Climate Change in Baden-Württemberg

Facts – Impacts – Perspectives

LUBW

Baden-Württemberg

MINISTRY OF THE ENVIRONMENT, CLIMATE PROTECTION

AND THE ENERGY SECTOR

Contents

Our climate

Everyone is talking about the nature and impact of climate change. Most people are aware that climate change is a global problem which will pose a huge challenge to the world community in the course of this century. Far fewer people realise that the regional effects of climate change will also be felt in Germany as well as by all of us here in Baden-Württemberg.

What specific impact has climate change already had in Baden-Württemberg or will it have in the future? What regions of our country and what aspects of our society will be directly affected and to what extent?

These are the questions which this climate booklet is intended to address.

The State of Baden-Württemberg began studying climate change and its consequences at a very early stage and launched a collaborative project with the Free State of Bavaria and the German Meteorological Service on climate change and the consequences for water management (KLIWA) back in 1999. The objective of KLIWA is to enhance our understanding of the potential impact of climate change on the regional water balance in the period 2021 to 2050 and to use the findings to develop correspondingly adaptive water management measures.

The "Climate change – impacts, risks, adaptation" (KLARA) study investigated areas other than water management in 2001 and the research programme on the Challenge of Climate Change in Baden-Württemberg was performed from 2006 to 2010. In 2006 Baden-Württemberg published the Baden-Württemberg climate atlas, which describes the climate and changing weather patterns over a 30-year period from 1971 through to 2000. Various aspects of climate change were also studied as part of the natural resources and environment safeguard programme (BWPLUS) research plan and in projects undertaken by the State Institute for Environment, Measurement and Nature Conservation (LUBW). The current research programme on climate change and the modelling of adaptation strategies in Baden-Württemberg (KLIMOPASS) were launched in 2011. Both basic and applied research projects will be undertaken in the framework of this programme. With KLIMOPASS the State Government is pursuing its aim of promoting research into the regional impact of climate change and of closing gaps in current knowledge. The next step will be for researchers to deliver an even more detailed description of the regional and local scale and impact of climate change and to reduce uncertainties further.

These many different activities are the focus of this climate booklet. They enable us to make fairly accurate predictions today about regional climate change and its likely impact in Baden-Württemberg. They also make it possible to identify areas in which adaptive measures may be required.

The findings show that climate change is already a reality. Intensive climate change mitigation measures are necessary in order to limit the extent of climate change and reduce it to manageable proportions. However, it is now clear that coping with the effects of climate change will demand a major commitment of resources. The summary of the latest state of knowledge about climate change in Baden-Württemberg provided in this booklet is an important contribution to this endeavour, particularly in terms of informing the people who live in Baden-Württemberg. The Cabinet has also decided to draw up a strategy for adaptation to the unavoidable consequences of climate change for Baden-Württemberg. This strategy will be substantially based on currently available scientific evidence.

Franz Untersteller
Minister of the Environment,
Climate Protection and the Energy Sector

Global climate change

The temperature is going up and up

Average global temperatures increased by around 0.7°C between 1900 and 2005; about 0.6°C of this increase has occurred in the last 50 years. Temperatures in northern Europe may even rise by more than 6°C by the year 2100.

The United Nations and the World Meteorological Organization (WMO) established the Intergovernmental Panel on Climate Change (IPCC) in 1988 to investigate the threat of climate change. In its most recent report, issued in 2007, the IPCC concluded that climate change may take on more dramatic proportions than previously assumed. The IPCC found that, in the last 50 years alone, global temperatures rose almost twice as fast as in the previous hundred years. Numerous climate models show that if current CO_2 emission levels persist average temperatures will rise even further. While wide-ranging climate change mitigation policies adopted in Germany, Europe and many other countries have already reduced emissions in a number of areas, these have not been enough to compensate for overall increases in global emissions. Current mitigation policy efforts are not enough to stop climate change in the decades ahead. Because the climate system is sluggish, temperatures would continue to rise even if emissions were eliminated entirely and immediately. More needs to be done given that in many countries the effects of global warming will alter and in some cases threaten the natural resources on which life itself depends as well as the continued existence of many plants and animals.

TODAY'S CLIMATE

Greenhouses gases, such as carbon dioxide and water vapour, warm the earth by absorbing heat which would otherwise be radiated by the planet back into space. The more of these gases there are in the atmosphere, the thicker the greenhouse "glass" around the earth becomes.

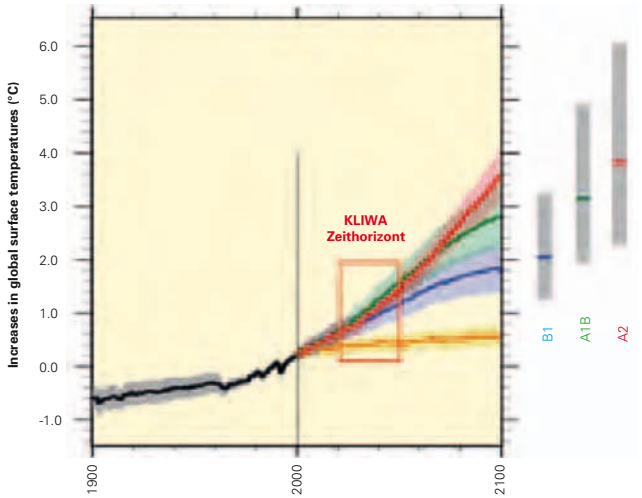
In its 2007 report the IPCC concluded that global greenhouse gas emissions have increased continuously since the late eighteenth century. The largest increase occurred between 1970 and 2004. Pre-industrial CO_2 concentrations in the atmosphere were relatively constant at around 280 ppm (parts per million). The combustion of fossil fuels (coal, oil and gas) is continuing to push these values and average temperatures upwards.

Since the turn of the century in 1900 almost all measurements show a worldwide rise in temperature of 0.7°C. Extreme weather is also a growing problem. In 2003 the whole of Europe suffered for a number of weeks from a heat wave in which temperatures went up to 40°C. Mean global temperatures of 12.7°C in January 2007 were the highest ever measured for this month. Globally, 2009 was the second warmest year since 1880, and Germany was no exception: the previous decade was the warmest in 130 years. Since the turn of the century in 1900 almost all measurements show a worldwide rise in temperature of 0.7°C. Extreme weather is also a growing problem. In 2003 the whole of Europe suffered for a number of weeks from a heat wave in which temperatures went up to 40°C. Mean global temperatures of 12.7°C in January 2007 were the highest ever measured for this month. Globally, 2009 was the second warmest year since 1880, and Germany was no exception: the previous decade was the warmest in 130 years.

TOMORROW'S CLIMATE

IPCC climate models are carefully evaluated against extensive historical records. The IPCC assesses current atmospheric CO_2 concentration at just below 400 ppm – an increase of about 30 per cent since the year 1750. The IPCC and the Federal Government's Advisory Council on Global Change (WBGU) calculate that CO_2 concentrations of over 450 ppm would push up average global temperatures by more than 2°C. Ultimately, reducing greenhouse gases will be essential. While climate models may not be crystal balls, they do enable us to estimate future changes. These models make future projections in scenarios which combine meteorological computer models with different assumptions about population growth, economic development, the use of resource-efficient technologies and greenhouse gas emissions. All the calculations used in the IPCC scenarios point towards further rises in temperature in the future.

INCREASES IN GLOBAL SURFACE TEMPERATURES (1900–2100)

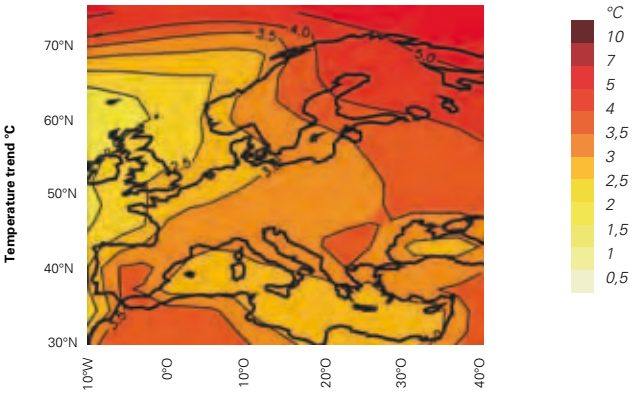


Model-based projections derived from emission scenarios developed by the Intergovernmental Panel on Climate Change (IPCC) reveal the potential global warming trends on our planet.

- *Scenario with regionally oriented economic development (A2)*
- *Scenario with high economic growth based on a balance across fossil and non-fossil energy sources (A1B)*
- *Globally sustainable economic development (B1)*
- *Constant year 2000 concentration*
- *20th century*

Source: IPCC 2007: AR4-WGI

TEMPERATURE CHANGE IN EUROPE (2080–2099)



Simulated temperature changes for the late 21st century (2080–2099) compared with the period 1980–1999. The simulation is based on emission scenario A1B.

Source: IPCC 2007: AR4-WGI

Climate Change 2007: The Physical Science Basis. Working Group I Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Figure 11.5. Cambridge University Press

Regional climate change

Climate change in Baden-Württemberg

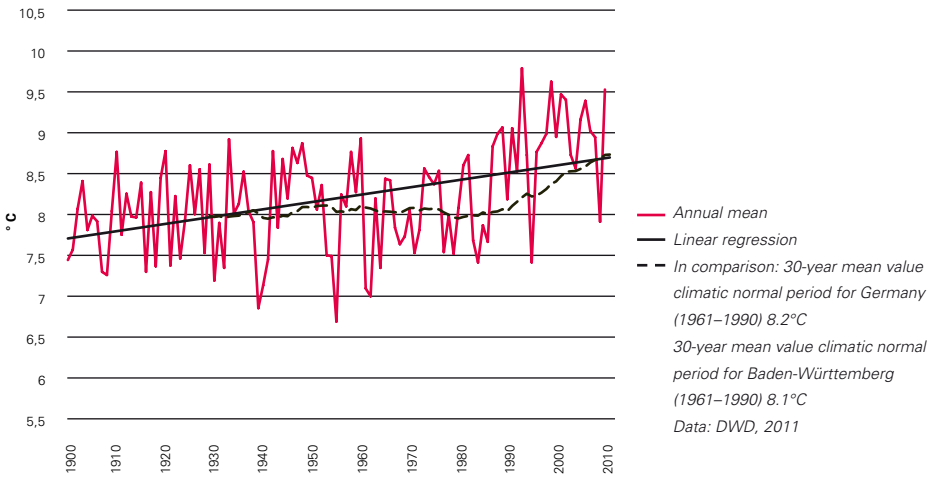
Baden-Württemberg will not be spared the effects of climate change: in fact temperatures have already risen noticeably, particularly in winter. This trend will become stronger – with all the consequences.

The State of Baden-Württemberg is already experiencing the impact of changes in the climate which will very likely accelerate even further in the future. Thanks to the KLIWA (Climate change and the consequences for water management), KLARA (Climate change – impacts, risks, adaptation) and the Challenge of Climate Change in Baden-Württemberg research programmes financed by the state, a great deal of data is already available. Over 250 meteorological stations and around 40 stream gauges have already been evaluated for KLIWA alone. As well as collecting data, scenarios of future developments in Baden-Wurttemberg have also been produced. The findings show that the mean temperature in Baden-Württemberg rose significantly in the course of the 20th century. Temperatures will also continue to rise in the future – with all the effects on the weather, flora, fauna and human beings which this entails. The first decade of the new millennium was the warmest in Germany for at least 130 years. Mean temperatures in Baden-Württemberg have risen by over 1°C compared with around 0.7°C worldwide (IPCC comparison period 1906–2005).

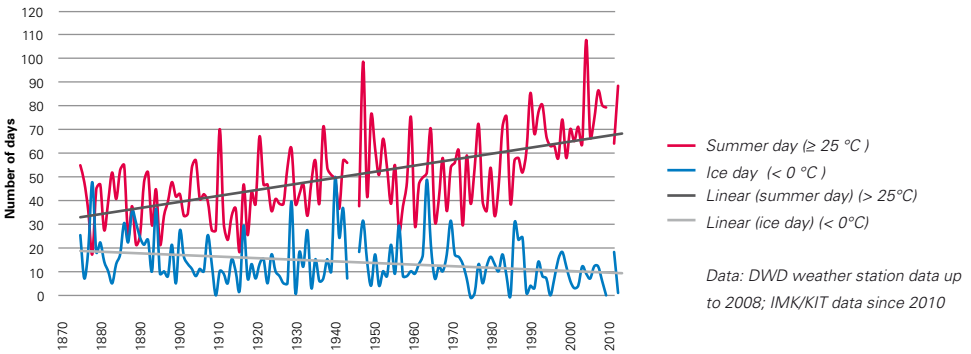
CLIMATE CHANGE NOW

Climate change is well underway in Baden-Württemberg. The mean annual temperature has risen from 1901 to the present day from around 8°C to over 9°C. The biggest increase has taken place over the last 30 years since 1980. One example illustrates the effects of this apparently minor change. Temperatures in Karlsruhe are now the same as they were in Lyon, France 75 years ago. Over the last 30 years maximum winter precipitation levels have risen by 35 per cent, as have the number of flood events. On the other hand, summers tend to be drier than in the past. The number of days on which lower-lying areas are covered in snow has decreased by an average of 30 to 40 per cent. Evaluations by the State Institute for Environment, Measurement and Nature Conservation (LUBW) of measurements taken over a period of many years at selected meteorological stations in Baden-Württemberg also confirm the climate change trends. In 1953, for example, Stuttgart still had 25 ice days (on which temperatures remained below 0°C) and an equal number of summer days (highest temperature of at least 25°C). By 2009 the number of summer days in Stuttgart had risen to 45, while the number of ice days had fallen to just 15.

MEAN ANNUAL TEMPERATURE IN BADEN-WÜRTTEMBERG (1901–2011)



ANNUAL NUMBER OF SUMMER AND ICE DAYS IN KARLSRUHE (1878–2011)



CLIMATE CHANGE IN THE FUTURE

Calculations based on all the climate scenarios for Baden-Württemberg show that temperatures will continue to rise up to the year 2050 by 0.8 to 1.7°C. Hot days (on which temperatures are at least 30°C) will occur at least twice as frequently. At the same time there will be a substantial reduction in the number of frost and ice days.

The Rhine Plain will be affected particularly severely. The number of summer days in Karlsruhe, for example, will increase from just under 60 now to over 80 days by the middle of the century. Winter precipitation will increase by up to 35 per cent in some regions. This will be accompanied by an increased risk of flooding.

In the case of the Neckar, for example, studies show that, up to the year 2050, the most dramatic floods could involve a 15 per cent higher volume of water than has been the case to date. This means that new flood protection schemes need to be built on a much larger scale or existing works upgraded to meet requirements. The number of violent thunderstorms is also projected to increase and consequently to threaten smaller rivers and streams with flooding. Overall, there are likely to be more and longer periods of drought during the summer months.

Looking to the future

Predicting the future with climate simulations

Global climate models are not capable of forecasting climatic impact at the local level. Higher resolution simulations can reduce uncertainty and offer higher quality data.

The Institute for Meteorology and Climate Research at the Karlsruhe Institute for Technology (KIT) has performed a series of regional climate simulations for the recent past (1971 to 2000) and the future (2011 to 2040) as part of the Challenge of Climate Change in Baden-Württemberg research programme. In this context researchers used the COSMO-CLM regional climate model, with a seven kilometre resolution, for the first time. Compared with other climate models this enables much better regional forecasts to be made. Although models of this type only describe hypothetical future scenarios, they do enable the responsible local authorities or district offices to assess much more accurately the kind of impact they can expect climate change to have in their areas. This also means that it is possible to consider and plan possible adaptation strategies, such as flood protection measures, with much greater precision.

Fire fighters building a flood barrier

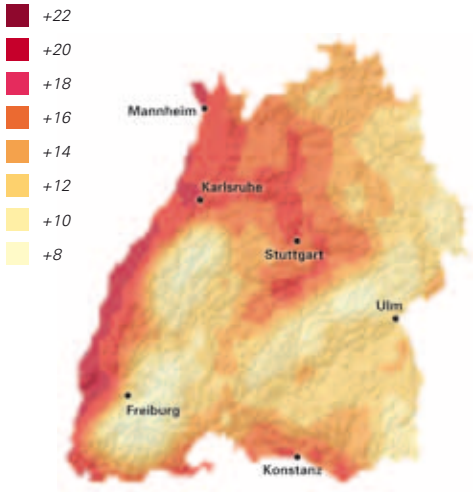
WARM SUMMERS, MILD WINTERS

From 1971 to 2000 the Rhine Valley had 50 summer days a year, while the middle and higher ranges of the Black Forest and the Swabian Alb experienced just 10 summer days.

In the future (2011 to 2040) the number of summer days (maximum temperatures of at least 25°C) will increase, albeit at different rates according to region. The number of summer days in the Rhine and Neckar Valleys as well as Lake Constance will increase by 15 to 20 days a year; in higher-lying areas by just under 10 days. While this means an increase of "just" 40 per cent for the Rhine Valley, these figures imply twice as many summer days in parts of the Black Forest and the Swabian Alb. What is more, the KLARA research programme shows that some of the lower-lying areas of Baden-Württemberg in particular, such as the Upper Rhine Valley, will have up to 15 more hot days (maximum temperatures of at least 30°C) in the period 2046 to 2055 than they did between 1951 and 2000.

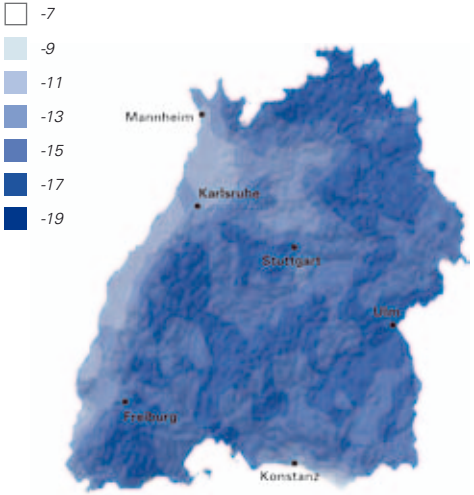
A similar picture – in reverse – emerges for frost days: to date the medium and higher altitudes of southern Germany's low mountain ranges experienced over 120 frost days (lowest temperatures of under 0°C) in the period 1971 to 2000 compared with less than 80 days in the Rhine Valley. In the period 2011 to 2040 global warming will reduce the number of frost days by around 10 days a year in the Rhine and Neckar Valleys as well as around Lake Constance and by around 15 to 20 frost days in higher areas. In relative terms the fall will be more dramatic in lower-lying areas which already experienced fewer frost days in the past.

NUMBER OF SUMMER DAYS



Change in the number of summer days (≥25°C), 1971–2000 and 2011–2040. Source: IMK-TRO/KIT, 2010

NUMBER OF FROST DAYS

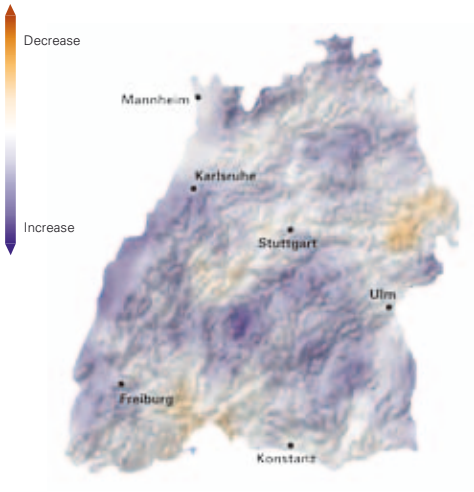


Change in the number of frost days, 1971–2000 and 2011–2040. Source: IMK-TRO/KIT, 2010

LESS FREQUENT BUT HEAVIER RAINFALL

The Karlsruhe Institute of Technology (KIT) has also studied the probability of an increase in heavy rainfall in Baden-Württemberg in the future. In order to make predictions with more confidence the KIT has developed the world's first high resolution ensemble method by performing and statistically evaluating a series of simulations which use different boundary conditions. The findings reveal that flooding following heavy rainfall, landslides or erosion poses a real danger in low mountain ranges in particular. The map shows that, in the future, there is a greater probability of some regions of Baden-Württemberg being hit by more frequent and more intensive heavy precipitation (blue areas) during the summer months. Precipitation levels will remain unchanged in some areas and will decrease in only a very few. The climate simulations suggest that while the total amount of precipitation will remain much the same throughout the course of the year, the incidence of rainfall will be distributed differently. Years with particularly wet and dry periods will become more probable in the future. Overall there will be an increase in extreme weather events in Baden-Württemberg.

HEAVY RAINFALL IN THE SUMMER



Probability of decrease or increase in heavy summer rainfall in the period 2011–2040 compared with the period 1971–2000. Source: IMK-TRO/KIT, 2010

Extreme events

Heavy storms and more frequent hail

Extreme weather events can cause serious damage. Will there be more frequent and intense storms, hail and thunderstorms in the future?

There is still no conclusive proof that the increase in the frequency of extreme weather events is linked to climate change. However, there have been far more severe winter storms over the last 20 years which have also hit Baden-Württemberg. Examples include the winter storms Daria (1990), Vivian and Wiebke (1990), Lothar (1999), Kyrill (2007) and most recently Xynthia (2010). Gust speeds during these storms reached 150 km/h in lower areas and over 200 km/h in regions with low mountain ranges.

An evaluation performed at various meteorological stations in Baden-Württemberg has shown that gust speeds at valley stations have risen somewhat in the past in contrast to speeds measured at mountain stations. The frequency and intensity of hailstorms have also increased. Building insurance data for Baden-Württemberg show that there was a substantial rise in insurance claims between 1986 and 2008. The number of days on which claims for hail damage were made rose from around 10 a year in the 1980s to 20 days a year in the 1990s and is now between 30 and 40 days. The economic and social benefits associated with improved knowledge about potential changes in the frequency and intensity of extreme events are substantial.

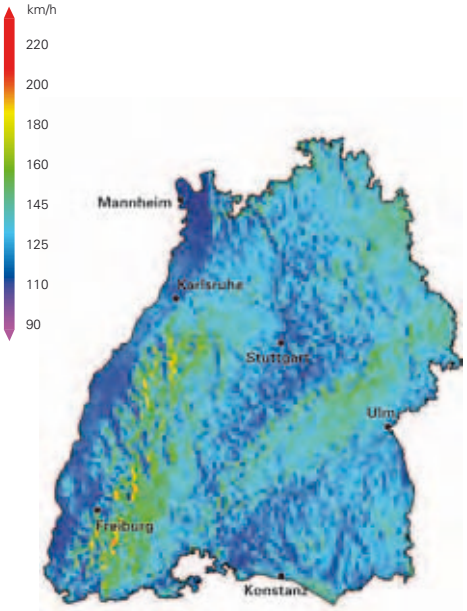
THE COSTS OF HAIL AND STORMS

Severe hailstorms can cause massive damage to buildings, vehicles and fields. In Baden-Württemberg hail is responsible for almost 40 per cent (approximately 50 million euros) of all damages to buildings caused by natural events. The total costs of one-off winter storms are even higher. According to figures produced by reinsurers Munich Re, the damage caused by the hurricane-force storm Lothar alone totalled 8.64 billion euros for southern Germany, northern France, Switzerland and Austria. Half of these damages were insured. Storms with high winds generate disproportionately high costs.

Research undertaken by the interdisciplinary Center for Disaster Management and Risk Reduction Technology (CEDIM) shows that a storm with wind speeds just 10 per cent faster than those recorded during Lothar would cause three times more damage. Studies suggest that the storm climate will not change significantly in Baden-Württemberg by 2050. However, we should continue to expect storms of similar severity to that of Lothar in the future. Higher temperatures and humidity exacerbate the potential for thunder and hailstorms.

More thunderstorms and heavy rain

STORM HAZARD MAP



The map shows the areas in Baden-Württemberg which are threatened by storm. Source: Heneka et al., Nat. Hazards Earth Syst. Sci., 2006; Hofherr and Kunz, Clim. Res., 2010

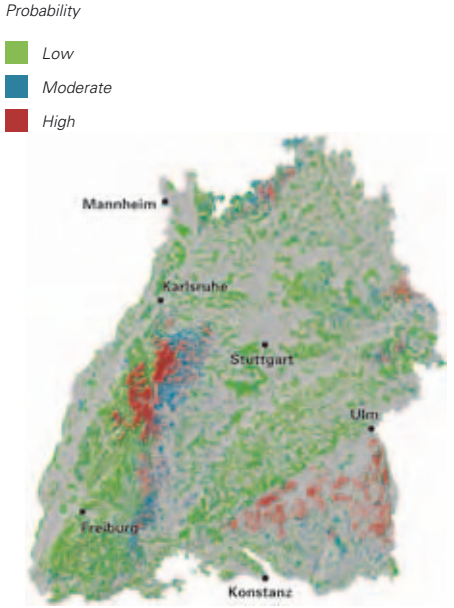
WHERE WILL DANGEROUS WINDS BLOW?

The storm hazard map shows the wind speeds which can be expected on average every 50 years. High wind speeds tend to be most frequent at higher altitudes and over terrain with highly structured surfaces, such as the Black Forest or the Swabian Alb. However, there is only a risk of damage where there are vulnerable buildings or trees susceptible to wind breakage.

The RESTER (Strategies to Reduce the Storm Risk of Forests) joint research project has examined large areas of tree damage in the forests of Baden-Wurttemberg resulting from the winter storms Wiebke (1990) and Lothar (1999) to calculate storm damage probabilities for Baden-Württemberg's entire forest area. Assuming a maximum gust speed of over 126 km/h, storm damages are most probable in areas of coniferous forest at highly exposed locations with wetdry soils on new red sandstone. Areas which are threatened by storm include the mountain ridges of the northern Black Forest and the eastern parts of the Odenwald range.

Forest damage following the winter storm Lothar in 1999.

STORM DAMAGES IN FORESTS



Susceptibility of forests to damage in Baden-Württemberg based on the winter storms Wiebke and Lothar. Source: Meteorological Institute, University of Freiburg

Human health

The human health risks of climate change

More heat waves and sultrier weather are particularly stressful for the elderly. Climate change may also bring new diseases and allergy-producing plants with it.

Up to now we have been very lucky here in Baden-Württemberg. According to the State Statistical Office the population of Baden-Württemberg has a very high life expectancy. On average women live to the age of 83.3 and men to 78.6. This means that life expectancy in Baden-Württemberg is among the highest in the EU.

However, studies undertaken by the Intergovernmental Panel on Climate Change (2007) as well as the findings of the KLARA and KLIWA studies do show that people living in central Europe will have to contend with even hotter days and longer heat waves in the future. This is particularly true of south-west Germany. As Baden-Württemberg becomes hotter more people may become ill and die earlier than at present. In order to produce more precise figures on this risk the KLARA research project has also investigated the impact of climate change on temperature-related mortality in Baden-Württemberg.

Our health may soon be threatened by disease-carriers from warmer climes. Ticks are becoming more prevalent. New species of fauna and flora are migrating. In the worst possible case we may even have to cope with tropical diseases such as chikungunya and dengue fever.

FACTS

sheep tick (Dermacentor marginatus) is complicit in the spread of Q fever, a serious infectious bacterial disease. The Q fever pathogen is first transmitted by ticks to livestock, such as cows, sheep and goats, and can infect humans who inhale contaminated dust. In the future we must expect an increase in tick-borne infections such as Mediterranean spotted fever.

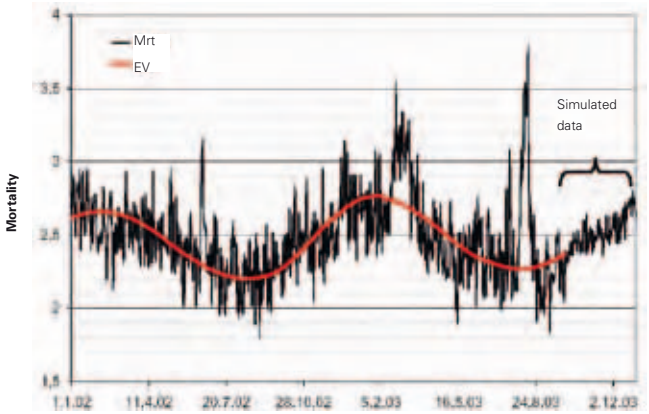
Common ragweed (Ambrosia artemisiifolia), a strong allergen, is also spreading rapidly, particularly in the Upper Rhine region and in and around Stuttgart. Concentrations of Ambrosia pollen are still fairly low. However additional wind-dispersed pollen from France may cause problems for people with allergies.

HEAT AND DANGEROUS ORGANISMS

Human beings prefer a balanced climate. During the extremely hot summer of 2003 around 2000 mainly elderly and infirm people in Baden-Württemberg died as a result of the heat! The causes of these deaths included heart attacks, cardiovascular disease, kidney diseases, respiratory diseases and metabolic disorders.

The number and proliferation of organisms which may transmit or cause disease increase as average temperatures rise. In 2008, sand flies were shown to have colonised nine new locations in Baden-Württemberg, for example. These blood-sucking insects are known to be potential vectors of the tropical parasitical infection leishmaniasis, which to date has only been encountered in Mediterranean areas of Europe. Ticks which can transfer lyme borreliosis or TBE (tick-borne encephalitis) are already very common in Baden-Württemberg. The

TOTAL MORTALITY PER 100,000 INHABITANTS, 2002–2003



Total mortality in Baden-Württemberg, 2002–2003 (mortality: statistically registered; EV: expected value)
Source: Potsdam Institute for Climate Impact Research (PIK), 2005: KLARA

OPPORTUNITIES AND RISKS FOR HEALTH

OPPORTUNITIES

- Fewer days with cold stress
- Decreased cold-related morbidity and mortality

RISKS

- More days with heat stress
- Increased heat-related mortality
- New and more infectious diseases
- New allergy-producing plants
- Fall in labour productivity during heat waves

IMPACT/ PERSPECTIVES

MORE HEAT-RELATED DEATHS IN BADEN-WÜRTTEMBERG

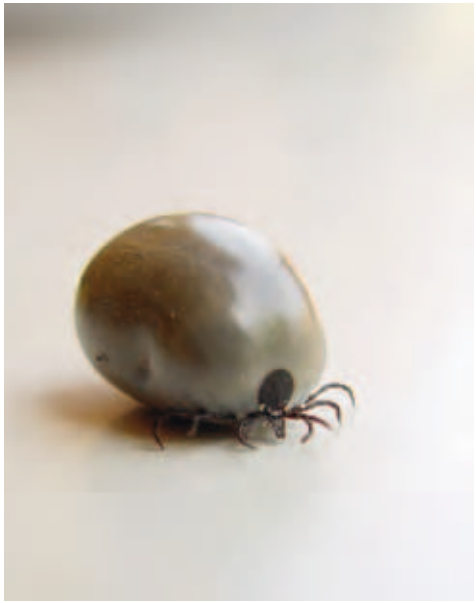
Researchers at the Potsdam Institute for Climate Impact Research working on the KLARA project have assessed how many people in Baden-Württemberg may die as a result of the health effects of climate change. They have done this by comparing the estimated weather-related deaths in an underlying scenario (1951–2000) with those in a second climate scenario (2046–2055). These two scenarios show that there will be a substantial increase in the number of days causing heat stress at all altitudes up to the year 2055. This will be accompanied in most districts by a fall in the number of days inducing cold stress, although not by the same degree as the increase in the number of hot days.

Researchers have also drawn on mortality data to determine how sensitively the population reacts to heat and cold stress. The findings show that people over 75 are particularly sensitive. By multiplying the number of people in this age group with the frequency of thermal stress it is possible to derive the vulnerability of the population to hot or cold stress. As the population of Baden-Württemberg is becoming increasingly older, the vulnerability of the population will increase by an average of 20 per cent. This means that by 2055 an additional 180 to 400 additional heat-related deaths may be expected to occur throughout Baden-Württemberg unless adaptation measures are taken. This increase will not be compensated for by the positive effects of fewer days of cold stress.

LEARNING FROM EXTREME EVENTS

Bearing these developments and the lessons learned from the extreme year 2003 in mind, adaptation measures must be taken as a matter of urgency. The first step has been taken by setting up a heat/health warning system which notifies around 1,400 nursing homes in Baden-Württemberg alone about the imminent arrival of extreme weather events. In the long term town planners and architects will have to plan and build climate-adapted urban settlements and buildings.

We will probably suffer from more infectious diseases as well as heat in the future. Disease-bearing ticks are becoming more prevalent. Tropical and subtropical pests such as the Asian tiger mosquito may also spread diseases such as chikungunya and dengue fever in Baden-Württemberg. In order to assess future infection risks it is extremely important that the distribution and development of vector populations and pathogens are recorded. Action must also be taken to combat the spread of common ragweed, which was mainly introduced to Baden-Württemberg in contaminated bird food and which is able to profit from the favourable climatic conditions here. The widespread proliferation of invasive species such as these can only be suppressed at a very early stage.



An engorged tick

THE IMPACT OF THERMAL STRESS ON THE HUMAN BODY

Class	Perceived temperature °C	Thermal perception	Thermophysiological stress
- 4	< - 39	Very cold	Extreme cold stress
- 3	- 26 to - 39	Cold	Strong cold stress
- 2	- 13 to - 26	Cool	Moderate cold stress
- 1	0 to - 13	Slightly cool	Slight cold stress
0	0 to + 20	Comfortable	Comfort possible
1	+ 20 to + 26	Slightly warm	Slight heat load
2	+ 26 to + 32	Warm	Moderate heat load
3	+ 32 to +38	Hot	Strong heat load
4	> + 38	Very hot	Extreme heat load

Thermal stress classes based on a perceived temperature which takes account of physiological strain on the human organism (based on Association of German Engineers [VDI], 1998). Source: Potsdam Institute for Climate Impact Research (PIK), 2005: KLARA

REGIONAL IMPACT

THE HIGHER UP YOU LIVE, THE BETTER

The scenarios show that in the lower-lying and consequently warmer parts of Baden-Württemberg more people may die as a result of the heat-related effects of climate change than in higher areas. At altitudes of between 0 and 400 metres an average of 2.4 to 3.6 additional heat-related deaths may be expected per 100,000 inhabitants every year. The lower-lying regions of northern Baden-Wurttemberg and the districts of Emmendingen and Freiburg may be expected to be hit particularly harshly. At altitudes of between 400 and 800 metres an average of 1.6 to 2.4 additional deaths per 100,000 inhabitants may be expected every year – a somewhat better figure than in the lower-lying regions. In the scenarios presented here the fewest additional deaths may be expected upwards of 800 metres – a "mere" 1.6 to 2 deaths per 100,000 inhabitants. These projections only apply, however, if no adaptation measures are taken.

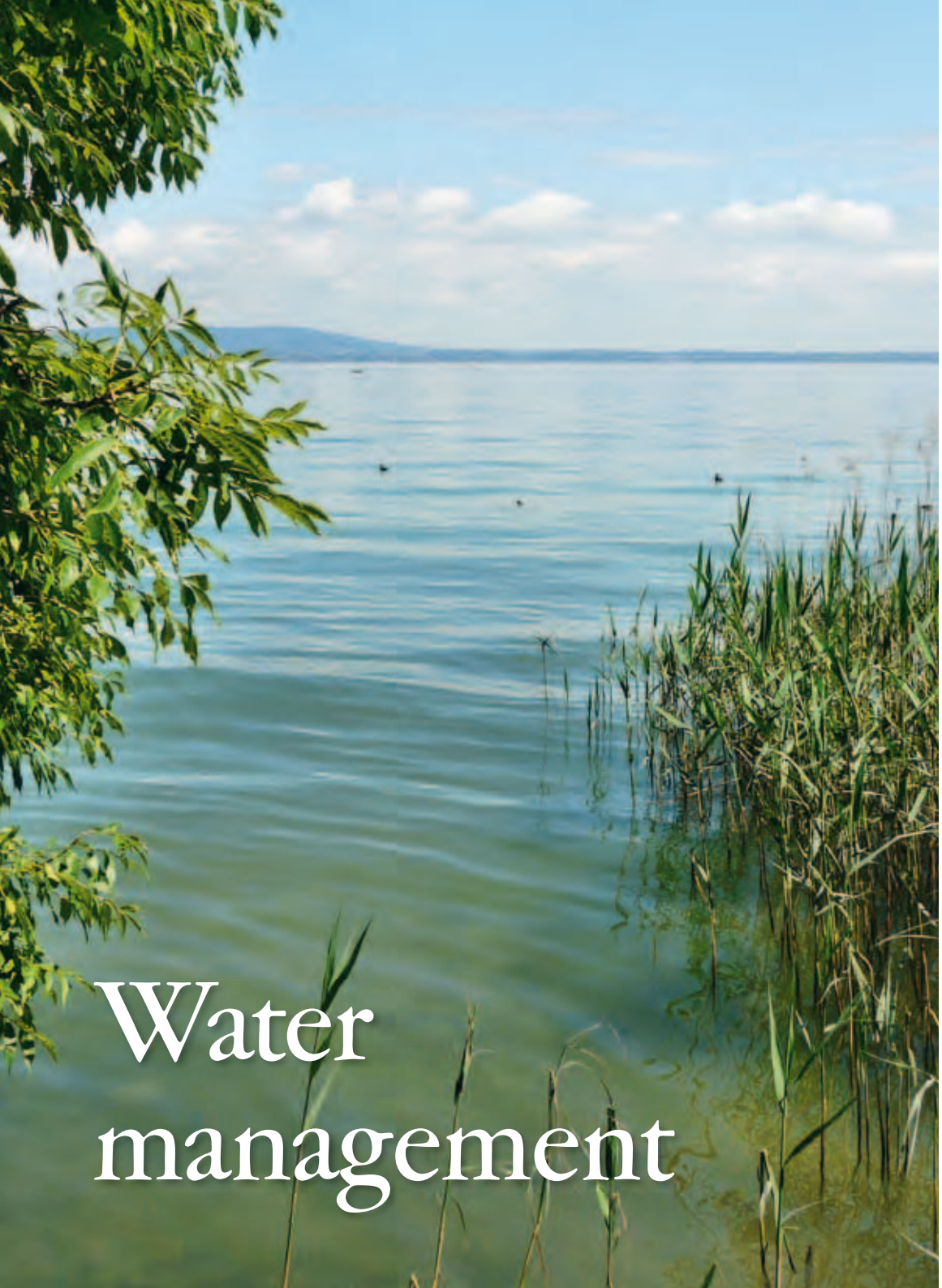
RAGWEED GAINS GROUND IN THE WEST

Surveys and evaluations undertaken by the ragweed unit at the State Institute for Environment and Nature Conservation (LUBW) show that there are three regions in which the allergy-causing Ambrosia artemisiifolia occurs more frequently. Stands of several tens of thousands of plants can be found between Rastatt and Mannheim in particular, as well as in and around Freiburg and Stuttgart.

The allergy-producing ragweed plant is spreading

MAP SHOWING THE SPREAD OF COMMON RAGWEED

Abundance 2009. Source: State Institute for Environment and Nature Conservation (LUBW)



Water management

Low water levels in summer, flooding in winter

First the good news: our groundwater will continue to supply us with drinking water for a long time to come. Nonetheless, climate change will have a tangible effect on the water balance.

Baden-Württemberg is well endowed with groundwater and will continue to be so in the future. Climate scientists do not believe that there will be any major change in the volume of annual rainfall. What will change, however, is the distribution of precipitation. The summers are already drier and winters wetter than in the past. This is due to the increased prevalence of westerly weather patterns and associated rainfall during the winter months. This is also the reason for the more frequent occurrence of flooding in the last 30 years.

Changes in the water balance not only have an immediate impact on the way water is used directly as drinking water and for agricultural irrigation, or indirectly as a coolant for power stations and a medium for transport by ship, they also influence the ecological status of bodies of water themselves and of water quality.

Baden-Württemberg is a partner in the KLIWA (climate change and the consequences for water management) collaborative project. The objective of KLIWA is to study the consequences of potential climate change on the water balance of particular river basins, to identify - impacts and make recommendations for water resource planning.

FACTS

INCREASING FREQUENCY OF EXTREME WATER LEVELS

The climate simulations performed in the framework of the KLIWA project show that by 2050 temperatures may have increased by 0.8 to 1.7°C. Thermometers may even measure increases in temperature of up to 2°C in the months from December to February. This means that more of the abundant precipitation brought by weather patterns from the west will fall as rain rather than snow. As a result rivers will probably burst their banks more often.

While some regions can expect up to 35 per cent more precipitation in the winter, water levels will fall in summers, which are expected to be up to 10 per cent drier. The probability of a very dry growing season has increased six fold since 1985.

However, it is not just inland navigation which suffers from low water levels. Agriculture and the energy industry also struggle with the effects of dry periods. The economic costs of the hot and dry summer 2003 were higher than those for the catastrophic floods along the Rhine, Oder and Elbe. Drought periods affect much larger stretches of land – and consequently the water balance as well as flora and fauna – for much longer periods of time than do floods.

Danube flood in Riedlingen in 1990.

Low water level on the River Murg in 2006.

OPPORTUNITIES AND RISKS FOR WATER MANAGEMENT

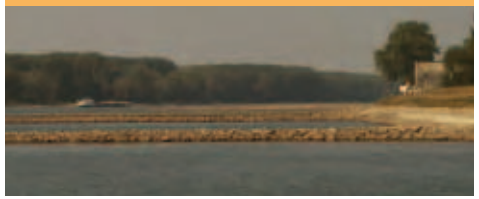
OPPORTUNITIES

- Baden-Württemberg continues to have plentiful groundwater

RISKS

- Damage caused by more floods
- Higher flood protection costs
- Low water levels impede inland navigation
- Water shortages can result in a lack of cooling water for nuclear and conventional power stations

IMPACT/ PERSPECTIVES



ONE FACTOR IN CLIMATE CHANGE

Flood barriers are often built on a scale designed to cope with exceptionally severe floods which, statistically, only occur about once a century. High-resolution climate models show that the levels of almost all rivers rise owing to flood discharges in winter. This is taken into account in the dimensioning of new flood barriers. The impact of climate change is taken into account in calculations in the form of a climate change load condition. In the event of a "once-in-a-century" flood in the period up to 2050, for example, around 15 per cent more water would flow along the Neckar. This water flow volume is calculated into the dimensioning of new building structures with the factor 1.15. Bridges will also be built on a much larger scale if required and dams and embankments planned in a way which allows them to be raised in the future. Alongside strategies for action to provide technical flood protection, flood prevention measures are also particularly important.

FORCED HOLIDAYS FOR INLAND WATERWAY CARRIERS?

While the danger of flooding in the winter will become more acute, rivers will have much less water from June to November. The drop in water levels will be particularly marked in the south-west and south-east of Baden-Württemberg. Lower water levels are caused by long dry periods. Lack of precipitation will be exacerbated by water losses from higher evaporation as a result of higher air temperatures. This means that low water periods during the summer months will last for longer in most regions: more than 50 per cent longer south of a line from Karlsruhe to Wertheim and by 25 to 50 per cent longer north of this line. However, this is not the worst case. If the temperature rises more than expected, low water discharges and periods might develop even more adversely. The low water management forecasts produced by the State Institute for Environment and Nature Conservation (LUBW) can already be used for low water management purposes.

THE WATER UNDER OUR FEET

As annual precipitation is not expected to change dramatically in the near future (2021–2050), only small deviations in average annual groundwater recharge are anticipated. Nonetheless, longer dry periods during the summer months may, as is already the case, lead to local and temporary bottlenecks in water supplies. A number of measures will have to be taken to deal with these supply shortages, including continuing the development of networked regional and supra-regional solutions and more efficient methods of agricultural irrigation.

In the winter, on the other hand, longer phases of continuous rain may lead to higher groundwater levels in the future – a factor which might need to be taken into account when designating building areas which may be susceptible to water logging.

CLIMATE CHANGE FACTORS

An addition factor to the once-in-a-century flood discharge in the dimensioning of flood barriers takes account of the potential impact of climate change. The spillway crest helps to prevent flood barriers being breached by wave and wind build-up.

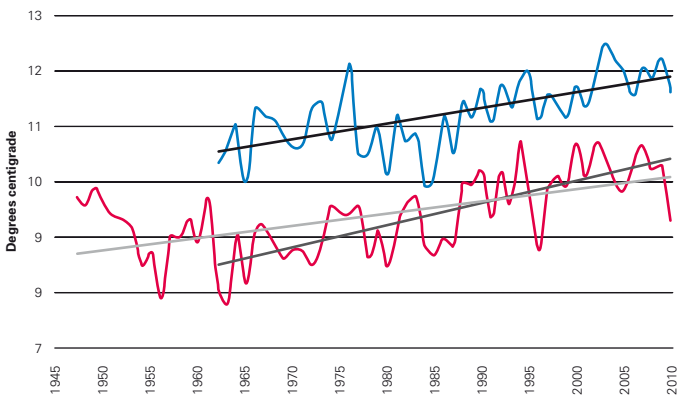
REGIONAL IMPACT

STABLE LAYERS IN LAKE CONSTANCE

Lake Constance, Europe's largest reservoir of potable water, supplies over four million people with drinking water. A KLIWA project has studied the impact of climate change on the hydrophysical processes in Lake Constance, including temperatures, thermal layering and vertical circulation.

There are already signs that the temperature of surface water has risen as average air temperatures have gone up. This could have serious implications for the complex relationships within the ecological system of the lake. As winters become increasingly milder surface water will no longer able to cool down enough to be able to penetrate through to the deepest parts of the lake. This will impair the oxygenation of deeper waters, which is important for the lake's ability to support life at these depths and which also influences the breaking down of nutrients in the sediment.

WATER AND AIR TEMPERATURES IN AND ON LAKE CONSTANCE (1962–2010)

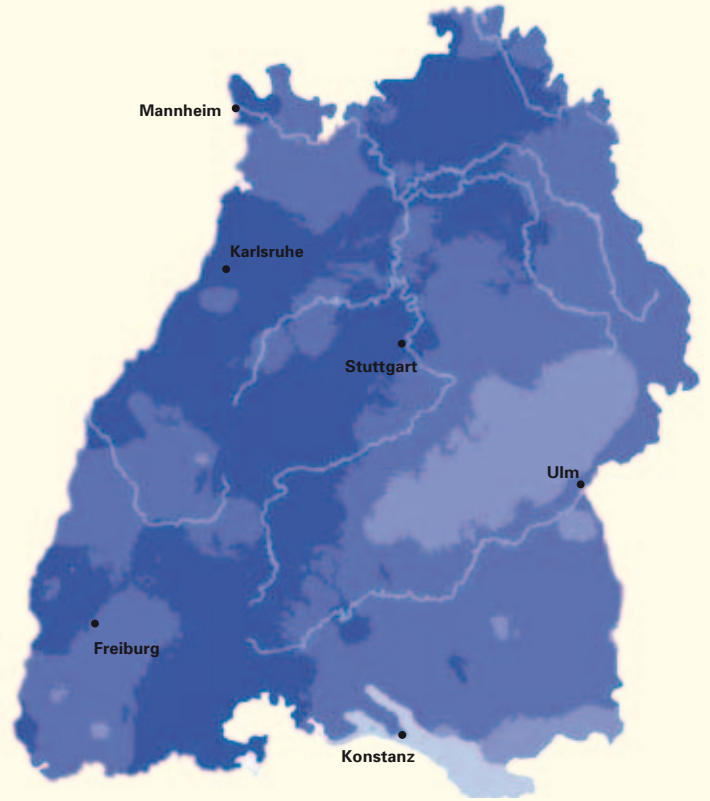


Temperatures of near-surface water measured in the middle of the lake and air temperatures measured by the Konstanz meteorological station. Source: KLIWA Monitoring Report, 2011

Air temperature near Konstanz
Trend 1962 to 2010
Trend 1947 to 2010

Mid-lake water temperature at a depth of approximately 0.5 m
Trend 1962 to 2010

DEVELOPMENT OF WINTER PRECIPITATION TO 2050



Percentage change in total winter (Nov-Apr) precipitation. The period 2021 to 2050 was simulated with reference to 1971 to 2000. Source: LUBW, 2007: KLIWA

Lakes
Rivers

Percentage change in total precipitation

2.1 – 5.0
5.1 – 10.0
10.1 – 20.0
20.1 – 30.0
30.1 – 50.0

Soil conservation

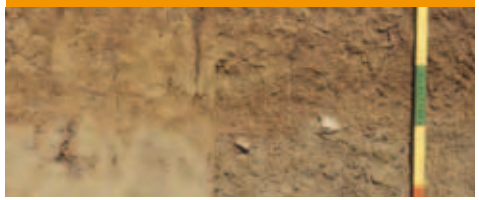
The interplay of soil and climate

Soil conservation and climate change mitigation are closely connected. There is a real danger, however, that increasingly heavy rains will literally wash top soils down the drain!

Soils play an important role in climatic processes. Soils are directly affected by future climate changes. At the same time, however, climate-related changes in the material and energy cycles in the earth in turn influence the climate itself. Soils can also respire or sequestrate climate-relevant gases. Bog habitats and other soils with high concentrations of organic matter are especially sensitive to changes in use and climate.

It takes a long time for soil to form – in fact, at most 0.1 millimetres of new soil is created every year. An extreme precipitation event, however, can lead to more than fifty years of soil formation being lost in one fell swoop. Losses of soil material damage soil fertility, cause agricultural losses and harm the environment as considerable quantities of humus and nutrients are lost with eroded soil. Damage is also caused away from erosion areas. Bodies of water can be polluted with nutrients and contaminants. Mitigating climate change is therefore one way of helping the soil. And vice versa, protecting soils and bog habitats in particular is also a way of mitigating climate change.

FACTS



SOIL AS A CARBON SINK

Soils are our planet's second largest natural reservoir of carbon after the world's seas and oceans. Around 450 million tonnes of organic matter and with it 1,651 million tonnes of CO_2 are stored in depths of up to one metre in the soils of Baden-Württemberg. The way soils are used and cultivated can have an influence on the role of soils in the carbon cycle. Just by switching to no-till farming or converting from arable land to grassland would increase the humus content of soils up to an equilibrium status and with it carbon dioxide, at least in the upper soil layers. For example, it is estimated that zero tillage would trap 1.3 tonnes of carbon dioxide per hectare and year, and that conversion to grassland could sequester around 4.9 tonnes of carbon dioxide in every hectare of soil. However, there are limits to how far these measures can be applied in practice. Continuing sustainable land management would be essential and it would also have to be possible to use crops grown on grassland, for example. Bog habitats are a special case: these wetlands are considered to be all but climate neutral. Bog habitats which are drained and intensively cultivated release the carbon which was previously stored in peat as CO_2.

Bog lake in the Black Forest

Flat lowland moors are the most common type of bog habitat in Baden-Württemberg. A study of the Donauried fluvial topography has shown that drainage and agricultural use has resulted in average peat extraction of 7.2 mm a year from lowland moors during the measurement period of 1951 to 1990. This is equal to the release into the atmosphere of around 23 tonnes of CO_2 per hectare every year, twice as much as annual per capita CO_2 emissions in Germany. However, soils are important not only for the carbon cycle, but also for the nitrogen cycle. Laughing gas (N_2O), which has an around 300-fold more powerful greenhouse effect than CO_2, escapes from soils, for example. The tilling of grassland into arable land releases nitrogen reserves and nitrous oxide into the atmosphere as tilling breaks down the humus. The extent to which nitrous oxide is released depends on a number of factors, such as soil compaction or soil water content. Soils which have been particularly intensively fertilized with organic or mineral matter with a high nitrogen content are most likely to produce much higher emissions of nitrous oxide. Nitrogen fertilisation tailored to the real needs of crops enables farmers to reduce the amount of nitrogen being released.

OPPORTUNITIES AND RISKS FOR SOILS

OPPORTUNITIES

- Increased biological activity
- Faster soil warming in spring

RISKS

- Potential decrease in humus concentration
- More erosion from heavy rain
- Washing of nutrients and pollutants into bodies of water and other ecosystems through erosion

IMPACT/ PERSPECTIVES

THE DECLINING PRODUCTIVITY OF SOILS

The impact of climate change on soils in Baden-Württemberg can only be described in qualitative terms at present. No precise figures or local projections are available, although the effects described in the following may probably be expected.

If there is more rainfall in the future, susceptible soils in areas such as in the Kraichgau region will suffer from greater water erosion. The loss of humus and nutrient-rich top soils will also lead to soil degradation. The humus content may also fall. Dry summer periods will affect soils influenced by groundwater and/or perched water in particular. Organic substances which were previously conserved by excluding air (inundation) decompose faster when exposed to air. Warmer and damper winters may mean that this mineralisation process even continues throughout the cold season. Initial estimates suggest that global warming of two degrees would reduce humus stocks under grassland and forests by 20 per cent. In bogland habitats such as the Donauried the destruction of peatlands may be accelerated by climate change.

RESEARCH AND ACTION FOR THE SOIL

The humus content of soils is influenced not only by climate factors, but also by the use to which land is put. For this reason work is underway as part of a KLIMOPASS research project on developing a way of studying the impact of both factors on the volume and quality of humus.

Other BWPLUS and KLIWA research projects will examine the climate relevance of wetlands in Baden-Württemberg as well as the future impact of soil erosion caused by heavy precipitation.

Erosion damage after heavy summer rain

Lowland moorland put to agricultural use

Eroded earth on agricultural track

REGIONAL IMPACT

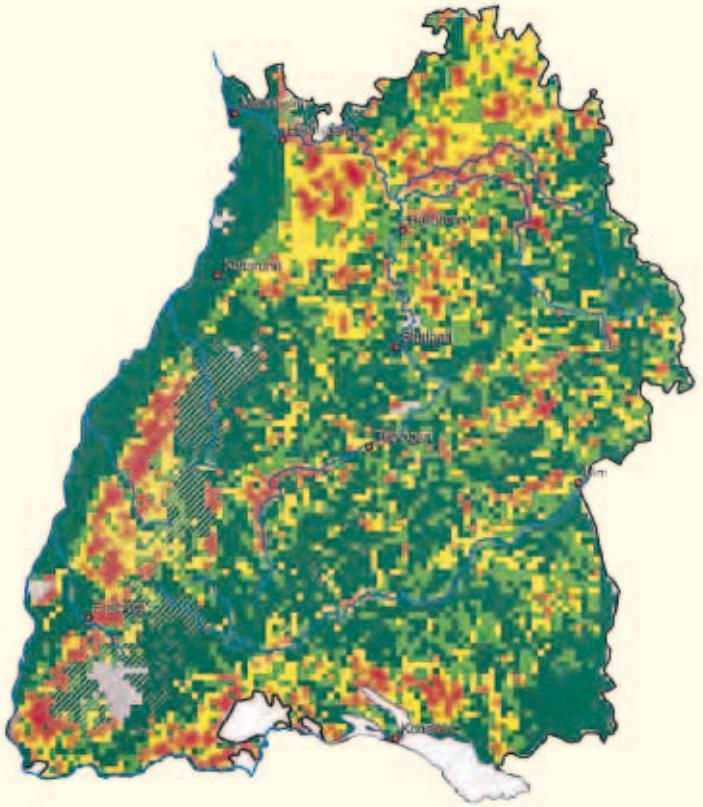
KRAICHGAU LOSING GROUND

The impact of climate change differs both regionally and locally. It is particularly important in the case of soils that consideration be given to the different effects of climate change from one location to the next.

Whether and to what extent the effects described will actually materialise can only be determined on the basis of precise information about soils, their use and the relevant climate influences. Erosion, for example, does of course affect very large areas which are already susceptible. These include parts of northern Baden in particular, such as Kraichgau or the mid and south-eastern Upper Rhine lowlands. Earlier studies measured soil losses in Kraichgau of over 80 tonnes per hectare and year. Whether heavy rains will fall more frequently in these areas in the future and whether this will heighten the danger of erosion is the subject of current research work.

Extensive soil erosion

SOIL EROSION ATLAS



Area-weighted soil erosion on arable land. Erosion in tonnes per hectare and year
Source: Gündra et al., 1995: Soil erosion atlas of Baden-Württemberg, Agrarforschung in Baden-Württemberg, Volume 24, Stuttgart.

- *0.0 - 1.0*
- *1.1 - 2.0*
- *2.1 - 3.0*
- *3.1 - 4.0*
- *4.1 - 5.0*
- *5.1 - 15.0*
- *> 15.0*
- *Mean inclination on arable land > 12 degrees*

Agriculture

Global warming winners and losers

A glance into a hotter future: less winter wheat, more maize and – unfortunately – more pests and diseases as well.

Highly-industrialised Baden-Württemberg is still agricultural in character. Forty-one per cent of the land is used by farmers, gardeners and winegrowers. Of this land 58 per cent is used as arable land and 38 per cent as grassland. Vineyards, vegetables and fruit are grown on just four per cent of farmland. However, it is these specialty crops which promise the biggest profits.

With average annual temperatures of over 9°C in the last decade and a vegetation period of 170 days, the south-west is already one of the warmest parts of Germany. If the climate in Baden-Württemberg becomes even warmer and to some extent damper or, in places, drier, this will have a dramatic impact on the agricultural sector. Ultimately, of course, plant growth depends crucially on warmth and water. Even small increases in temperature can make entire crops wilt or flourish.

The State of Baden-Württemberg has tasked the KLARA project with studying probable changes in agriculture drawing on the example of important crops. Maize generally thrives at higher temperatures, wheat needs more water, fruit and wine may be threatened by pests.

FACTS

THE APPLE WILL STRUGGLE

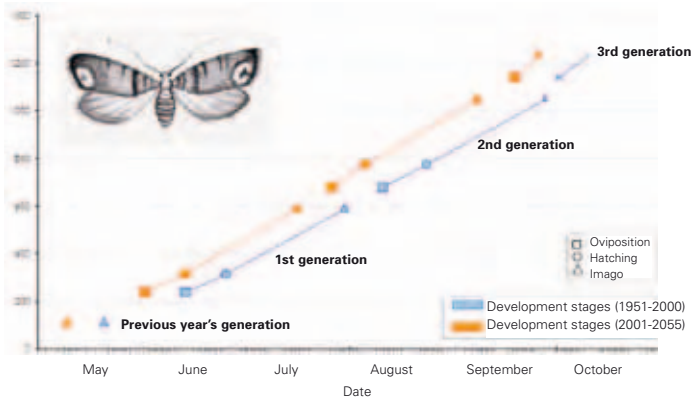
Apple scab is one of the most dangerous diseases affecting fruit growing. This fungus reduces yields by up to 70 per cent and leads to brown lesions on the fruit which make it unmarketable. As with most types of fungus, apple scab likes warm and damp weather. As well as an increase in regional fungal attacks, fruit growers will also have to cope with more insect pests. The effect of warm weather on the main pest, the codling moth, has been simulated for the Lake Constance area. The codling moth's larvae eat their way through apples and other pomaceous fruit. The greatest damage is inflicted by the second generation of maggots in the year, which is more likely to appear as temperatures rise. In southern Europe the moth even has three generations a year.

The cultivation of late-ripening varietals was still restricted to small areas along the Upper Rhine Valley and in Württemberg up until the 1960s. These areas grew in area during the 1990s.

As the atmospheric concentration of CO_2 has increased, so has the photosynthesis performance of some crops. The first field-grown experiments involving treating wheat and potatoes with higher CO_2 concentrations showed that while yields improved, the quality deteriorated. This is because the protein contents of harvested products declines. Higher protein contents are especially important in baking-quality wheat and determine how much farmers can get for their produce.

Adaptation of wheat varieties may reduce crop losses

GENERATIONAL DEVELOPMENT OF THE CODLING MOTH IN THE LAKE CONSTANCE REGION



Change in the generational development of the codling moth (Cydia pomonella) in the Lake Constance area (the size of the symbol corresponds to the frequency of climatically advantageous years for the development of the phenological stage)
Source: Potsdam Institute for Climate Impact Research (PIK), 2005: KLARA

OPPORTUNITIES AND RISKS FOR AGRICULTURE

OPPORTUNITIES

- It is also possible to grow maize in higher areas
- Late-ripening varietals thrive
- Cultivation of new strains and species of crop
- Higher yields from some types of crop

RISKS

- Heat/dryness may reduce yields from sensitive crops (such as winter wheat)
- Pests may occur several times a year and new pests establish themselves
- Better conditions for certain types of fungal diseases

IMPACT/ PERSPECTIVES

MAIZE YIELDS MAY RISE EVEN FURTHER

Global warming could bring about an increase in the amount of maize grown in south-west Germany and result in this feed and energy crop flourishing in areas which were previously too cold or high. In contrast, the findings for the regions modelled in KLARA show that winter wheat yields will fall by an average of 14 per cent. However, the KLARA research project does not take account of the potential CO_2 impact of fertilisation. The extreme summer of 2003 demonstrated that the assumed competitive advantage of maize can only be realised if sufficient water supplies are available.

Crops such as soya and sunflowers, which prefer warmer climes, may be planted more extensively, whereas sugar beet cultivation will decline. It should be possible to grow certain types of vegetables, such as red or green peppers, aubergines or artichokes, in the open air. On the other hand, fruit growers will have to contend with significantly more scab disease (Venturia inaequalis) as the danger of infection with fungal spores is much higher in the damper spring months. Flourishing fungi may also prove problematic for grape vines. Higher temperatures favour the development of several generations of pests. The codling moth, for example, may be expected to produce a second generation of maggots in two of every three years instead of in one of every five as has been the case to date.

2003: THE SHAPE OF THINGS TO COME?

The extremely hot summer of 2003 may well have given us a glimpse of what the future holds in store. The Augustenberg Agricultural Technology Centre has evaluated yields right across Baden-Württemberg and come to the conclusion that harvests declined from the previous year according to crop by between twelve per cent (winter wheat) and almost thirty per cent (sugar beet). The only crop which produced higher yields was summer barley. The findings vary according to crop and region. The impact of the hot summer was much greater in the typically warm district of Karlsruhe than in the cooler and rainier district of Heidenheim, for example. This means that farmers working land in warmer areas will have to adapt their growing activities to climate change much faster. This will not only demand more work on breeding new varieties of plants but also adaptations in crop rotation, sowing, fertilisation, tillage and pest control. Valuable crops will also need more watering and irrigation to secure yields and quality.

Maize fields will also thrive at higher altitudes in the future

HIGHER PLANT PROTECTION COSTS

Farmers may be able to compensate for lower winter wheat yields by sowing more baking-quality wheat, in other words crop plants with higher protein content. A similar picture emerges when switching from silage maize (feedstuff) to grain maize (food). All in all, farmers – and not just fruit growers – will have to do more to protect plants from an anticipated increase in insect pests and plant diseases and will therefore have to budget for correspondingly higher costs. Organic farmers who are prohibited from using synthetic pesticides are likely to be particularly hard hit and will have to invest in the selection of pest-resistant crops.

Invasive fruit crop pests encouraged by climate change. Drosophila suzukii ("spotted wing drosophila")

REGIONAL IMPACT

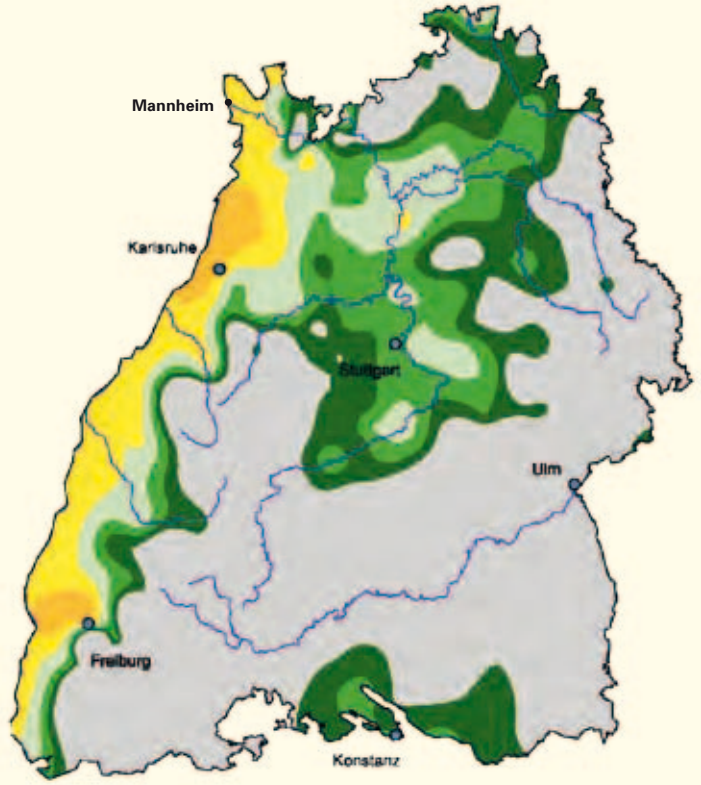
THE SOUTH AND NORTH-EAST WILL BENEFIT; WINEGROWERS MAY BE LEAST AFFECTED

Water shortages will probably result in reductions in yields of winter wheat and maize in the central Rhine Graben. In contrast, harvests in southern and north eastern parts of Baden-Württemberg are likely to improve (maize) or at least only be marginally reduced (wheat). More grain maize will probably be cultivated in the north east in particular. Viticulture will probably be least affected by climate change. The Huglin index shows where different types of vine develop and grapes ripen best. Specifically, the index measures the sum of mean and maximum warm temperatures in the period from April to September. As a rule, the higher the temperature is, the more late-ripening varieties growers are able to cultivate. While a variety such as Müller-Thurgau can cope with a Huglin index of 1500, a Merlot needs 1900.

Yields have been stable since the 1990s with relatively little fluctuation from one year to the next. These low crop losses are due in part to fewer bud-damaging winter frosts as well as the improved wood maturity which comes from higher overall temperatures. This trend is likely to continue through to 2030. Winegrowers can rely more on late-ripening varieties in the future.

Winegrowers benefit from climate change: Late-ripening varieties can be grown over much wider areas

THE VITICULTURE POTENTIAL OF WINE-GROWING REGIONS UP TO 2030



The Huglin index is the sum of mean temperatures between April and September. The index helps to classify the viticulture potential of various regions
Source: Potsdam Institute for Climate Impact Research (PIK), 2005: KLARA

Forestry

The changing face of Germany's forests

Hot and dry summers as well as recurrent storms will put the adaptability of trees and forest habitats to a severe test.

With around 1.4 million hectares of forest – or 38 per cent of its total land area – Baden-Württemberg is the state with the second largest expanse of forestland in Germany. Woodland in the south-west of the country is correspondingly valuable, both ecologically and economically. In an age of climate change forests play an invaluable role in storing carbon by absorbing CO_2 from the atmosphere and sequestering it in wood. At the same time, global warming is also having a powerful impact on our forests. This is because, in addition to other factors, the climate also determines which species of tree can flourish and spread. But which species of tree will be particularly suitable for the climate of the future here in Baden-Württemberg?

Climate change is already apparent in the forest: trees and plants shoot, flower and bear fruit earlier. In damp areas this results in rampant growth with more wood, whereas in other areas tree species, such as spruce in warm and dry regions, are being forced back. Whether storms are likely to become more frequent and pests more prevalent as the climate changes cannot (yet) be proven with absolute scientific certainty. There are still many issues which need to be clarified. The facts are important, bearing in mind that forest owners in particular need to be able to think and plan over the long term.

FACTS

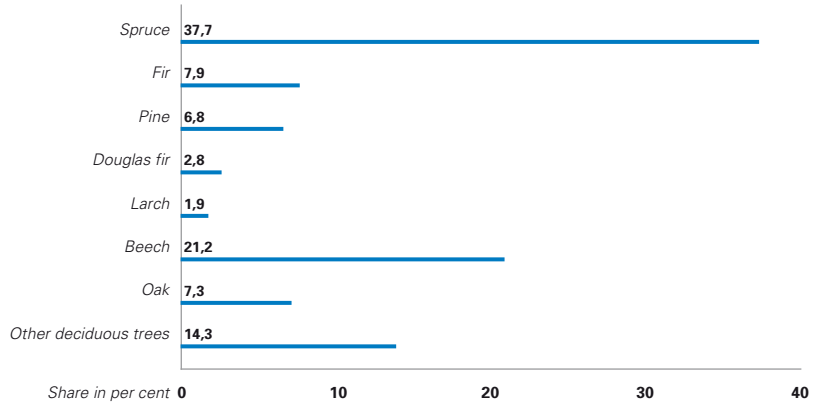
THE RIGHT SPECIES OF TREE IS CRUCIAL

Not all species of tree in Baden-Württemberg are capable of coping with long dry periods and the associated water shortages. This is one reason why forestry scientists fear that some species may decline or even disappear entirely in the long term. Beech and spruce trees in Baden-Württemberg already showed significant damages as early as 2003. While beech forests have recovered again to some extent, beech and spruce trees would find it difficult to cope with a spate of several consecutive hot and dry years, especially those trees growing in unfavourable locations.

The vitality of our main tree species has already suffered in recent years. Studies undertaken by the Baden-Württemberg Forestry Research Institute (FVA) demonstrate that needle drop and foliage loss among beech and spruce trees has increased substantially since 2001. Populations of spruce in areas of intensified climatic stress, and drought stress in particular, have been especially severely affected.

There has also been a major increase in storm damage over the last twenty years. The Wiebke, Vivian (1990), Lothar (1999), Kyrill (2007) and Xynthia (2010) storms uprooted whole stretches of forest, leaving them exposed to threats from parasites, forest fires and erosion. The only ray of hope is that warmer weather also prolongs the vegetation period. Trees can then grow faster, provided there is enough water available to them.

DISTRIBUTION OF TREE SPECIES IN BADEN-WÜRTTEMBERG



Results of the 2002 Federal Forestry Inventory
Source: Baden-Württemberg Ministry for Food, Rural Development and Consumer Protection

OPPORTUNITIES AND RISKS FOR FORESTRY

OPPORTUNITIES

- Longer vegetation periods
- Faster growing trees
- Some tree species will benefit
- Reduced danger of forest fires in some areas

RISKS

- Damage to trees in dry summers
- Foliage loss and needle drop from spruce and beech
- Retreating spruce at higher altitudes
- Increased danger of forest fires in some areas

IMPACT/ PERSPECTIVES

CHANGING PATTERNS OF FORESTRY

Forestry needs innovative thinking. While forest owners have chosen species of trees in the past to suit particular locations and current climate conditions, they will have to take projected climate changes into account in the future. How will tree populations develop in a warmer climate? These are dynamic factors which it is extremely difficult to estimate. Forestry experts assume that as things stand our forests will not be able to adjust if the temperature of the earth's atmosphere rises by around 3°C.

THE SPRUCE WILL DISAPPEAR; THE BEECH WILL STAY

Douglas fir would be an appropriate alternative to spruce, which will retreat in the warmer and lower areas of Baden-Württemberg. Beech trees, in contrast, will manage to hold their own, except on lower lying plains. As most of Baden-Württemberg's forests grow at higher altitudes, however, highly competitive beech trees will tend to account for an even greater share of all trees. Ash, sweet chestnut, large and small-leaved lime, hornbeam, wild cherry and wild service trees will probably do better. Only the Norway maple will stagnate.

As trees will develop shoots earlier in the year in the future, the productivity of individual trees may increase. For example, on average it has been calculated that, taking all areas of deciduous woodland as a whole, the beech will put out shoots three days earlier and the oak even six days earlier in the future. On the other hand it is important to realise that there will be a shift in distribution of different species in favour of slower growing trees (beech, oak).

FORESTRY SCIENTISTS FACE MANY UNANSWERED QUESTIONS

Despite very severe weather phenomena over the last twenty years there is no evidence that we are threatened by more storms in Baden-Württemberg.

Calculations using the COSMO-CLM regional climate model for southern Germany show that mean wind speed in the decades ahead will increase slightly. There is no way of proving, however, that high wind speeds will be more frequent in the future. The picture is very different in northern Germany, however.

Beeches will become more prevalent in Baden-Württemberg's forests

Forest fires are relatively rare in Baden-Württemberg compared with other parts of Germany, and when they do occur they are usually caused by people. The danger of forest fires as a result of climate change will only increase slightly in Baden-Württemberg in the future in the lee of the Black Forest and will in fact fall somewhat in the north and west.

It is not clear, however, how and what parasites may proliferate in the future. The common assumption that "warmer weather equals more parasites" is not necessarily true. In fact, the ecological relationships between host plants, harmful organisms and climatic conditions have not as yet been adequately explained. Despite the uncertainties in this field, forest owners can take action already by taking steps to support richly-structured deciduous and mixed forests which are appropriate to their localities. Biologically diverse forests are best suited to meeting changes of all kinds.

REGIONAL IMPACT

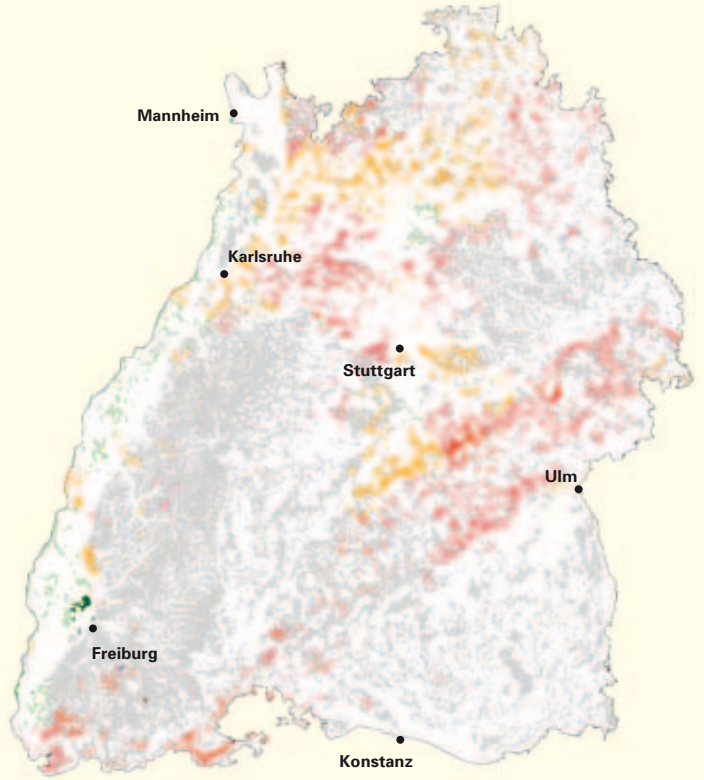
THE CHANGING BLACK FOREST

Nowhere else in south-west Germany is climate change apparent in such a small area as it is in the Black Forest. If the atmosphere becomes 3°C warmer, the tree line would move up by 300 to 500 metres. Competitive beech-oak forests would even grow at an altitude of 1,000 metres.

Experts believe that central European forests would in some places begin to resemble the forests of northern Italy. Climate change will also change the aspect of the Black Forest heights. The spruce which currently dominates the landscape will gradually give way to pine and Douglas fir. Other deciduous species will also spread.

Beech-oak forests may grow up to an altitude of 1,000 metres in the Black Forest

CHANGE IN LEAFING UP TO 2055



Change in timing of leafing for oaks in deciduous woodland. Source: Potsdam Institute for Climate Impact Research (PIK), 2005: KLARA

Nature conservation and species protection

Flora and fauna migrating from southern Europe

Animals and plants react more sensitively to climate change than people. There will be winners and losers if mean temperatures increase.

Every single animal and plant has its own peculiar habitat. If these habitats change in any way – for example, due to climate change – species either adapt, migrate or die out. Some species can benefit from such changes – such as those whose habitats become larger. Climate change has an enormous influence on the habitats of fauna and flora in Baden-Württemberg. If annual mean temperatures rise, if more rain falls or less falls for a short period, this all has a permanent impact on the habitats of many species. There is then a danger that some previously native species might disappear altogether. At the same time, species which thrive in warmer climes, such as millet or the marbled fritillary butterfly, which was originally native to southern Europe and Asia through to Japan, are migrating from Mediterranean areas in particular and becoming established here. Migratory species of butterfly such as the Admiral now appear in Baden-Württemberg much earlier than they did in the past. In other respects we can expect both positive and negative impacts. Birds may hatch out larger broods, while a huge increase in insect pests could cause problems for farmers.

FACTS

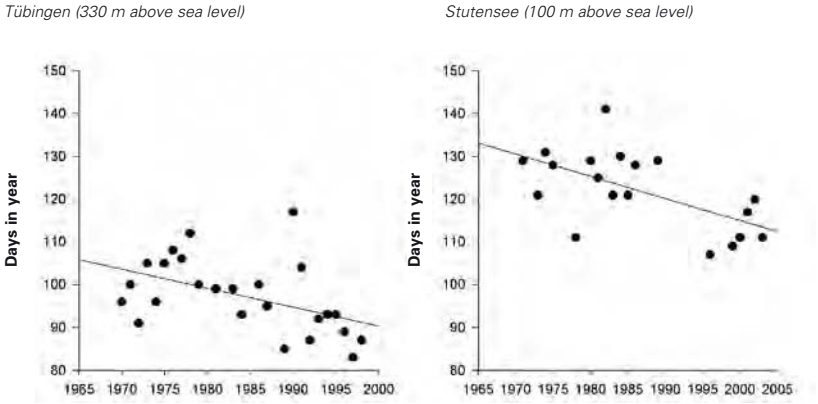
SHORTER ROUTES FOR MIGRATORY BIRDS

Bird life is highly sensitive to climate change. A total of 17 species of migratory bird were systematically observed between 1970 and 2003. The studies have shown that on average these birds arrive three to five days earlier with every new decade that passes. Many migratory birds therefore now arrive in Baden-Württemberg over two weeks earlier than they did in 1970. It is probably the case that their wintering grounds are no longer as far south as they once were. Long-distance migrants which previously crossed the Sahara are now increasingly wintering in the Mediterranean area. Previous short-distance migrants are turning into resident birds which are now able to sit out the milder winters.

These birds are also being joined by new species. The number of species of birds which are generally more common in southern climes generally increased in south-west Germany between 1980 and 2000. This is also true of plants and insects. The halictus bee has been permanently resident in Baden-Württemberg since 1990, for example.

Plants which thrive in warm climates, such as millet or ailanthus, and which had not previously grown here in the wild, have been found in increasing numbers in Aalen, Ulm, Stuttgart, Konstanz and Karlsruhe in recent decades. More problematic is the introduction of disease-spreading vector insects such as the tiger mosquito and sand fly.

ARRIVAL DATES OF FIRST COMMON HOUSE MARTINS SINCE 1970



Common house martins have been arriving in Tübingen and on the Stutensee Lake earlier every year since 1970.
Source: Potsdam Institute for Climate Impact Research (PIK), 2005: KLARA

OPPORTUNITIES AND RISKS FOR NATURE AND SPECIES

OPPORTUNITIES

- Biological diversity increases if the climate warms up by up to 1°C
- New species become native
- Migratory birds do not have to fly so far
- Birds can successfully breed more young

ADVERSE IMPACTS

- Biological diversity sinks if temperatures increase by more than 1°C
- Established biotic communities may be destabilised
- Species which thrive in colder climates may be threatened
- Bog habitats will dry out for part of the year

IMPACT/ PERSPECTIVES

A WARMER CLIMATE MEANS FEWER SPECIES

Climate change is shifting Europe's climate zones northwards or up to higher altitudes. Plants and animals which have never been found before in our latitudes, or only in warmer areas, will find new and permanent habitats in Baden-Württemberg in the future. Scientists assume that a moderate increase in temperature in central Europe of up 1°C would foster greater biodiversity.

At the same time, however, the spread of species adapted to warmer conditions is often associated with negative consequences. The explosive expansion of hairy oak processionary caterpillars, for example, is indelibly stamped on many people's memories. Higher temperatures also increase the rates at which pests such as the bark beetle reproduce. Many ecosystems and their inhabitants will find it almost impossible to adapt to climate change, however. Biological diversity will almost certainly decline as soon as mean temperatures rise by more than 1°C. This will mainly affect species which flourish in colder conditions, such as the brown trout.

In the case of plants, a rise in temperatures of 1.8°C would threaten over 30 per cent of species with extinction, a negative development which would visibly affect 40 per cent of the total land area of Europe.

Winner: Mantis

Winner: Southern migrant hawker

WINNERS AND LOSERS

The State of Baden-Württemberg has studied the consequences of climate change for both individual species and for entire biotopes. As the main impact of climate change on Baden-Württemberg will be drier summers, biotopes which are highly dependent on plentiful water are particularly threatened. If phases of drought last longer in the future, species of flora and fauna which thrive in wet conditions will tend to disappear. Permanently wet areas, such as bog habitats, may well then dry out for longer periods at a time. This would not only release CO_2 which is currently captured in the ground but would also displace rare plants such as peat moss and cotton grasses which are native to bog habitats. Progressive global warming will produce more and more winners and losers. The losers will be found among the Alpine species in Baden-Württemberg's low mountain ranges in particular. Whether this reduction in the number of species can be "balanced out" by new species migrating from the south remains to be seen. The first nature conservation strategies for responding to the impact of climate change on biological diversity have already been worked out. The greater the biodiversity of a particular ecosystem, the more elastically it is able to respond to changes. Climate-driven migratory movements of species must therefore be supported and sufficiently dense clusters of appropriate habitats offered.

Loser: Northern wheatear

Winner: Large copper

Loser: Brown trout

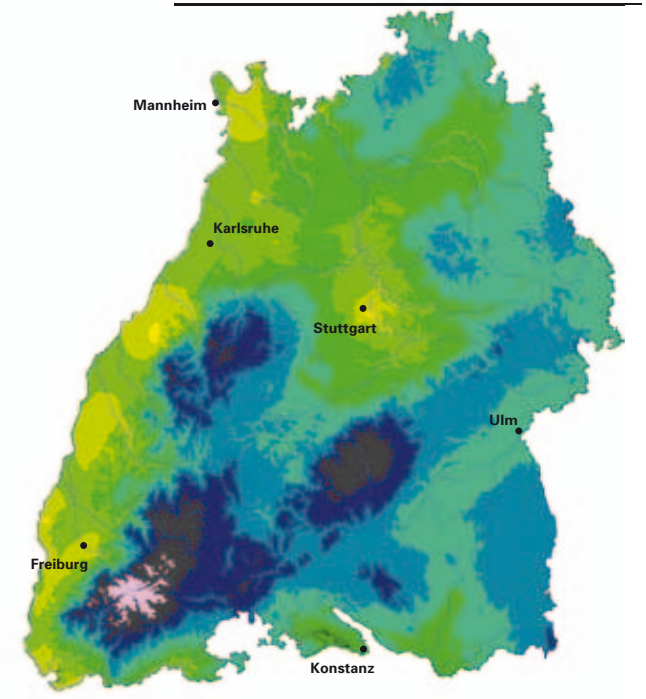
REGIONAL IMPACT

regions which previously had quite harsh climates. Observations from the Murg Valley show that, in 2007, apple blossom "migrated" from the Rhine Plain (120 m above seal level) to Schliffkopf (1043 m) at a rate of 66 m a day in just 14 days – almost twice as fast as in 2006.

EARLIER SPRINGS

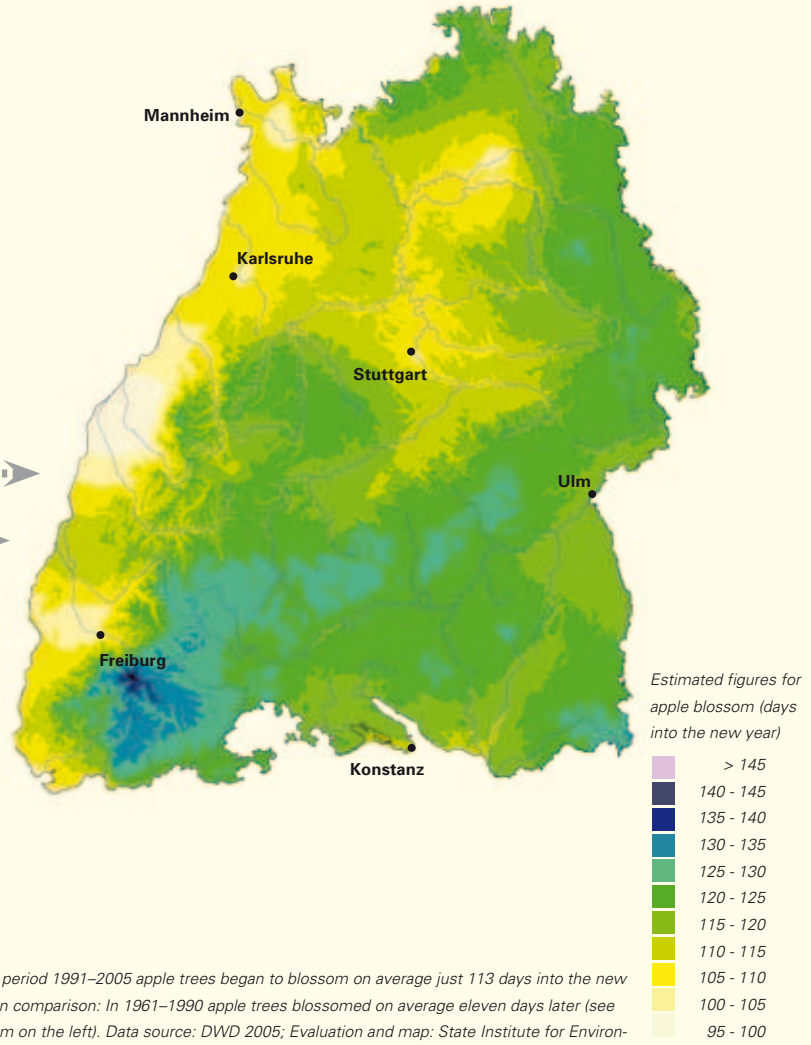
The first days of spring are considered to coincide with the apple blossom period. Depending on altitude and microclimate spring begins on different dates in the various regions of Baden-Württemberg – much earlier in the Upper Rhine Valley than on the slopes of the Black Forest, for example. However, all regions have one thing in common: spring has arrived earlier and earlier over the last two decades. From 1991 to 2005 spring plants have bloomed on average eleven days earlier than in the period 1961 to 1990. Apple trees are blossoming earlier in more and more regions, including in those

APPLE BLOSSOMING 1961–1990



Time at which apple trees begin to blossom, 1961–1990: On average 124 days into the new year.
Data source: DWD 2005; Evaluation and map: State Institute for Environment and Nature Conservation (LUBW)

APPLE BLOSSOMING 1991–2005



In the period 1991–2005 apple trees began to blossom on average just 113 days into the new year. In comparison: In 1961–1990 apple trees blossomed on average eleven days later (see diagram on the left). Data source: DWD 2005; Evaluation and map: State Institute for Environment and Nature Conservation (LUBW)

Tourism

Sunny outlook for summer tourists

More days for swimming in the summer and less snow in the winter. That, in a nutshell, is how climate change will be experienced in Baden-Württemberg. Good news for summer tourism at any rate.

With 45.6 million overnight stays a year Baden-Württemberg is one of the most popular tourist destinations in Germany. Only Bavaria attracts more visitors. With around 280,000 jobs in tourism, the industry generates total net turnover of 22.4 billion euros and added value of 7.5 billion euros. This means, of course, that the impact of climate change may be equally momentous. Businesses operating in the tourist sector, such as hotels, restaurants and inns or open-air swimming pools, are very sensitive to the weather. Tourists are unlikely to book a holiday on a drizzly Lake Constance, for example. And unless it was able to offer alternative attractions the Feldberg, the highest mountain in the Black Forest, would soon be abandoned by its winter skiing visitors if there was no longer any snow on its slopes.

The challenge which climate change poses for tourism can be most easily studied by looking at some of the most popular tourist activities. In the summer season these include the swimming season on Lake Constance and the hiking season in the Black Forest. In the winter months the skiing season is most important, of course. What will be the advantages and disadvantages for tourism in these areas if it becomes even warmer in Baden-Württemberg? This issue was at the heart of the major KLARA research project.

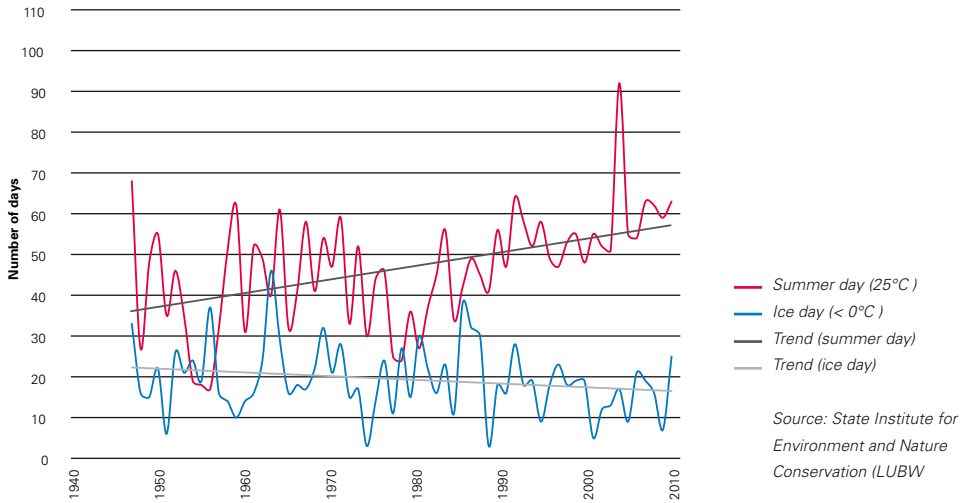
FACTS

SUMMER TOURISTS LIKE IT WARM AND DRY

Reliable data on current and earlier climate conditions are needed before it is possible to produce a reasonable projection of the probable impact of climate change. For fairly obvious reasons the KLARA researchers chose to measure the number of swimming days on the shores of Lake Constance as well as the number of hiking days in the Black Forest as criteria for the attractiveness of summer tourism in Baden-Württemberg. In this framework they defined a swimming day using the following parameters: the highest daytime temperature should be over 23°C and the sun should shine for at least nine hours under no more than broken cloud cover. This combination guaranteed the highest number of visitors to the open-air swimming pools around Lake Constance. A similar picture emerges for hiking days in the Black Forest: the longer the sun shines and the less rain falls, the more visitors can be found walking the Wutach River Gorge, for example. Winter tourists seek exactly the opposite kind of weather. These visitors need cold and wet weather if there is to be enough snow for their winter sport activities. However, Baden-Württemberg is unlikely to have this kind of weather in the future. Westerly weather patterns with relatively warm air masses are likely to become more predominant in the winter. While the weather from the west brings enough water, it turns into snow less and less often.

Skiers can no longer always rely on finding snowy slopes

ANNUAL NUMBER OF SUMMER DAYS AND ICE DAYS IN KONSTANZ



Source: State Institute for Environment and Nature Conservation (LUBW

OPPORTUNITIES AND RISKS FOR TOURISM

OPPORTUNITIES

- More swimming days during the year
- More days a year suitable for hiking
- Opportunities for new tourism attractions

RISKS

- Less snow, including on higher slopes
- Danger of increasing damage to tourist infrastructure
- Danger of slump in the sales of specific tourist operators

IMPACT/ PERSPECTIVES

GOOD FOR SWIMMING AND HIKING, BUT BAD FOR SKIING AND TOBOGGANING

The prospects are mixed for summer and winter tourism in Baden-Württemberg in the future. According to the KLARA study, the number of days on which visitors will be able to swim comfortably might increase in the period 2026 to 2055 by an average of four days. The economic significance of these figures becomes apparent when compared with the minimum of eight swimming days (in Bodman) which were anticipated in 1972. In comparison: the maximum in Immenstaad for the year 2000 was 43 swimming days. The swimming season will also go on for longer. In the future tourists will probably be able to enjoy the first swimming days 14 to 21 days earlier than in the past or even take their lakeside holidays three or four weeks later in the year.

Hiking weather in the Black Forest was examined by studying maximum daily temperatures, air humidity and daily sunshine duration. The findings show that in the future (2026–2055) walkers will probably be able to anticipate slightly more sunshine during the spring months. Overall the weather will also become drier and warmer – by an average of at least 1°C over a 30-year period. All in all, the weather forecast is good for tourists looking forward to hiking in the Black Forest!

BLEAKER PROSPECTS FOR WINTER SPORTS ENTHUSIASTS

The picture looks quite different for winter tourism. As was to be expected, global warming will mean less snow on the upper slopes of the Black Forest. Climatologists assume that westerly weather patterns of warmer and damper air masses will become increasingly predominant in the winters of the future and that arctic highs will occur less regularly. Precipitation will only settle as snow at the highest altitudes.

Compared with the years 1994 to 2003, the number of snowy days in the years 2021 to 2030 in lower areas will fall by more than 18 per cent and by around 23 per cent at higher altitudes between 500 and 1,000 metres. The prospects for the years 2041 to 2050 are even less rosy: researchers expect 25 to 44 per cent fewer snowy days on Black Forest peaks and up to 65 per cent fewer snowy days in lower lying areas. The future for ski tourism looks gloomy indeed.

Hikers in the Black Forest can expect more daily sunshine

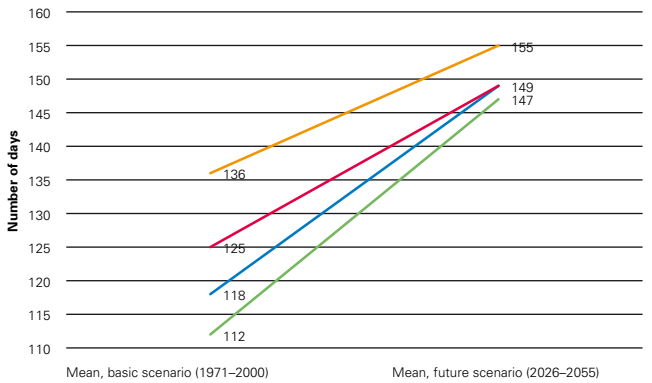
REGIONAL IMPACT

OPPORTUNITIES AND RISKS

Climate change brings opportunities and risks for the tourism industry. Changes in the Mediterranean climate will enhance the attractiveness of somewhat cooler regions. More people will wish to travel north – including to the benefit of Baden-Württemberg. More summer days will have a positive impact of the number of days on which visitors can comfortably go swimming and on the duration of the swimming season, particularly in the tourist region around Lake Constance. At the same time, however, cycling, hiking and green tourism will also benefit from warmer and drier summers – a positive development for many of the regions in Baden-Württemberg with countryside which is attractive for tourists. Cultural tourism, including visits to Baden-Württemberg's towns and cities, is also expected to grow.

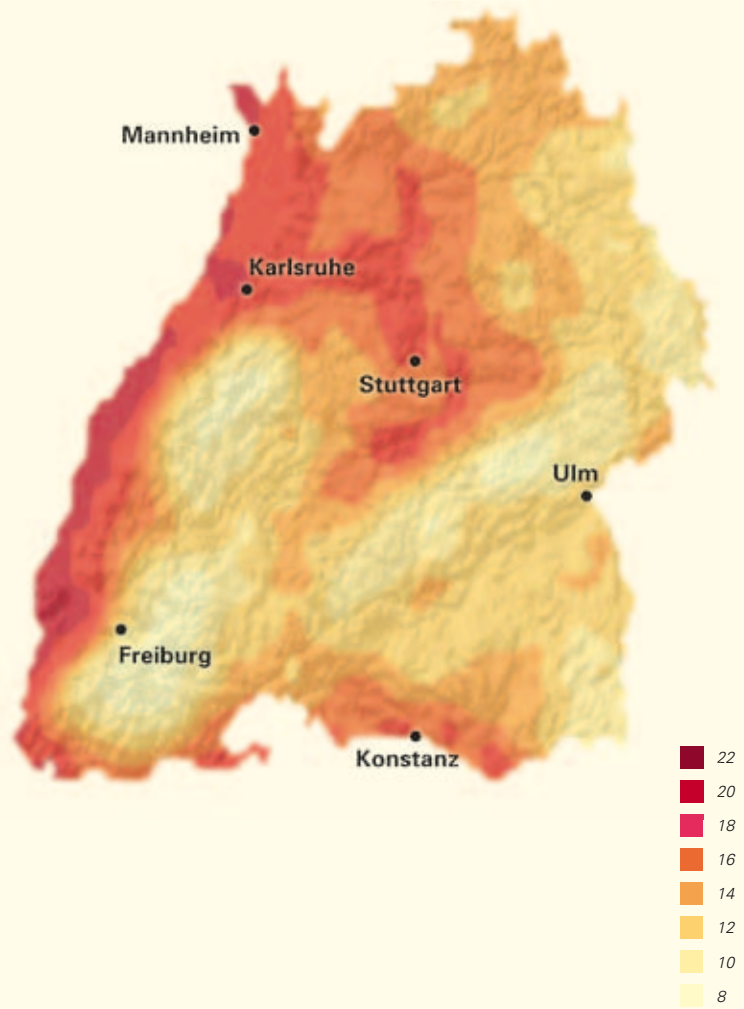
On the other hand, climate change will cause greater damage to the tourist infrastructure in various regions of Baden-Württemberg as a result of flooding or severe storms, for example. Rising temperatures on the Swabian Alb and in the Black Forest will mean it is no longer possible to guarantee snow. The tourism industry faces the challenge of adapting the winter sport activities it is able to offer and of creating new attractions and holiday activities which exert a pull on visitors.

DURATION OF THE SWIMMING SEASON ON LAKE CONSTANCE



Change in range of potential swimming days in the Lake Constance region (All values are averaged over the 30-year study period).
Definition of potential swimming day: Maximum temperature 23°C, mean cloud cover < 3/8 and sunshine duration min. 9h.
Source: Potsdam Institute for Climate Impact Research (PIK), 2005: KLARA

PROJECTED NUMBER OF SUMMER DAYS UP TO 2040



Change in the number of summer days (25°C), 1971–2000 and 2011–2040.
Source: IMK-TRO/KIT, 2010

The economy

Climate protection and adaptation save costs

Unless appropriate adaptation measures are taken, climate change will entail huge costs all around the world, such as for storm and flood damages. Investing in climate protection and adaptation measures would be far more cost effective for everyone.

Global warming may also prove to be an economic problem. Extreme weather events, such as storms, hail or flooding, may be more intensive and occur more frequently in the future. More damage will be sustained by buildings and vehicles and in the agricultural and forestry sectors. If the climate continues to change at its current pace we will be confronted by huge economic costs. The British government's 2006 Stern Report predicts that a rise in temperature of 4.5°C will – depending on the scenario adopted – cost between 5 and 20 per cent of global gross domestic product by the year 2100. A gigantic sum of money! On this reckoning climate change could lead to a worldwide recession.

Investments in reducing CO_2 emissions and adaptation measures would therefore save considerable costs. Inaction is not an acceptable alternative. Making efficient use of the available financial resources is all the more important given that climate change can now only be mitigated but no longer stopped altogether. At the same time, every degree by which temperature increases can be reduced will save billions.

FACTS

THE HIGH COST OF CLIMATE CHANGE

Germany has experienced more heat waves and heavy rain in recent years. The Elbe "flood of the millennium" in particular caused huge damage: the insurance company Munich Re estimated the costs of this flood at 9.2 billion euros in Germany alone.

Munich Re reported the global cost of extreme climatic events in 2002 at 52.5 billion euros. According to the calculation by the world's largest reinsurance company, these costs have increased by the factor 15 in the last 30 years.

However, losses arising from infrastructure damage, loss of production as well as illness and deaths must also be added to the insured damages. The German Institute for Economic Research (DIW) estimates the costs to the European economy as a whole of the hot summer of 2003 at between 10 and 17 billion euros. Even if some branches of industry manage to profit from reconstruction work, the costs caused by climate change are considerably higher.

DAMAGE COSTS GENERATED BY CLIMATE CHANGE

Costs (accumulated up to 2050) of climate change damages according to federal state in billions of euros. Compared to other states in Germany, Baden-Württemberg will be severely affected by the costs of climate change damages. Source: Calculations made by the DIW Berlin, 2008

OPPORTUNITIES AND RISKS FOR THE ECONOMY

OPPORTUNITIES

- Climate protection measures create jobs, such as in the building trade and solar industry
- Adaptation measures promote economic development

RISKS

- Climate change damages are the cause of billions of euros of damages
- Labour productivity falls and temperatures rise
- Insurance premiums go up

IMPACT/ PERSPECTIVES

RISK OF COSTS IN THE BILLIONS

International negotiations must be successfully completed to ensure that action to mitigate climate change and effective climate protection measures are adopted. Unless suitable adaptation measures are taken the Institute for Economic Research (DIW) estimates that German industry will have to find up to 800 billion euros to cope with the damages caused by extreme events such as flooding, heat waves or storms in the next 50 years. This would be tantamount to around three per cent of gross national product in this period.

In addition to the direct economic consequences for energy production, agriculture and industry, economists also take account of the costs associated with the greater risk of forest fires. Investments in measures to reduce CO_2, which would prevent even worse global warming and would thereby stop costs from rising even further, would be equal, according to the DIW, to around one per cent of gross national product. A fast-acting and effective climate protection policy would allow up to 169 trillion euros to be saved worldwide up to the year 2050.

PREVENTION CUTS COSTS

The wide range of regulations which now apply to buildings are good examples of sustainable climate policy. Investments in energy efficiency measures pay off in the long term by reducing energy costs. They also have positive economic effects by stimulating the building and energy industries.

The renewable energies sector already employs more than 250,000 people and is expected to generate even more jobs in the future. Innovative, CO_2-free energy technology "made in Germany" may prove to be an even greater export hit in the future, provided that we manage to maintain our technological lead. A coordinated European climate protection policy and more efforts to implement measures to adapt to climate change are critical complementary steps. Climate protection policy begins today; an energy and resource efficient approach to the economy will secure our country's long-term competitive edge. According to calculations produced by the DIW, hesitant climate protection policy will lead to dangerous global warming and huge costs as a result. Steps must be taken today to ensure that real progress is made in the cause of climate protection. The necessity of such action is underlined by the growing scarcity of resources such as oil and gas.

Danube flood in Riedlingen

Information booklet issued by the Baden-Württemberg Ministry of the Environment, Climate Protection and the Energy Sector on the Renewable Heat Act.

REGIONAL IMPACT

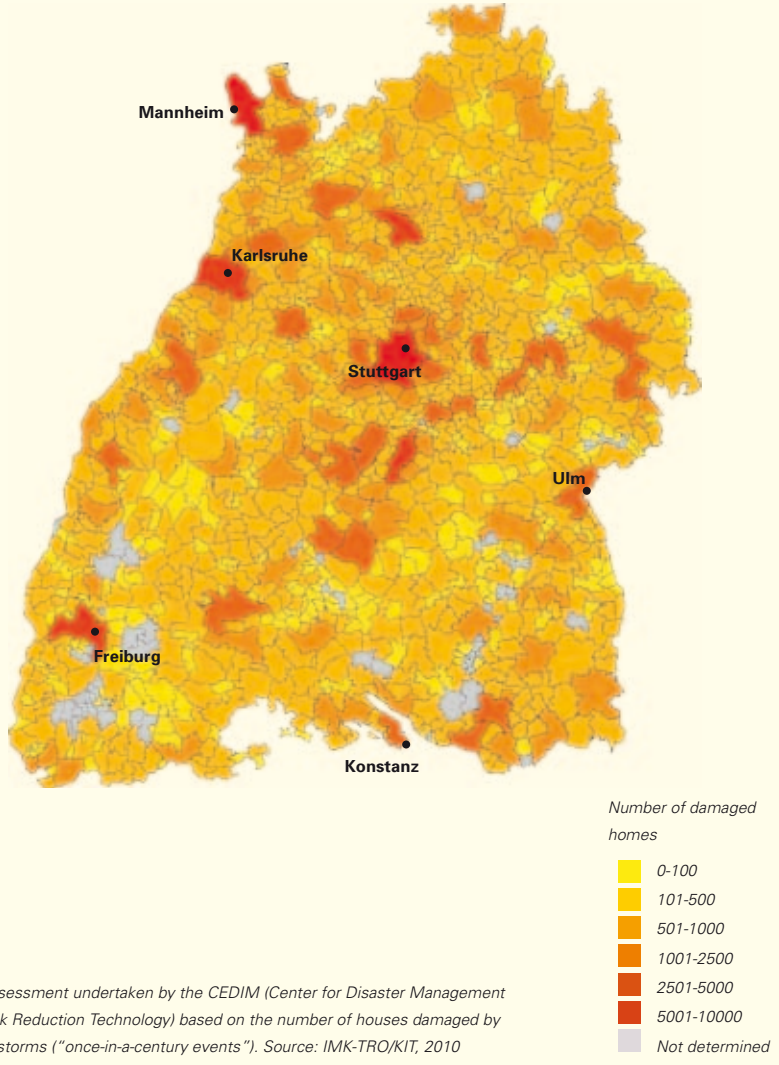
REGIONAL

Several winter storms have already caused massive damage to buildings in Baden-Württemberg. As well as the storm depression Lothar (1999, total of 8.6 billion euros) Germany has been hit by the storms Vivian and Wiebke (1990), Martin (1999), Kyrill (2007) and Xynthia (2010). Baden-Württemberg can expect to be exposed to the risk of much greater flooding in the future, particularly in the winter. If average global temperatures rise by 4.5°C by the year 2100, and in particular if appropriate adaptation measures are not taken, the federal states with the healthiest economies and largest populations will be most affected by damages caused by extreme weather events.

According to DIW estimates, these costs could amount to over 100 million euros in Baden-Württemberg alone in the decades ahead.

Houses, cars and infrastructures damaged by storm and other extreme events

SUSCEPTIBILITY OF REGIONS TO DAMAGE FROM WINTER STORMS



Risk assessment undertaken by the CEDIM (Center for Disaster Management and Risk Reduction Technology) based on the number of houses damaged by winter storms ("once-in-a-century events"). Source: IMK-TRO/KIT, 2010

Outlook

Development of adaptation strategies

The current state of scientific knowledge shows that climate change is now a fact. However, with a determined climate change policy it will still be possible to limit the impact of global warming.

Above all, the continuing process of climate change, i.e. the depth and speed of such changes, must be limited by extensive climate protection measures.

Scientists and policymakers are largely in agreement that if the increase in global average temperatures can be limited to no more than 2°C above their pre-industrial levels, the consequences could be absorbed by suitable and timely adaptation measures and serious impacts largely avoided. This target – set by Germany and the European Union – requires a substantial reduction in greenhouse gas emissions. As a highly developed and technologically leading state, Baden-Württemberg intends to act as an example and make an effective contribution to achieving national and international climate protection objectives. The State Government will therefore re-focus its energy and climate policy. To begin with it will pass its own climate protection act for Baden-Württemberg which will include binding goals for the reduction of greenhouse gases. This will be followed by an integrated energy and climate protection concept with the measures needed to achieve the defined goals.

The research results available so far also demonstrate the need to consider the impacts of

Flood protection barrier protecting an entrance

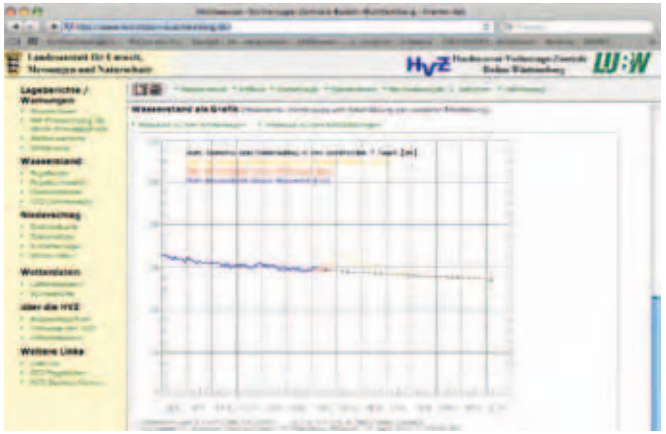
Low water

climate change, including at the regional level, as early as possible. Responsible climate policy will therefore not only aim to protect the climate by avoiding emissions of damaging greenhouse gases but also involve developing adaptation measures in response to the unavoidable consequences of climate change.

The task of adaptation to climate change concerns state authorities at every level, from the European level to local authorities. The European Commission submitted a White Paper on adapting to climate change as well as various strategic considerations on how to respond to climate change in 2009. This White Paper qualifies climate change as an overarching task embedded in the EU's various policy efforts. Germany's Federal Government adopted the German Strategy for Adaptation to Climate Change (DAS) in December 2008. The continuing elaboration and specification of the DAS resulted at the end of August 2011 in the adoption by the Federal Cabinet of the "Adaptation Action Plan" (AAP) drawn up with the federal states. Baden-Württemberg has already contributed content to the DAS and AAP and will continue to be involved in their ongoing implementation.

Baden-Württemberg also plans to develop its own adaptation strategy which will take account of the German Strategy for Adaptation to Climate Change and the action plan and which will be particularly focused on needs in Baden-Württemberg. This will create a framework for action with goals and implementation structures for measures to adapt to the consequences of climate change in Baden-Württemberg. This will avoid the negative impact of climate change, exploit potential opportunities and reduce the costs of climate change. The consequences of climate change will affect many different areas of society, albeit along varying time lines. This means that Baden-Württemberg's own adaptation strategy will be elaborated and pursued in collaboration with those affected and already active in various fields. In this context use will also be made of the results of the latest KLIMOPASS research programme. Baden-Württemberg will also use the adaptation strategy to inform those affected by climate change about the appropriate adaptation measures they can take to help themselves. Decisions on the actual form and implementation of specific measures must be taken locally. This means that adaptation to climate change is also an important issue for local authorities. Particularly urgent adaptation measures have already been adopted. These include the heat wave warning service, flood protection and low water management measures already referred to in this booklet.

WATER-LEVEL FORECAST, LOW WATER MANAGEMENT



Flood Warning Centre, Baden-Württemberg: Water level forecast for Horb am Neckar for 15 April 2010. Source: www.hvz.lubw.baden-wuerttemberg.de

Further information

MORE INFORMATION CAN BE FOUND AT OUR WEBSITE

www.um.baden-wuerttemberg.de

www.lubw.baden-wuerttemberg.de

www.hvz.lubw.baden-wuerttemberg.de

www.herausforderung-klimawandel-bw.de

www.themenpark-umwelt.baden-wuerttemberg.de

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www.dwd.de

www.klimadiagramme.de

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