2).
– Network existing expertise and improve dialogue between research, public administration and practice (national and international) (H3).

Information/awareness-raising

– Improve existing information and advisory services. Encourage the exchange of information between research, public administration and practice (H1).
– Create a central help and information centre which can be contacted in the event of an incident. Encourage the exchange of information with spatial and urban planning circles and in animal husbandry (H2).
– Step up information campaigns highlighting the health risks associated with mishandling food. Periodically update information (H3).

Promoting and implementing measures

– Intensify cooperation between the federal offices and the cantons. Provide the necessary expertise (human and veterinary medical education and training; laboratory diagnostics). Implement Switzerland's International Health Regulations (IHR/WHO) obligations (H1).
– Encourage the exchange of experience among the cantons on what to do in the event of heatwaves. Establish heat warnings and according to uniform criteria (H2).
– Continually update the monitoring of microbiological contamination. Periodically assess the need for action in the area of water hygiene. Implement Switzerland's International Health Regulations (IHR/WHO) obligations (H3).

Legal framework

– Adapt the Epidemics Act[20]/Epizootic Diseases Act[21]/Epizootic Diseases Ordinance[22] to new and recurring climate-related diseases; clarify issues of responsibility at the interface between ecology and health (deal with non-native organisms that are harmful to health) (H1).
– Incorporate new evidence on temperature tolerance and heat protection of farm animals in animal protection legislation; adapt construction standards to rising temperatures (H2).
– Epidemics Act: create a coordination body ("Zoonoses platform") (H3).

4.9 Spatial development

4.9.1 Fields of action requiring adaptation in spatial development

Spatial development can make a key contribution towards adapting to the impact of climate change by developing resilient and robust spatial structures. Some of the challenges faced by cities/agglomerations and rural areas are very different, while other similar challenges are shared. The fields of action identified are as follows (Figure 4.9):

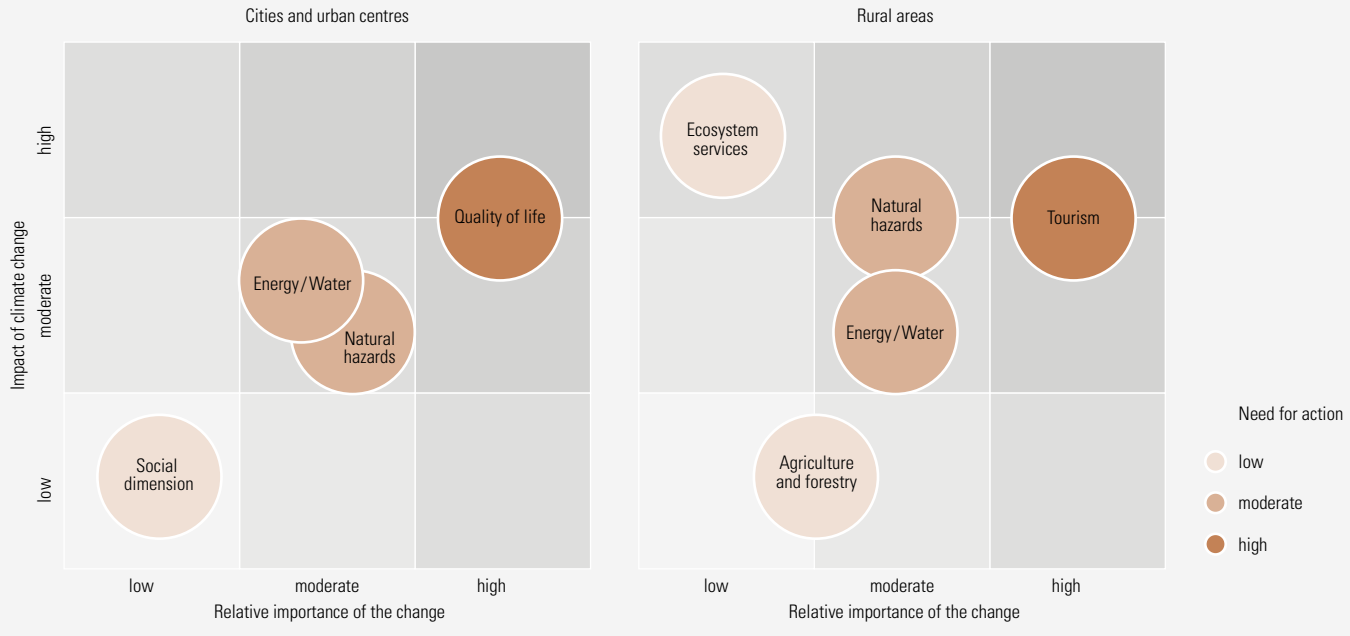
S1 Quality of life in cities and agglomerations: Cities and agglomerations are particularly sensitive to the increase in heatwaves expected due to climate change. There is a growing need for preserving green spaces and cool areas despite the pressure to continue building. Spatial planning has the responsibility of taking into account the growing importance of open spaces in agglomerations and cities in urban planning and in the relevant federal and cantonal instruments. In response to the spatial planning trends of inward urban development and urban densification, it is important to pay attention to quality, to preserve sufficient open spaces and create new ones. Conflicts of objectives need to be identified and resolved. Concentrating urban development along with preserving and creating open areas can also reduce sealed area to a minimum, thus improving heat dissipation. Measures providing shade and green spaces also improve the quality of the living environment. Well-designed traffic systems are particularly important for improving the quality of air in urban areas.

S2 Tourism[k]: Climate change will continue to increase the upper limit of guaranteed snow. Tourism is also challenged by the expected increase in natural hazard events and the loss of attractiveness of certain landscapes due to glacier melt. The pre-Alpine areas will be most affected by climate change due to the increasing upper limit of guaranteed snow. Regional adaptability will determine whether the changes can be seized as an opportunity to develop summer tourism and diversify tourist attractions, for example. Authorities will, however, come under increasing pressure to open access to still untouched and higher-lying areas for winter tourism. Spatial planning experts need to ensure the adaptation process is as compatible as possible with the landscape and to minimise the consumption of resources.

S3 Natural hazards: Climate change is expected to increase the frequency and intensity of natural hazard events. While rural and tourist areas in the Alpine region are affected by an overall increase in extreme

k Tourist attractions are discussed in Chapter 4.6, while this chapter focuses on tourism and the landscape.

Figure 4.9 Assessment of the relevant areas of the spatial development sector in urban and suburban areas and in rural areas in relation to impact of climate change, relative importance of climate-related change and climate-related need for action.



events, including permafrost degradation, avalanches, debris flows, floods, rockfalls and landslides, in the Mittelland the larger cities and agglomerations in particular will be particularly affected by an increase in floods and heat waves. It is the task of spatial planning authorities to steer urban development so as to prevent any further increase in risk and damage potential and to provide sufficient open areas. Above all, re-zoning and the construction of buildings and infrastructure in areas particularly at risk should be avoided. Existing data and documentation on natural hazards should be updated regularly.

S4 Energy/water: Climate change affects both energy and water consumption (e.g. air conditioning, irrigation, etc.) and the resources needed to produce energy and supply water, and it also ultimately affects the required infrastructure. Buildings retrofitted for energy efficiency do not only contribute directly to lowering energy consumption, they also heat up less, and thus do not require additional energy demand for air conditioning. New renewable energies (e.g. wind) help boost the energy supply with technologies that are less vulnerable to climate change. However, planning and building infrastructure for renewable energies often leads to landscape conflicts. It is the task of the authorities to consider these projects in terms of spatial planning, considering the relative merits of protection and use, and to play a mediating role in the case of conflict between opposing parties.

4.9.2 Adaptation goals in the spatial development sector

Spatial development should in principle use existing instruments and implement existing policies even more consistently in adapting to climate change. The following goals have been defined for the priority fields of action:

S1 Quality of life in cities and agglomerations
- Develop new or established and improved open areas and green infrastructure that offsets heat island effects.
- Ensure heat dissipation by avoiding more sealed areas.
- Optimise traffic routing to ensure adequate ventilation in cities and residential areas.
- Improve the quality of the surroundings by creating shade and green spaces.

S2 Tourism
- Support adaptation measures by developing summer tourism and diversifying tourist attractions while at the same time conserving natural resources.
- Reconcile conflicts between protection and use by expanding and opening access to ski areas at higher altitudes.
- Develop attractions in a sustainable and environmentally friendly way.

S3 Natural hazards
- Incorporate a risk-based approach to natural hazards in planning.
- Include future hazardous situations in hazard mapping.
- Avoid re-zoning and building on areas at risk in order to limit damage potential.
- Provide adequate space for watercourses.

S4 Energy/water
- Ensure spatial structures that help to save resources.
- Develop an integrated territorial energy planning.
- Coordinate planning of infrastructure to generate renewable energy which takes into account landscape conservation concerns.
- Develop and implement an integrated water management strategy.

4.9.3 Guidelines for reaching goals

Spatial planning instruments (federal sectoral plans, cantonal structure plans, agglomeration programmes and zoning plans) already contribute – indirectly and not explicitly – to supporting and easing adaptation to climate change. Existing measures need to be applied more systematically and rigorously. In addition, further specific measures need to be applied in some of the fields of action and goals mentioned above. The focus is on the following options for action at federal level:

Fundamentals

- Draw up guidelines for the cantons and cities on how spatial planning can respond to the impact of climate change and how to increase the adaptability of spatial planning.
- Add risk-based approaches and best practices to existing recommendations for natural hazards and spatial planning (PLANAT project in progress).
- Create information basis for coordinated planning of infrastructure for renewable energy, in particular for considering protection versus use.
- Create information basis for assessing the expansion of and opening access to ski areas at higher altitudes and mostly still untouched areas.

Information/awareness-raising

- Raise awareness among all levels of spatial planners at information events and meetings (in cooperation with the Swiss association for land use planning, the professional association of Swiss planners, Swiss conference of the cantonal planners, etc.)

Promoting and implementing measures

- Review (and approve) the cantonal structure plans, also in terms of the strategies and principles that need to be formulated and the measures that need to be taken in adapting to climate change (inward urban development linked with creating and preserving adequate open and green areas, developing ski areas, avoiding areas that are heavily exposed to natural hazards in urban and infrastructure planning, improving energy efficiency and generating renewable energy, etc.).
- Address adaption to climate change and any related potential spatial planning measures in Switzerland's spatial planning policy.
- Consider the challenges of climate change in the development of agglomeration policy (e.g. greater development of open areas and green infrastructure in cities and residential areas).
- Promote the development of suburban open areas in joint projects at federal level (e.g. a project for the development of suburban open areas, sustainable neighbourhood development, etc.)
- Initiate joint model projects or pilot projects as instruments for implementing the federal adaptation strategy.

Legal framework

- Anchor planning principles for adapting to climate change (and for impacting climate change) in the Spatial Planning Act (Art. 3 Spatial Planning Act[23] SPA) (second stage of the partial revision of the SPA).
- Establish impact assessment for planning at all stages (in particular for cantonal structure plans), which should also lead to optimising planning and individual projects in terms of the necessary adaptation to climate change (second stage of the partial revision of the SPA).
- Cantons review and, where necessary, rezone building areas (envisaged in the first stage of the partial revision of the SPA) also taking into account site suitability and natural hazards; amend directives accordingly.

Corvatsch glacier in the Upper Engadine (Canton Graubünden) on 24 August 2011: Glaciers have been melting at an ever increasing rate in recent decades. To slow the ice melt, glaciers are protected from the summer sun with tarpaulins.

5 Interfaces between the sectors relevant to adaptation

There are numerous interfaces between the sectors discussed in the first part of the adaptation strategy, irrespective of whether we are considering climate change or not. Interfaces between fields of action in various sectors are important for the adaptation strategy, as they may lead to synergies or indeed conflicts. Table 5.1 provides a summary of the interfaces that relate to at least two of the fields of action from various sectors identified in Chapter 4.

The table contains the following information for each interface: (1) a short description of the interface, (2) the federal office primarily responsible for dealing with the interface and (3) other sectors in which a field of action is affected by the interface. Measures to exploit synergies and deal with conflicts are not listed. These have to be developed when implementing the adaptation strategy (cf. Chapter 6).

Where two or more federal offices are responsible for dealing with the interfaces, they are listed separated by commas. If a federal office is primarily responsible for the interface but another office is involved to a large degree, the second is listed in brackets. As this is a federal strategy, no mention is made of the cantons, even where they are partly involved in dealing with the interface.

In the list, the *other sectors affected* are abbreviated as follows: water management (W), natural hazards management (N), agriculture (A), forestry (F), energy (E), biodiversity management (B), health (H) and spatial development (S). Interfaces with the tourism sector were not analysed.

Table 5.1 Interfaces between the fields of action identified in Chapter 4

Interface between water management and natural hazards management
– Lake regulation for flood protection (creation of reservoir capacity) (Primary responsibility: FOEN; other affected sectors: none)
– Use of reservoirs (energy production and processing versus flood protection) (Primary responsibility: FOEN; other affected sectors: E, S)
– Water management installations in the river/lake zone and flood protection (Primary responsibility: FOEN; other affected sectors: none)
Interface between water management and agriculture
– Irrigation requirements (water distribution and water storage) (Primary responsibility: FOAG; other affected sectors: B, E, N, S)
– Substance transport via precipitation and irrigation (on the surface; via infiltration) (Primary responsibility: FOAG; other affected sectors: none)
Interface between water management and forestry
– Conservation of forest structures that provide the filtration required so that groundwater from woodlands can be used as drinking water (Primary responsibility: FOEN; other affected sectors: none)

Interface between water management and energy
– Exploitation of potential of reservoirs for other uses in the event of water shortages
(Primary responsibility: FOEN (SFOE); other affected sectors: A)
– Water distribution: times of low water flow result in conflicts for smaller and even some medium-sized watercourses between use for hydropower and other uses or protection concerns
(Primary responsibility: FOEN; other affected sectors: B, H, A, S)
– Residual flow: review of the statutory regulations due to changed discharge regime
(Primary responsibility: FOEN; other affected sectors: B, S)
– Use of water for cooling purposes for installations (thermal power stations, air conditioning): thermal discharge into bodies of water (incl. ground water)
(Primary responsibility: SFOE (FOEN); other affected sectors: B, H)
– International obligations relating to the regulation of water bodies and use of hydropower (transboundary waters)
(Primary responsibility: FOEN (SFOE); other affected sectors: none)

Interface between water management and biodiversity management
– Water distribution: coordination of growing water demand with the needs of the various habitats as part of an integrated water management plan (catchment area management). In the case of transboundary waters, in coordination with neighbouring countries.
(Primary responsibility: FOEN; other affected sectors: E, A, N, S)
– Combating and preventing the spread of invasive alien species along water bodies. In the case of transboundary waters, in coordination with the neighbouring countries.
(Primary responsibility: FOEN; other affected sectors: none)
– Avoidance/reduction of water quality impairment due to proliferation of aquatic organisms (e.g. algae blooms) in standing waters
(Primary responsibility: FOEN; other affected sectors: none)

Interface between water management and health
– Times of low water flow result in conflicts for smaller and even some medium-sized watercourses in relation to water use. This also affects use as drinking water (by humans and animals).
(Primary responsibility: FOEN; other affected sectors: B, E, A, S)

Interface between water management and spatial development
– Promotion of integrated water management
(Primary responsibility: FOEN; other affected sectors: B, E, A, N)

Interface between natural hazards management and agriculture
– Prevention of construction along water and drainage corridors; (re-)use of more of river/lake zone for flood protection and prevention, or creation of flood diversion corridors and planned flood plains
(Primary responsibility: FOEN; other affected sectors: S, W)
– Adaptation of agricultural use to the new hazard situation
(Primary responsibility: FOAG; other affected sectors: none)

Interface between natural hazards management and forestry
– Maintenance of protective capacity of the forest under changing climatic conditions and following events (drought, storms, forest fires, etc.)
(Primary responsibility: FOEN; other affected sectors: B, W)

Interface between natural hazards management and energy
– Use of reservoirs for the purpose of flow regulation (flood prevention)
(Primary responsibility: FOEN; other affected sectors: S, W)
– Protection of energy transport infrastructures against mass wasting in the mountains
(Primary responsibility: FOEN; other affected sectors: S)
– Assessment of forest aisle width for transmission lines in protection forests so that the latter maintains its protective function
(Primary responsibility: SFOE; other affected sectors: F, S)

Interface between natural hazards management and biodiversity management

– Consideration of ecological aspects when planning and devising protection or preventive measures for slopes prone to erosion and slides, debris flows/slope stabilisation, flood and avalanche protection as well as revitalisation of watercourses
(Primary responsibility: FOEN; other affected sectors: A, W, S)
– Prevention of and combating spread of invasive alien species when constructing protection and/or prevention infrastructure (above all flood protection, protection against landslides, bioengineering measures)
(Primary responsibility: FOEN; other affected sectors: none)
– Consideration of ecological aspects when maintaining the protective function of forests in forest reserves
(Primary responsibility: FOEN; other affected sectors: F, W)

Interface between natural hazards management and spatial development

– Risk-based, long-term spatial planning as sustainable instrument in hazard prevention in order to reduce existing risks, avoid new risks and protect existence of open spaces.
(Primary responsibility: FOEN, ARE; other affected sectors: none)
– Disposal sites for large volumes of bed load material in mountain valleys.
(Primary responsibility: ARE, FOEN; other affected sectors: E)

Interface between agriculture and biodiversity management

– Identification and development of instruments to establish a system of agriculture that suits local conditions with appropriate forms of agricultural management and crop systems:
  – to avoid loss of nutrients (in particular after heavy rainfall),
  – to maintain and encourage biodiversity through spatial distribution and networking of biodiversity promotion zones (BPZs) with regard to warming scenarios (stepping stones, gene flow, refuges, etc.) and with structures that gain in importance due to climate change (e.g. marshy areas, pools)
  – to encourage climate-sensitive species
(Primary responsibility: FOAG (FOEN); other affected sectors: W)
– Devising measures to prevent and combat invasive alien species and harmful organisms and encourage exchanges on the success or failure of these measures
(Primary responsibility: FOEN (FOAG); other affected sectors: H)

Interface between agriculture and health

– Implementation of species-appropriate livestock husbandry systems: shading, ventilation, temperature regulation, supply of fluids etc.
(Primary responsibility: FOAG, FVO; other affected sectors: none)
– Monitoring of vitality/mortality of temperature-sensitive farm animals
(Primary responsibility: FVO; other affected sectors: none)
– Monitoring, prevention and combating of new species that are harmful to health
(Primary responsibility: FVO, FOPH (FOAG); other affected sectors: B)
– Monitoring, prevention and combating of vectors/host animals that are of significance in the occurrence of new and already known pathogens
(Primary responsibility: FOPH, FVO; other affected sectors: B)

Interface between forestry and biodiversity management

– Coordination of adaptation goals with all ecosystem functions, in particular with the requirements for biodiversity; priority of ensuring that the available genetic diversity is maintained when carrying out measures to adapt the forests to climate change and with the aim of spreading risks around a variety of tree species
(Primary responsibility: FOEN; other affected sectors: none)
– Prevention of spread of invasive alien organisms with silvicultural measures
(Primary responsibility: FOEN; other affected sectors: none)
– Use of indigenous tree species from other, e.g. drier growth areas or of other, non-invasive tree species, in order to guarantee ecosystem functions even in the event of extreme climate change
(Primary responsibility: FOEN; other affected sectors: none)
– Development of silvicultural measures to increase adaptability and risk diversification taking account of biodiversity factors
(Primary responsibility: FOEN; other affected sectors: none)

Interface between forestry and spatial development
– Securing open spaces and recreation areas
(Primary responsibility: ARE; other affected sectors: B)
– Securing the protection forest and the protective function of the forest
(Primary responsibility: FOEN; other affected sectors: W, B)

Interface between energy and biodiversity management
– Protection of aquatic ecology in the event of a changed discharge regime near power stations due to climate change or climate-related changes in operation:
  – minimum water flow in a watercourse, flushing out reservoirs, changes in habitats in and on waters
  – introduction of cooling water in cases of increased water temperatures in rivers (nuclear power plants, thermal power stations)
(Primary responsibility: FOEN; other affected sectors: W)

Interface between energy and health
– Establishment and implementation of building regulations that guarantee a pleasant living and working environment thanks to the optimised regulation of the inside temperature by means of construction and energy technology even under changed climate conditions. Here attention should be paid to particularly sensitive population groups (e.g. older persons, sick people, babies).
(Primary responsibility: SFOE (FOPH); other affected sectors: S)

Interface between energy and spatial development
– Implementation of spatial planning that reduces the overheating of residential areas by using green areas of a suitable type, layout and number (guarantee of air circulation/natural cooling in built-up areas)
(Primary responsibility: ARE (SFOE); other affected sectors: H)
– Safeguarding of critical energy supply infrastructures
(Primary responsibility: ARE (SFOE); other affected sectors: N)

Interface between biodiversity management and health
– Monitoring of occurrence and spread of new species that harm the health of humans and farm animals (vectors, host animals, allergenic plants)
(Primary responsibility: FOPH, FVO, FOEN; other affected sectors: A)
– Consideration of risks of wetlands as potential habitats for new, hygrophilous vectors
(Primary responsibility: FOPH, FVO, FOEN; other affected sectors: none)
– Ecological infrastructure support as the key link between urban biodiversity and the health of the urban population
(Primary responsibility: FOPH, FVO, FOEN; other affected sectors: S)

Interface between biodiversity management and spatial development
– Inclusion of biodiversity factors in residential development planning by setting aside sufficiently large and near-natural green areas
(Primary responsibility: FOEN, ARE; other affected sectors: none)
– Maintenance of landscapes with an abundant range of habitats and their ecosystem services as an element in spatial planning
(Primary responsibility: FOEN, ARE; other affected sectors: none)
– Coordination of residential areas and infrastructures with the national integrated biotope system (networking habitats)
(Primary responsibility: FOEN, ARE; other affected sectors: none)

Interface between health and spatial development
– Minimisation of heat-island effect with urban development measures (air circulation corridors, regulations on surface materials, green zones/planting)
(Primary responsibility: ARE; other affected sectors: E)

6 Stages in implementing the strategy

The adaptation strategy forms the basis for the federal offices' coordinated course of action for adapting to climate change. This is a long-term task. It is therefore vital that the strategy is continually improved and developed, taking account of advancing climate change, new scientific findings and experience gained and the progress achieved in the adaptation process.

This first part of the adaptation strategy does not contain a list of measures. Specific adaptation measures are to be agreed on by the responsible departments in a further step, and presented and coordinated in a joint action plan by the end of 2013. At federal level, the measures will be implemented as part of the relevant sector policies and are the responsibility of the respective federal offices.

The FOEN is responsible both for drafting the first part of the adaptation strategy and for coordinating the drafting of the action plan. Here the responsibilities of the Confederation, cantons and private individuals must be taken into consideration and the various players consulted. Likewise it will be necessary to coordinate measures with the Federal Council's other cross-sector strategies.

The action plan for adapting to climate change should include the following elements:

Measures to improve knowledge

To implement and develop the adaptation strategy, it will be necessary to improve our fundamental knowledge. Here the following priorities stand out:

Climate scenarios: In keeping with advances in climate science and the arrival of new, international climate models, climate scenarios for Switzerland need to be devised and made available on a regular basis.

Analysis of the effects of climate change: In all sectors there are gaps in what we know about the effects of climate change and the associated costs. In order to improve the basis for planning measures, these gaps have to be filled in.

Risk analysis: The analysis of climate-related risks and opportunities in Switzerland will provide important quantitative bases for deciding on the priorities in adapting to climate change. A method of integrated risk analysis has already been developed. It is to be applied throughout the country in the next stages of the adaptation process.

Measures to achieve the adaptation goals in the sectors

Taking account of the improved knowledge base, the responsible federal offices will draw up more specific details for the sectors' adaptation goals formulated in Chapter 4 and develop measures to achieve these goals. This package of measures will be summarised in the joint action plan.

Coordination of measures

As part of the action plan, the measures for the sectors should be coordinated with each other in order to exploit potential synergies in adapting to climate change and to recognise and deal with potential conflicts at an early stage. This is necessary because the most important challenges in adapting to climate change defined in Chapter 2 demand measures in various areas of responsibility and must thus be tackled by the federal offices concerned in a coordinated manner. Likewise there is a need for coordination in the bilateral interfaces between the fields of action in the various sectors that are identified in Chapter 5. In the action plan, responsibilities will be clarified and the measures for the sectors coordinated based on the sectoral goals set out in this first part of the strategy. The FOEN will supervise the coordination process.

Evaluation of the need for resources and funding

Careful consideration must be given to the resource requirement for the measures for adapting to climate change. If at all possible, it should be covered by fixing priorities within the budgets made available for the fields of activity. Where additional financial and human resources are required for new tasks, possible sources of funding will be proposed.

Cooperation with the cantons

This first part of the adaptation strategy deals with adapting to climate change at a federal level. Various options for action, however, also affect existing joint tasks carried out by the Confederation, cantons and communes or cantonal or communal tasks. In order to adapt to climate change in a coordinated and efficient manner, activities must be coordinated at all

institutional levels. In the coming years, the Confederation and the cantons will work more closely together in adapting to climate change.

Evaluation of success and reporting

Progress in adapting to climate change and in implementing the adaptation strategy will be reviewed at regular intervals to verify compliance with the goals and principles (Chapter 3). The key data for this audit will be specified in the action plan. The effects achieved by each individual measures will be assessed by the federal offices responsible as part of the ordinary effectiveness and performance audits. In addition, progress with implementing the action plan (implementation audit) as well as the overall contribution of the action plan to reducing climate-related risks will be subject to a regular and comprehensive assessment.

Development of the strategy

The adaptation strategy should be evaluated and revised at regular intervals, taking account of the progress achieved in adapting to climate change, the improved knowledge base and developments in neighbouring countries. The modalities of the evaluation and revision of the adaptation strategy form part of the action plan.

Irrigation in the vineyards of Salgesch (Canton Valais), summer 2005: In many places, Swiss agriculture is already dependent on artificial irrigation. In future, climate change will lead to more frequent dry periods in summer and increase the need for irrigation in agriculture.

Annex

A1 Procedure and methodology

The first part of the adaptation strategy was developed in six steps (Figure A1.1). Firstly, the climatological principles for the adaptation strategy were defined (Stage 1, Annex A2.1). Super-ordinate goals and principles for adapting to climate change were then formulated (Stage 2, Chapter 3). Thirdly, the most important sectors requiring adaptation at federal level were identified for the strategy (Stage 3, Annex A1.1). For these sectors, sub-strategies were developed (Stage 4, Chapter 4). In a further stage, the interfaces between the sectoral sub-strategies were analysed (Stage 5, Chapter 5). Finally – based on the results obtained in Stages 1 to 5 – the most important challenges in adapting to climate change at federal level were synthesised (Stage 6, Chapter 2).

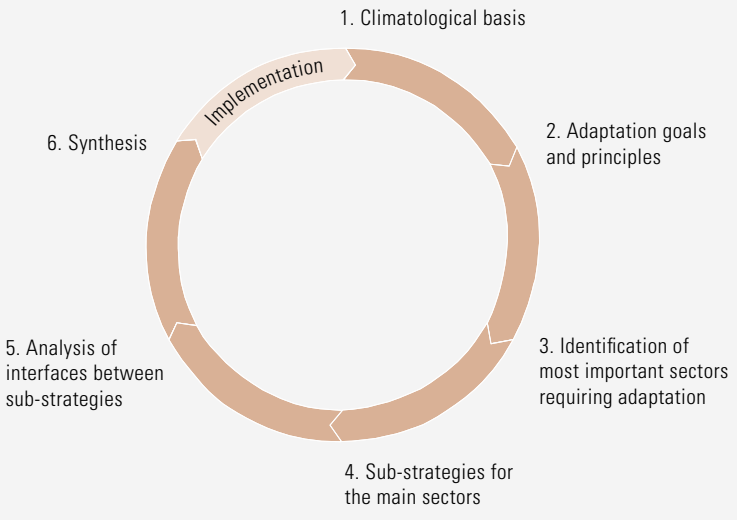
Adapting to climate change is a long-term process. The adaptation strategy is based on the current level of knowledge of future climate trends, the effects of climate change and possible adaptation methods. This knowledge base will improve as climate change progresses, advances are made in climate research and experience is gained with adaptation. It will be possible and necessary to evaluate and revise the strategy accordingly at regular intervals.

A1.1 The most important sectors in adaptation

Based on analyses of the effects of climate change on Switzerland[24,25,26,27], nine sectors were identified that are seriously affected by climate change. The selection focused on sectors in which there is a need to adapt as a result of direct climate-related changes in Switzerland and in which the Confederation has the opportunity to take action in adapting to climate change. As a result, migration or insurance are not taken into account here, for example. The transport infrastructure is the responsibility of the sector natural hazards management.

The most important relationships between the nine sectors and the direct and indirect effects of climate change are shown in Figure A1.2 in a simple impact matrix. The points indicate where there is unilateral or mutual interaction between the effects of climate change and the adaptation measures implemented by the sectors.

Figure A1.1 Procedures in developing the first part of the adaptation strategy.



A1.2 Procedure for the development of sub-strategies

For eight of the selected sectors, sectoral sub-strategies were developed according to a standard procedure. Summarised versions of these sub-strategies are provided in Chapter 4.

Adapting to climate change in tourism is dealt with in the Federal Council's growth strategy for Switzerland as a tourist location[10] and in the implementation programme for 2012–15, which is currently being drawn up. The most important issues are summarised in Chapter 4.6.

For the eight other sectors, the procedure involves the following stages:

1. Identification of the relevant areas
   For each sector, the areas affected by climate change were identified.

2. Assessment of the relevant areas
   The areas were assessed in relation to the following factors: "impact of climate change", "relative importance of climate-related change" and "climate-related need for action" (Table A1.1). The various factors were assessed qualitatively according to a three-level scale (low – moderate – high). The areas were assessed from the standpoint of the relevant sector. The same area may be assessed differently by different sectors. As the individual factors are not based on any standard quantitative measured variables, the assessments of the areas are only comparable with each other within a sector and not between sectors. The assessment of the areas is shown in a nine-field matrix (Figure A1.3).

3. Identification of the areas in which adaptation is needed (fields of action)
   As a result of the assessment of the areas, fields of action where adaptation is needed were identified in each sector. Fields of action are those areas in which all three dimensions have

Figure A1.2 Effect matrix: Direct and indirect effects of climate change and the affected sectors.

Adaptation measures	**Climate change** (temperature, precipitation, wind)				
	Water – precipitation – discharge – groundwater – water quality – snow – ice	**Soil** – carbon sink – fertility – erosion	**Air** – ozone – aerosols – particulate matter	**Biodiversity** – phenology – colonisation – extinction – migration – invasive species – …
Water management	●	●	●		●
Natural hazards management	●	●	●		●
Agriculture	●	●	●	●	●
Forestry	●	●	●	●	●
Energy	●	●			●
Tourism	●	●		●	●
Biodiversity management	●	●	●	●	●
Health	●	●		●	●
Spatial development	●	●	●	●	●

been assessed as moderate or high. Areas that are assessed in one dimension as low are not made a field of action.

4. Strategic goals for the fields of action
   Strategic goals for adapting to climate change were formulated for each field of action.

5. Options for action
   Lastly, an approach was devised for achieving the formulated strategic goals at federal level.

No comprehensive, quantitative studies on the effects of climate change are available for any of the sectors under consideration. In developing the sub-strategies, therefore, decisions were based primarily on the opinions of experts. In order to guarantee that no strategy was based on a single opinion alone, the sub-strategies were assessed by specialists from within the administration or by external specialists and the opinions on each sub-strategy consolidated.

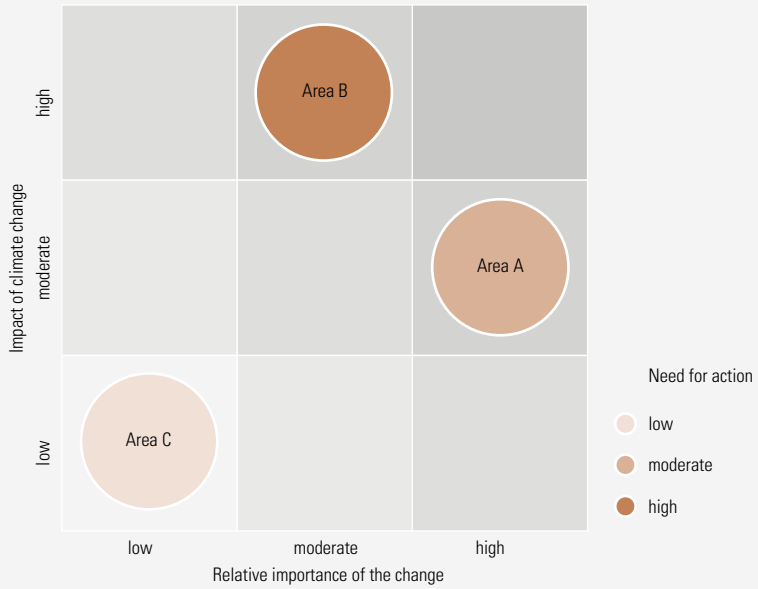
Table A1.1 Three dimensions to the assessment of the areas

Impact of climate change
The **impact of climate change** describes how much an area can be directly or indirectly influenced by climate change. This may relate to both negative and positive changes.
Assessment: low, low to moderate, moderate, moderate to high, high

Relative importance of the change
The **relative importance of the change** shows how important the expected climate change is in the area concerned from the overall view of the sector. The criteria for the assessment are sector-specific.
Assessment: low, low to moderate, moderate, moderate to high, high

Need for action
In assessing the **need for action,** account is taken of the adaptation measures already carried out and those that are also possible. It is also possible that areas with moderate to high influence on the axis of climate change and/or a relative importance to the axis of the change indicate a low need for action, as the possible measures have already been initiated. A need for action that exists irrespective of climate change is not taken into account in the assessment.
Assessment: low, moderate, high

Figure A1.3 Nine-field matrix for the assessment of the areas of a sector that are impacted by climate change. The areas are placed in the nine-field matrix as coloured circles according to their assessment. The fictitious areas A, B and C are given as an example.



A2 The future for Switzerland's climate

A2.1 Climate scenarios for Switzerland

As the essential basis for devising the adaptation strategy, reliable information on *observed* and *future* climate trends is required. The adaptation goals for the sectors (Chapter 4) and the measures to achieve these goals must aim to deal with potential changes in the climate. In this first part of the strategy, reference was therefore made to the climate scenarios prepared as part of the project *Climate change and Switzerland 2050* (the CH2007 scenarios)[26,28].

In parallel to devising the adaptation strategy, various research institutes, coordinated by the Federal Office of Meteorology and Climatology (MeteoSwiss), have updated the CH2007 scenarios[29]. These new "Swiss CH2011 climate scenarios" (www.ch2011.ch) will form the basis for future work on the adaptation strategy.

A2.1.1 Climate trends observed in Switzerland

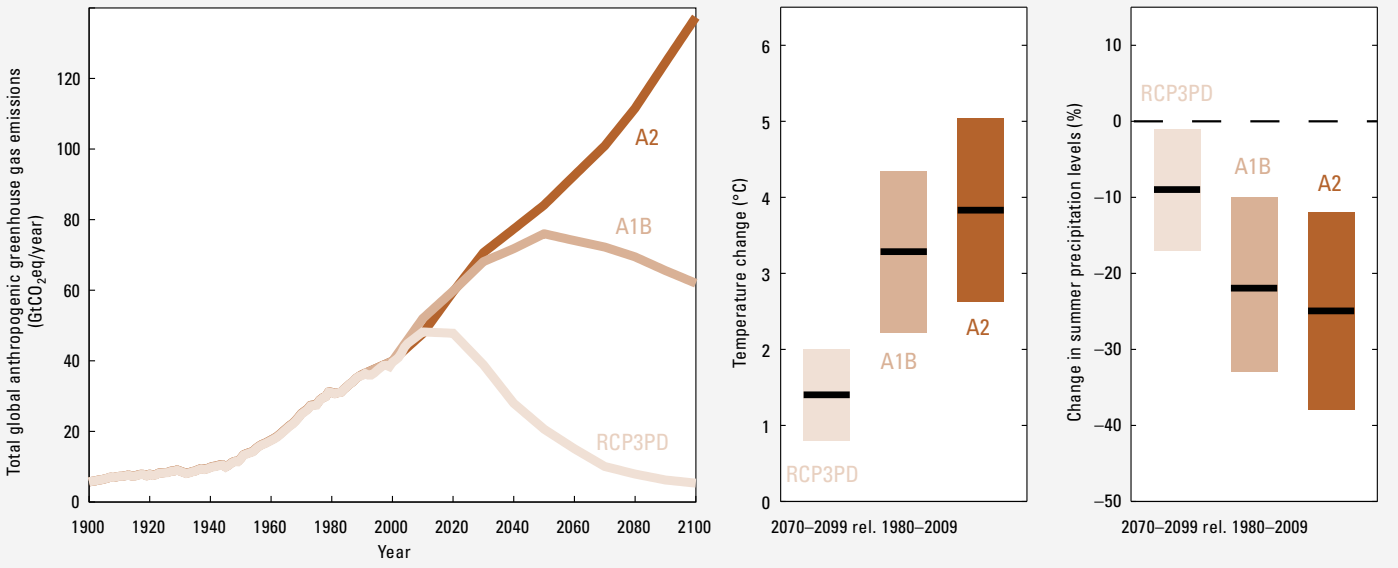
In order to assess the current climate trends, a unique source of information is available in the form of a high quality and detailed series of climate-related measurement data on Switzerland, dating back as far as the 19th century[30]. This data forms the basis for calculating the relevant climate indicators (e.g. heatwaves, heavy precipitation, periods of drought).

Analyses show that:
- There is clear evidence that temperatures are rising in Switzerland, the increase amounting to around 1.7 °C from the start of industrialisation (1864) to 2010. Over the same period, global temperatures have risen by around 0.7 °C.
- Hardly any change in average precipitation is detectable as yet due to substantial annual fluctuations.
- There is a tendency towards more hot summer days and heatwaves, especially in the Mittelland.
- The number of days of frost has clearly fallen since the 1960s.
- The zero degree line in winter has risen by around 300 m since the 1960s.

A2.1.2 Future Swiss climate trends according to the new CH2011 climate scenarios

From the middle of the 21st century, the climate in Switzerland will be increasingly influenced by future trends in global greenhouse gas emissions. As a basis for the CH2011 scenarios therefore, three different emission scenarios were used (Figure A2.1 left). In two of the emission scenarios (A2 and A1B) a further increase in emissions has been assumed, and in one emission scenario (RCP3PD) it is assumed that by 2050 emissions will have fallen by 50 per cent when compared with levels in 1990. This last scenario corresponds approximately to a scenario where global warming is limited to 2 °C from the start of industrialisation.

Figure A2.1 Three different pathways of global past and future anthropogenic greenhouse gas emissions (left) and the expected changes in mean temperature and precipitation in Switzerland. Annual temperatures (centre) and summer precipitation (right) in Switzerland for the period 2070–2099 in comparison with 1980–2009. The coloured bands show the best estimate of the future projections.



The new CH2011 results show that with reduction measures aimed at limiting global warming to 2 °C, resultant warming in Switzerland would be two to three times lower (1.4 °C as the most probable value) than if no reduction measures are taken (Figure A2.1 centre). Additional warming of 1.4 °C corresponds approximately to the warming observed between 1864 and 2010 (1.7 °C).

Based on the CH2011 climate scenarios, the following changes in comparison with the average values for the period 1980–2009 may be expected by the end of the 21st century. Here it should be noted that Switzerland's climate has already changed considerably since the start of industrialisation in the mid-19th century:
- *Temperature:* Average temperatures will very likely increase in all regions and seasons. Without intervention measures, a temperature increase in Switzerland of 2.7 °C to 4.8 °C should be expected. Even with intervention measures, the Swiss climate will still warm up, but to a far lesser extent, between 1.2 °C and 1.8 °C.
- *Precipitation:* In the second half of the century, average levels of precipitation in summer will likely decrease everywhere in Switzerland (–18 to –28 %, Figure A2.1 right), while winter precipitation in the south of Switzerland will likely increase. According to model predictions, rainfall levels in other regions and seasons may increase or decrease.

Along with these changes in the average temperature and average precipitation, a change in the character of extreme events should be expected.

- It is assumed that there will be more frequent, intense and longer lasting summer warm spells and heatwaves, while the number of cold winter days and nights is expected to decrease.
- Projections of the frequency and intensity of precipitation events are subject to a serious degree of uncertainty, and major changes cannot be excluded.
- No certain comment can be made on hailstorms and other storms at present.

Due to the methodological differences in CH2011 and CH2007, a quantitative comparison is not possible. A qualitative comparison shows that:
- projected summer warming and drought in CH2011 is slightly lower than in CH2007.
- CH2011 shows no consistent change in precipitation for autumn, winter and spring, i.e. the level of precipitation may either increase or decrease. CH2007 projected consistent changes in precipitation for these three seasons.

A2.2 Effects of climate change on Switzerland

Climate change in Switzerland also affects natural systems and socio-economic sectors. A detailed analysis of the effects on the environment, society and the economy was published in 2007.[26] In this chapter the most significant climate-related changes, as expected based on the climate scenario up to 2050 described in A2.1, are summarised in the overview.

A2.2.1 Climate-related changes in natural systems

Water-cycle

Below is a summary of the climate-related changes expected in the water-cycle over the coming decades:
- *Change in precipitation distribution:* By 2050 in Switzerland as a whole, it is expected that average rainfall levels will increase by around 10 per cent in winter and decline by around 15 to 20 per cent in summer. For spring and autumn, the scenarios are less clear; an increase or a decrease in precipitation is possible.
- *Acceleration in glacier retreat:* Depending on the extent of warming and the change in rainfall levels by 2050, the area covered by Alpine glaciers will decline in comparison with the reference period of 1971–1990 by approximately 50 to 90 per cent.
- *Rising snowline:* By 2050, in the event of average warming in winter (+1.8 °C), the snowline will rise by approximately 360 m in comparison with the average level in the period 1959–97. At low and medium altitudes less precipitation will fall in the form of snow, and there will be more rain instead.
- *Dwindling snow reserves:* Due to the higher snowline and the fact that snow will melt earlier in the year, the amount of water stored in snow will decline in spring. The flow of water in Alpine rivers that are not fed by glaciers will therefore fall significantly in dry summers.
- *Increase in evaporation:* When there is sufficient rainfall, evaporation due to warming and the retreating areas covered by snow and ice may increase slightly.

- *Reduction in discharge:* The average annual discharge volumes of Swiss rivers will fall due to the reduction in rainfall levels and the increase in evaporation. The maximum discharge will also decline and will occur earlier in the year. In the summer, low water periods will last longer and the level of water flow will decline.
- *Water level in lakes:* The volume of water flowing into lakes will change according to the discharge regime (higher volumes in winter, lower in summer). The demand for water from lakes for raising low water levels, processed water needs and flood retention measures will increase (with the exception of Lake Constance and Lake Walen, all lakes are regulated), which again has an influence on the level of the lake.
- *Increase in low water periods:* In summer, the number of low water periods in small to medium-sized watercourses in the Mittelland, Jura and the Ticino will increase. In areas where glaciers are retreating, the discharge regime will change significantly, and in late summer periods of drought will become increasingly common.
- *Changes in flooding:* On the north side of the Alps below 1500 metres above sea level, higher flood peaks are expected in winter. In summer, flooding will be less common in lower-lying areas. However, in small catchment areas in particular, convective precipitation (thunderstorms) may cause flooding. In the Southern Alps, an increase in the number of floods is expected in winter and spring. In summer, due to the lower rainfall levels, the discharge peaks in larger catchment areas could decline[31].
- *Bedload transport:* The thawing of the permafrost and retreating glaciers will increase the potential bedload in the Alpine region. The rise in the intensity of precipitation means that higher volumes of bedload and suspended sediment loads will find their way into mountain streams and reservoirs.
- *Rising water temperature:* Global warming will lead to a rise in the water temperature in watercourses. Given the decline in areas covered by snow and ice, the water temperature in the higher-lying regions will probably rise disproportionally.
- *Decrease in water quality:* Higher water temperatures lead to reduced oxygen content in waters. In extreme low water periods, pollutant concentrations may therefore increase. Where such water infiltrates the groundwater, groundwater quality and therefore drinking water quality may be adversely affected.
- *Change in groundwater recharge:* Levels of groundwater recharge will fall in summer and autumn in all areas that are not served by melting glaciers, but in winter recharge will increase in areas not covered by snow.

Soil

The soil is a habitat for organisms, the substrate for vegetation, and it regulates the water and material cycle. It is important in the carbon cycle as a carbon sink. These important functions are being adversely affected by climate change to an increasing extent:

- *Increase in erosion:* Due to more frequent and heavier precipitation, erosion will increase in certain areas. Farmland with less vegetation cover and debris-covered areas on slopes in formerly glaciated Alpine valleys are particularly affected.
- *Reduction in slope stability:* As a consequence of melting glaciers, thawing permafrost and increasingly heavy precipitation, slope stability in the areas affected will decline. This will increase the risk of landslides, rockfalls and debris flows.
- *Reduction in soil moisture:* Long periods of drought have negative effects on vegetation. At the same time, there is less moisture in the soil to evaporate, and the cooling effect of evaporation – an important buffer in the event of heatwaves – is reduced[32].
- *Humus composition and decomposition, soil minerals:* Increasing temperatures speed up the decomposition of humus. As a result, storage, buffer and filter capacity of the soil declines. Depending on the altitude, vegetation can adapt to different climate conditions within a few decades. The spread of new plant species can lead to changes in the composition of humus and soil minerals.
- *Change in carbon storage capacity:* There are major uncertainties as regards the processes of carbon absorption in the soil and the carbon emissions from the soil. The higher carbon concentration in the atmosphere may (in the short term) lead to increased plant growth (CO_2 fertiliser effect). More organic carbon will find its way into deeper soil layers via expanding root systems. Carbon already stored in the soil will possibly be mobilised at an earlier stage due to the microbial decomposition that begins there. In general, due to higher temperatures, the activity of soil organisms in the decomposition of organic material and the related CO_2 emissions from the soil will increase[33].

Air

The effects of climate change on air quality are largely determined by trends in the relevant general weather situation (winds, radiation, cloud formation, rainfall levels and temperature). For Switzerland, estimates of these trends are still not precise enough to draw any clear conclusions.

A possible scenario is that stable high pressure systems could become more frequent in Central Europe as a consequence of climate change. These are a prerequisite for high pollutant concentrations in the air. In the summer, sunshine, high temperatures and stagnating air masses increase the chance of ozone forming. This means that high temperature periods such as those experienced in the summer of 2003 could occur more frequently. In the winter, in areas where there is less air flow, this could lead increasingly to stable weather inversion with high concentrations of particulate matter.

Biodiversity

Biodiversity may in some cases be irreversibly changed by climate change. The effects[34] can be summarised as follows:

- *Phenological changes:* Warming will shift the development phases in plants and change the rhythm of life of certain animals[35].
- *Change in interaction between species:* Phenological changes may disrupt the way in which certain interactions between species are coordinated, for example flowering time and the presence of pollinators, or predator-prey-relationships[36,37].
- *Changes in the range of individual species and populations:* Species that rely on a specific climate will if possible adapt their habitat to the changing climate. As a result of these shifts, local changes in species composition will occur: new species will appear, and certain indigenous species will become more common, while others will become rarer or disappear[38].
- *Extinction of species:* The continued existence of some species may be threatened by climate change if their range is reduced or lost entirely, or if the species cannot colonise new potential habitats due to limited dispersal potential, natural or anthropogenic barriers or changed competitive and feeding relationships.
- *Migration/introduction of new species:* As a consequence of climate change, new species may migrate to Switzerland from warmer countries or – if introduced by humans – they may establish themselves in this country. Some species may be regarded as an enrichment to the indigenous flora and fauna. But new species may also include invasive organisms that harm human or animal health or force out indigenous animal and plant species[39].
- *Harm to evolutionary processes through genetic impoverishment:* The climatic reduction and shifting of species ranges will cause habitats to fragment. This will adversely affect genetic exchange between populations and may lead to reduced genetic adaptability among species.
- *Harm to ecosystem performance:* The changes described could mean that certain functions of ecosystems are adversely affected and important functions that they have performed so far can no longer be provided to the same extent.

The direct and indirect effects of climate change may contribute to a reduction in the diversity of natural habitats and to changes in the characteristics of the landscape longer term.

A2.2.2 Climatic changes in socio-economic areas

Climate change (A2.1) and the consequences for natural systems (A2.2.1) will also have an effect on society and the economy. The following sections summarise the most important changes in the sectors concerned.

Water management

Climate-related changes in the hydrological cycle have an effect on all water management sectors. Water use is affected firstly by the slightly lower discharge levels (reductions in electricity production) and secondly by the possible increase in drought and low water in summer. Conflicts over use may arise in small and medium-sized catchment areas, especially as in summer there is a greater need for water for irrigation (agriculture) and process water (cooling water) purposes. Household water management is also affected: any shortages in water resources limit private drinking water supplies that are inadequately networked; wastewater treatment, which relies on adequate water flow in the receiving streams for discharging and diluting the treated wastewater, is adversely affected by low water levels. The increase in water temperatures raises questions of quality and places limits on water cooling, in particular in energy generation in thermal power stations. It will be a challenge for water protection systems to guarantee sufficient residual flow and sufficient water quality, particularly in the event of more frequent low water levels. A possible climate-related increase in flooding represents a further challenge for flood protection systems.

The expected changes will entail new requirements for lake regulation (lakes near the Alps) and for the management of Alpine reservoirs. Greater account will have to be taken of the interests of neighbouring countries over international waters.

Agriculture

The agricultural sector is directly exposed to progressive warming, changes in the water-cycle and soil characteristics as well as to the potential greater frequency and intensity of extreme events. An average temperature rise of 2 to 3 °C may help to make Swiss agriculture more productive, provided sufficient nutrients and water are available. The potential annual production of meadows will increase due to the longer growing season. The potential yield from many arable crops will also increase. Livestock production can benefit from cheaper domestic feedstuffs and a longer grazing period. Negative effects include a shortage of water due to an increase in evaporation from plants and the soil, while at the same time rainfall levels in summer fall and there is a greater prevalence of weeds and pests. An especially crucial factor is the potential greater frequency and intensity in extreme events. Stress due to heat, drought or moisture may cause a substantial reduction in yields, both in livestock husbandry and in crop production.[5, 26]

Forestry

Forestry is affected by climate change in several respects. In the coming decades, warming and a change in precipitation distribution will lead to major changes in the site conditions for forests. Extreme events, such as the Lothar winter storm in 1999 or the summer heatwave in 2003, cause enormous damage. With the expected increase in dry spells, the risk of forest fires will also rise. Furthermore, there will be damage caused by indirect factors such as the spread of harmful organisms. These changes also have direct effects on the timber processing industry and trade, for example due to forced usage and shifts in the supply of certain wood species.

Restrictions, reductions or at least temporary absences can be expected in relation to many of the functions of forests (e.g. their protective function) and forest products, while positive developments, such as additional wood growth or a rising tree line, will occur only gradually.

Energy generation and energy demand

Climate change will have an influence on both energy demand and energy generation. The increase in temperatures will mean that in future, less energy will be consumed for heating in winter and more will be needed for cooling in summer. There will be a shift in demand from heating fuels to electricity.

As far as hydroelectric power production is concerned, only minor changes are expected in the near future (2035). In the long-term (2085), however, due to the fall in water discharge, an average decline in production of between 4 and 8 per cent must be expected[40]. Due to higher water temperatures, nuclear power plants will not be able to obtain the same cooling effect from the rivers. On the other hand, new renewable energies could benefit from climate change. For example the potential steady decrease in the number of foggy days would have a positive effect on solar energy production. The influence of climate change on wind speeds and wind energy potential is unclear[26].

Tourism

Climate change brings both opportunities and risks for the tourist industry. Generally, in most regions the opportunities should outweigh the risks. Tourist destinations in mountain regions are particularly affected by climate change. In the Alpine foothills there will be less certainty of snow in the winter and low-lying ski resorts will not have enough snow to keep operations going without the constant production of artificial snow. In higher regions, climate change will have an effect on glaciers, the permafrost and possibly the risk of avalanches, meaning that additional safety measures and alterations to existing infrastructures will be required.

In the summer months, the Alpine region could become an attractive alternative to hot and dry holiday destinations in the Mediterranean. Due to the melting glaciers, however, the beauty of the mountain landscapes will decline. Swiss cities could well become more attractive as tourist destinations thanks to a certain "Mediterraneanisation".

Residential areas, buildings, transport systems and infrastructure

Residential areas, buildings, transport systems and infrastructure will be affected by climate-related changes in natural hazards.

In the Alps, the increase in mass wasting and flooding will pose a safety risk to residential areas, passenger and goods transport by road and rail, and gas and power cables. Dams could also be affected.

In lower-lying regions, the potential increase in flooding may lead to new risks for residential areas, buildings, traffic routes and infrastructure. In general, residential systems with large sealed surfaces are particularly vulnerable to heatwaves and floods, as they absorb much of the radiation and prevent infiltration. In the event of more frequent summer drought, there may be problems for buildings, transport infrastructure and underground pipes and cables as the ground shrinks.

Health

Changes in temperature extremes have a direct effect on public health. Higher maximum temperatures, more hot days and heatwaves lead to higher mortality rates, above all among the elderly and infirm, due to heat stress and cardiovascular and respiratory complaints[41]. Work productivity falls during heatwaves[42].

Public health will be indirectly affected by changes in the spread of pathogens, pollutants and allergens and by changes in the frequency and intensity of natural phenomena. Higher temperatures bring higher ozone and pollen concentrations, causing asthma and other acute and chronic respiratory conditions. In addition, foodstuffs deteriorate more quickly at higher temperatures, which will increase the probability of cases of food poisoning. Fewer cold days, frosty days and cold spells will favour the spread and activity of some indigenous disease vectors (e.g. ticks) and the occurrence of new ones (e.g. tiger mosquitoes).

Glossary

The most important technical terms in the fields of climate change and adaptation used in the first part of the adaptation strategy are explained below. Unless otherwise indicated, the IPCC definitions are used[43].

Adaptation
Initiatives and measures to reduce the vulnerability of natural and human systems to the actual or expected effects of climate change.

Adaptive capacity
The whole of capabilities, resources and institutions of a country or region to implement effective adaptation measures.

Climate change
Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.

Climate model
A numerical representation of the climate system based on the physical, chemical, and biological properties of its components, their interactions and feedback processes. Climate models are applied, as a research tool, to study and simulate the climate, but also for operational purposes, including monthly, seasonal and interannual climate predictions.

Climate scenario
A plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships, that has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change, often serving as an input to impact models.

Climate variability
Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).

Extreme event (= extreme weather event)
An event that is rare within its statistical reference distribution at a particular place. Definitions of "rare" vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile. Individual extreme events cannot simply be attributed directly to the anthropogenic climate, as there is always a limited chance that the event in question could have occurred naturally.

Heatwave
Extreme warming event with air temperatures over 30 °C that lasts for several days[44]. (PLANAT)

Resilience
The ability of a social or ecological system to react to disruption and maintain its structure and mode of operation, the ability to organise itself and to adapt to stresses and changes.

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