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2019 Monitoring Report

on the German Strategy for Adaptation to Climate Change

Report by the Interministerial Working Group on Adaptation to Climate Change

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Content

Introduction

What are the impacts of climate change and how do we adapt?

Climate change and its consequences are already noticeable in Germany. The hot and dry summers of 2018 and 2019 as well as the heavy-rain events of 2016 and 2017 have resulted in raising public awareness of climate change. Consequences for human health, agriculture and forestry as well as private and public buildings and infrastructures have become more obvious, and climate change also triggers dynamic adaptation processes in nature (e.g. the displacement or immigration of animal and plant species) which in turn impact on humans and their economic activities. A total of c. 1,200 heat-related mortalities were recorded for summer 2018 in Berlin and Hesse by the Robert Koch-Institut (RKI/Robert Koch Institute). Drought also impacted on agriculture: Drought aid amounting to 340 million Euros was made available at Federal and Länder level. At the same time the GDV (German association of members of the insurance industry/Gesamtverband der Deutschen Versicherungswirtschaft e.V.) states an amount for 2018 of 2.8 billion Euros in terms of insured damage to buildings as well as trade and industrial enterprises. caused by storms, hailstones and heavy rain.

These losses make clear how urgent it is to take action, both in respect of protection from climate change and adaptation to the consequences of climate change. Even if humanity succeeds in limiting global warming in accordance with the climate targets agreed at the Paris Conference, our climate will continue to change. It is essential to make concerted efforts and to apply a co-ordinated approach to actions at all government levels in order to create the prerequisites for adaptation to the consequences of climate change in Germany.

In this light, the Federal government has, as early as 2008, under the auspices of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, submitted the **Deutsche Anpassungsstrategie an den Klimawandel (DAS/German Strategy for Adaptation to Climate Change)** which has been continually advanced ever since. This strategy provides the **framework at Federal level** for formulating policies regarding adaptation to climate change. The objective is to reduce the vulnerability of German society, economy and environment and to increase the country's freedom to act. In 15 central action areas the essential requirements for action are listed, and (within relevant competences) the **concrete steps and measures** taken at Federal level are described (in alphabetical order): Building Industry, Biodiversity, Soil, Energy Industry, Financial Services Sector, Fisheries, Woodland and Forestry, Trade and Industry, Agriculture, Human Health, Tourism Industry, Transport and Transport Infrastructure, Water Regime, Water Management, Coastal and Marine Protection as well as cross-sectional activities such as Civil Protection as well as Spatial Planning, Regional and Urban Development. This work was carried out in close collaboration with administrations at Länder (Federal States of Germany) and municipal level.

The DAS is a well-established, **ongoing long-term task**. It is based on an **inter-agency network** consisting of 28 Federal Government agencies, e.g. the Umweltbundesamt (UBA/German Environment Agency), the Deutsche Wetterdienst (DWD/German Meteorological Service), the Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK/Federal Office of Civil Protection and Disaster Assistance), the Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR/Federal Institute for Research on Building, Urban Affairs and Spatial Development), the Bundesanstalt Technisches Hilfswerk (THW/Federal Agency for Technical Relief) and the Bundesanstalt für Gewässerkunde (BfG/Federal Institute of Hydrology). This network incorporates a **continuous reporting system**.

As required by the DAS framework, the Federal Government now presents its second report, i.e. the **2019 Monitoring Report**. This Report underpins the impacts of climate change with solid scientific data, at the same time as providing the public as well as decisionmakers in all sectors of society with information on tangible impacts of climate change. The 2019 Monitoring Report therefore represents an update of the 2015 Monitoring Report. Future updates are to be carried out every four years. **Indicators and measured data selected from the 15 action areas** by experts were incorporated in the Report in order to demonstrate any climate-related changes which have already become apparent in present-day Germany; the Report also features any measures that were taken to counteract this trend. The consequences of temperature rise can already be seen, for instance, in terms of obvious impacts on uncultivated ecosystems (such as changes in seasonal phenology leading to extended growing seasons, as well as incipient changes in the composition of tree species in natural woodland reserves). The Monitoring Report furthermore shows evidence for precautionary efforts made at Federal Government level in view of increasing risks. The Report also makes clear that it is of vital importance to intensify our efforts in respect of protection from climate change in order to limit its impacts, at the same time taking action to adapt to climate change. This is essential in order to find effective ways of countering the unavoidable risks arising in ecological, social and economic terms and to minimise losses.

For this very reason, the Federal Government undertakes regular reviews of the DAS and subjects it to further development based on progress reports which are enacted every five years at Cabinet level. Action plan measures are agreed in conjunction with these progress reports. The next progress report on DAS is expected to be submitted in autumn 2020; it will contain the findings of the 2019 Monitoring Report.

The work was **supported and approved** at Federal Government level under the auspices of the Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit (BMU/Federal Ministry for the Environment, Nature Conservation and Nuclear Safety) within the Interministerial Working Group on Adaptation to Climate Change (IMAA). This working group incorporates representatives from nearly all federal ministries and the scientific agencies assigned to them. The Report and the underlying indicator system were developed with contributions from numerous experts in competent agencies at Federal and State level and from scientific establishments and private institutes. The work was organised by the UBA's department Fachgebiet KomPass – Klimafolgen und Anpassung in Deutschland (climate impacts and adaptation in Germany), acting as administrative office.

Key Findings

The Reporting Period 2014–2017 of the second, i.e. the 2019 Monitoring Report on DAS was characterised by a series of very warm years with extended droughts and violent downpours of heavy rain. The 2019 Monitoring Report on DAS does not contain a systematic indication of data from 2018 and 2019, because the processing of nationwide, statistically backed data tend to involve delays. Rather than illustrating the latest up-to-date developments, the ongoing monitoring under DAS focuses on the systematic observation of climate impacts and adaptation, on the basis of statistically well-founded time series. Nevertheless, as far as possible, an initial estimate of developments in 2018/19 was included in some texts of the report.

Increasing heat stress

The summers of 2003, 2018 and 2019 were the warmest in Germany since meteorological records in this country began. The annual air temperature as an aggregated mean for Germany between 1881 and 2018 was determined statistically to have risen by 1.5 °C. In the course of past decades, there is evidence for a trend towards extreme weather events marked by increasing heat extremes. In particular, the number of ‚hot days' on which the highest measured temperature amounted to 30 °C or more, has gone up significantly (Indicator GE-I-1). Based on nationwide data in 2003 the number of people dying from heat-related conditions was higher by 7,500 mortalities than would have been expected in the absence of a heatwave. For the years 2006 and 2015 respectively, approx. 6,000 additional mortalities were recorded (GE-I-2). Apart from preventative measures to protect human

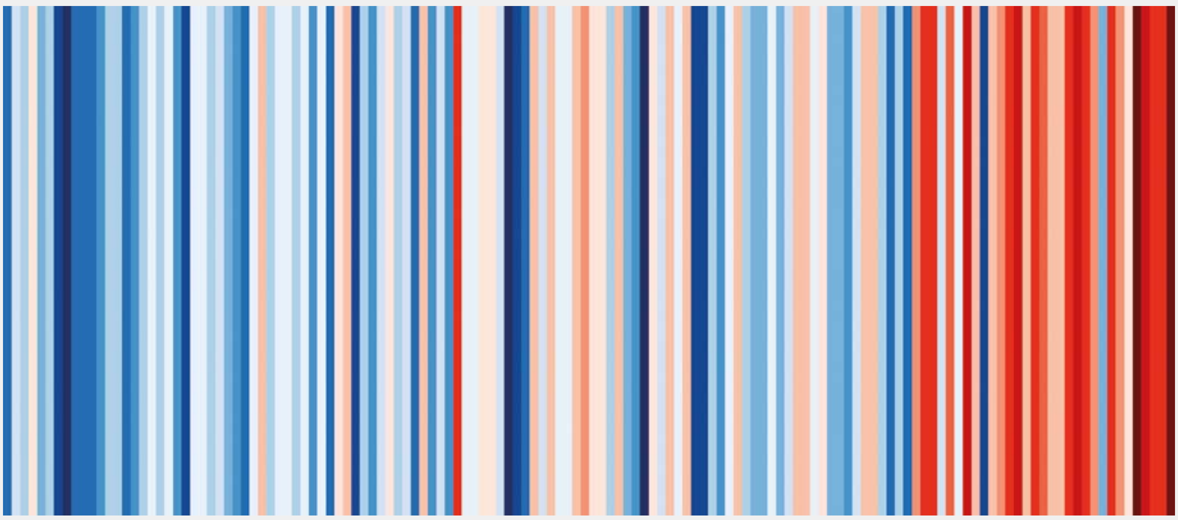


Figure 1: Chart of average temperature for Germany between 1881 and 2018 (each stripe representing one year, based on the DWD's dataset) Grafik: Ed Hawkins / showyourstripes.info

health, adaptation is also implemented at planning and construction levels, in order to reduce heat stress, especially in urban contexts (BAU-I-1, BAU-I-2, BAU-R-1, BAU-R-2, RO-R-4). Likewise, public awareness of health impacts from periods of great heat is on the increase, as demonstrated by the uptake of warning and information services and indicated by the outcomes of representative surveys (HUE-2, GE-I-1, GE-R-1, GE-R-3, BS-R-1).

Adverse effects on water usage owing to increased warming and more frequent summer droughts

The data of groundwater levels selected from nationwide statistics indicate that, in comparison with the long-term annual mean, the frequency of months with low groundwater levels below average has been increasing significantly (WW-I-1). In particular, precipitation deficits occurring in the course of several consecutive years led to reductions in groundwater levels or reduced spring flow in the years between 2013 and 2017. In view of a distinctly dry period, the data for 2018 point to the likelihood of a similar, presumably even more extreme situation arising.

The time series beginning in the 1960s for the mean flow levels of 80 river areas across Germany indicates distinct fluctuations between the years. For the hydrological winter season from early November till end of April, no statistically significant trend was discernible for the mean flow level. However, during the summer season, the flow level mean clearly drops significantly. This suggests a decrease in water availability during summer (WW-I-2). The difficult situation with regard to soil water supply (BO-I-1) as reported in 2015, is continuing. Agricultural management techniques have to be adapted in a way as to augment the soil's humus supply and to boost the soil water supply, in order to ensure being better prepared for drought periods. Between 2000 and 2017, climate change impacts were increasingly taken into account in aspects of landscape planning (in UK known as town and country planning) and in other specific fields of planning, e.g. the designation of surface areas for preventive flood protection (BD-R-1, RO-R-3).

Damage from heavy rain and flash floods in urban areas

For the first time, illustrations of heavy rain events in residential areas (BAU-I-4) have been incorporated in the 2019 DAS Monitoring Report. This is to focus the DAS Monitoring process more precisely on the outcomes of the vulnerability analysis which in 2015 identified heavy rain and flash floods as strategic focal points. One precaution against losses from heavy rain and flash floods in urban areas is incorporated in DAS Monitoring by means of addressing the density of extended insurance cover for damage from natural hazards. The data show that although the insurance density has increased significantly in recent years, looking at it nationwide, it is still relatively low, i.e. with 43 % for building insurance and with 24 % for building contents insurance.

Floodwater and river flooding

The development of floodwater days does not show any significant trends for the time series, either for the summer or for the winter season (WW-I-3). The development of floodwater is always related to specific combinations of weather conditions which have so far not occurred either systematically, regularly or repeatedly. One example of this are so-called Vb (or Five-B) weather conditions which e.g. caused the river Elbe to flood in 2002 as well as causing other floodwater events. The distribution of floodwater days impacting on hydrological winter and summer seasons has so far not indicated a trend. Apart from climate change, there are however numerous other developments which affect the phenomenon of floodwater events.

Sea level rise and storm surges

The levels of North Sea and Baltic Sea covered in the 2019 DAS Monitoring Report indicate a predominantly significant rise in sea levels (WW-I-8). The increasing intensity of storm surges (WW-I-9) can be attributed mostly to sea level rise. For coastal regions, especially for estuaries and low-lying coastal areas, this signifies a gradually increasing threat.

Changes in species composition and natural development phases resulting from gradual temperature rise

Rising temperatures also affect natural systems. As a result, the duration of the growing period has increased further since submission of the 2015 DAS Monitoring Report (BD-I-1). A comparison shows that e.g. characteristic development phases of wild plants (such as unfolding of leaves, development of flower buds or fruiting bodies in spring, summer or early autumn, begin earlier, and typical development phases at the height of autumn, in late autumnn and winter begin later than before. Changes in seasonal weather phases can have both positive and negative effects on agriculture. An earlier onset of apple blossom, for example, signifies a greater risk of late frost damage which can result in crop shortfalls or failures (LW-I-1).

Likewise, in ecosystems hardly affected by management activities, the greater frequency of warm and dry years demonstrates a distinct impact. For example, the content of beech trees compared to species better adapted to droughts in warm-dry natural woodland reserves has decreased (FW-I-1). The current condition of woodlands and forests and any changes since the last National Forest Inventory recorded in 2012 will not be available for consideration in the third monitoring report until after the next National Forest Inventory in 2022. Any impacts from increasing warming are also noticeable in significantly increased water temperatures in lakes (WW-I-5) and in the North Sea (WW-I-7).

Even if the annual mean temperatures rise continuously, impacts on ecosystems from long, cold winters will remain active. This is illustrated by the development of bird species communities (BD-I-2). Since 1990 the composition of bird species communities has shifted in favour of thermophilic species. In the years 2009/10 to 2012/13 there were a number of hard winters with adverse impacts on the numbers of many breeding birds. These hard winters particularly affected species which had migrated to Germany from more southerly climate zones.

The methodology of the DAS Monitoring Indicator System

Indicators

For the second report, i.e. the 2019 Monitoring Report, the indicator system dating back to 2015 was reviewed and developed further. The majority of indicators was updated in accordance with the methodology applied in 2015. A total of 21 indicators were reviewed and, where necessary, developed further.

In particular, the indicators for the action areas Human Health, Water Regime, Water Management, Coastal and Marine Protection, Building Industry as well as Transport and Transport Infrastructure were enhanced and extended by adding essential themes.

The action area Water Regime, Water Management, and Coastal and Marine Protection was developed in close collaboration with experts from the Federal and Länder governments within the framework of the German Working Group on water issues of the Federal States and the Federal Government (LAWA). The indicators were partly underpinned by comprehensive data made available by various authorities in individual states (Länder) of the Federal Republic. The objective was to establish a jointly agreed and approved indicator system on water management for use by the Länder for their own reporting systems alongside the Federal Government's reporting system on consequences of climate change.

In total, the DAS Monitoring Indicator System comprises, since redevelopment, 105 monitoring indicators, 56 of which describe climate change impacts (impact indicators), while 44 describe adaptation measures or activities and conditions to support the adaptation process (response indicators). In addition, there are 5 monitoring indicators which span several action areas; these indicators are not classified in the impact or response categories.

There are five indicators which cannot be featured in the report as their underlying data are no longer available. This applies to the following indicators covered in the 2015 DAS Monitoring Report: GE-I-4 Risks from oak processionary moth infestations, BO-R-3 organic soil areas, WW-I-6 duration of the stagnation period in standing water, LW-I-3 quality of harvested products, EW-I-4 potential and actual wind energy yields.

Principally, all monitoring indicators are intended to illustrate developments across the whole of Germany. Regional differences are illustrated only in a few exceptional cases. In respect of thematic aspects which are not sufficiently underpinned by nationwide data to allow the creation of indicators, it was possible to portray so-called case studies. Such case studies demonstrate by means of concrete spatially limited data sets, what statements might be generated at the nationwide scale given the relevant data.

Handling uncertainties

It is not possible, within quantitative analysis, to illustrate all relevant processes and action approaches by means of monitoring indicators. Many processes of data collection are still in their initial stages, and extended time series will be required before it is possible to interpret any developments. Restrictions on the availability of data also mean that the number of monitoring indicators used currently does not necessarily reflect the importance of relevant action areas or cross-cutting themes.

The data closing for updating the time series in the second, i.e. current Monitoring Report was 31.12.2017. It follows that principally, the last-named digits in the charts refer to the year 2017. Wherever possible the report texts provide a perspective of the developments in 2018 and 2019. In a few cases, the processes of data collection underpinning the monitoring indicators take place at longer intervals, as e.g. for the inventory of the national forest; in this case updating will take place when the next monitoring report is generated.

In several monitoring indicators it is difficult or impossible to identify the causality of climate change, owing to the multitude of various factors such as changes in the environment, society or economy. When assessing damage to forests, for example, it is necessary, in addition to any consequences of climate change such as seasonal heat or drought periods or severe storms, to take into account other impacts not related to climate change, such as nutrient inputs, acidification and high ozone concentrations which may impact on the health of trees. Intense discussions took place in the course of developing the DAS monitoring system regarding cause-and-effect-relationships.

Fuzzy interpretations can also occur in the course of allocating adaptation measures. It is indeed possible to describe many specific adaptation measures such as the operation of the DWD's heat warning service. However, other measures intended to further the adaptation to climate change impacts are not necessarily restricted to this objective alone, or indeed, they may have been motivated by completely different reasons. Nevertheless, these measures can be useful in supporting an effective adaptation process.

In view of the uncertainties and a degree of data fuzziness as discussed above, the intention is to continue reviewing and redeveloping the monitoring indicator system in the course of future updating cycles.

Lists of comprehensive related literature were intentionally not included as they might go beyond the range and multitude of themes addressed and they might also go beyond the framework of this Monitoring Report.

Assessing the developments

DAS Monitoring Indicators are intended to facilitate an assessment of developments. Benchmark is the DAS objective to reduce the vulnerability to climate change impacts and to maintain and increase the adaptability of natural and social systems to the inevitable impacts of climate change. The intention is that the political objectives outlined in various action areas can be maintained even when faced with changes in the climatic framework conditions. The objectives adopted here make reference to the objectives set in DAS 2008 and/or objectives laid down in other political strategies, laws and directives.

The actual DAS Monitoring Indicators do not contain any specific objectives or ratings. For this reason, the assessment is restricted to the outcomes of statistical trend calculations and an appraisal whether, judging by the DAS objectives, the trend is basically heading in the right direction.

Nevertheless, the appraisal of trends does not seem to be useful in all cases, because the consequences of changes are not always fully known. For example, an earlier flowering of winter rapeseed as a consequence of climate change is a sign that unwelcome climate change impacts on agricultural cultivation. However, the earlier flowering is not itself necessarily a negative phenomenon. In cases of this kind, the illustration is restricted purely to the outcome of the trend analysis without making an appraisal.

In respect of their trend developments, the time series were classified within the framework of statistical trend analysis. For all indicators the analyses were carried out by the Statistische Beratungslabor (Consulting Laboratory at the Institute for Statistics) of Ludwig Maximilian University, Munich. Both rising and falling trends and also trends with trend reversal (square trends) are illustrated. Trend

Trend description	
	Rising trend
	Falling trend
	Trend with trend reversal: first falling, then rising
	Trend with trend reversal: first rising, then falling
	No trend

Trend appraisal	
	Favourable development
	Unfavourable development
	Appraisal of development impossible

reversal is useful for describing, especially when observing extended time series, developments which started out as negative trends but, owing to successful adaptation measures, have recently become positive.

For all time series, trends were analysed by means of setting seven or more data points. In the process of trend analysis, all data points of the relevant time series were taken into consideration. Any data series with insufficient data points or based on surveys that were irregular or temporally too far apart were eliminated from analysis.

DAS Monitoring Indicators – an overview

Cluster 'Health'

Impact-Indicators – Effects			Response-Indicators – Adaptations	
Action area Human health				
GE-I-1	Heat exposure		GE-R-1	Heat warning service
GE-I-2	Heat-related mortalities		GE-R-2	Successes of the heat warning system
GE-I-3	Contamination with pollen of ragweed		GE-R-3	Information on pollen
GE-I-4	Pathogen carriers (former GE-I-5)			
GE-I-5	Contamination of recreational bathing waters with cyanobacteria (former GE-I-6)			

Cluster 'Water'

Impact-Indicators – Effects			Response-Indicators – Adaptations	
Action area Water regime, water management, marine and coastal protection				
WW-I-1	Groundwater level (basically revised in 2019)		WW-R-1	Water use index
WW-I-2	Mean run-off (basically revised in 2019)		WW-R-2	Investments in floodwater protection for inland waterways (new in 2019)
WW-I-3	Floodwater (basically revised in 2019)		WW-R-3	Riparian vegetation on the banks of small and medium-sized watercourses (new in 2019)
WW-I-4	Low water (basically revised in 2019)		WW-R-4	Investment in coastal protection (former WW-R-3)
WW-I-5	Water temperature of standing waters (case study, revised and extended in 2019)			
WW-I-6	Start of the spring algal bloom in standing waters			
WW-I-7	Water temperature in the sea (revised in 2019)			
WW-I-8	Sea levels (revised in 2019)			
WW-I-9	Intensity of storm surges (revised in 2019)			
Action area Fisheries				
FI-I-1	Distribution of thermophilic marine species			
FI-I-2	Occurrence of thermophilic species in inland waters			

Cluster 'Land'

Impact-Indicators – Effects		Response-Indicators – Adaptations	
Action area Soil			
BO-I-1	Soil moisture levels in farmland soil	BO-R-1	Humus content of arable land
BO-I-2	Rainfall erosivity	BO-R-2	Permanent grassland
Action area Agriculture			
LW-I-1	Agrophenological phase shifts	LW-R-1	Adaptation of management rhythms
LW-I-2	Yield fluctuations	LW-R-2	Cultivation and propagation of thermophilic arable crops
LW-I-3	Hailstorm damage in agriculture	LW-R-3	Adaptation of the variety spectrum
LW-I-4	Infestation with harmful organisms	LW-R-4	Maize varieties by maturity groups
		LW-R-5	Use of pesticides
		LW-R-6	Agricultural irrigation
Action area Woodland and forestry			
FW-I-1	Tree species composition in designated forest nature reserves	FW-R-1	Mixed stands
FW-I-2	Endangered spruce stands	FW-R-2	Financial support for forest conversion
FW-I-3	Incremental growth in timber	FW-R-3	Conversion of endangered spruce stands
FW-I-4	Damaged timber – extent of random use	FW-R-4	Conservation of forest-genetic resources
FW-I-5	Extent of timber infested by spruce bark beetle	FW-R-5	Humus reserves in forest soils
FW-I-6	Forest fire risk and forest fires	FW-R-6	Forestry information on adaptation
FW-I-7	Forest condition		
Action area Biodiversity			
BD-I-1	Phenological changes in wild plant species	BD-R-1	Consideration of climate change in landscape programmes and landscape framework plans
BD-I-2	Community temperature index for bird species	BD-R-2	Protected areas
BD-I-3	Restoration of natural flood-plains		

Cluster 'Infrastructure'

Impact-Indicators – Effects		Response-Indicators – Adaptations	
Action area Building industry			
BAU-I-1	Heat stress in urban environments	BAU-R-1	Recreation areas (modified in 2019)
BAU-I-2	Summer-related heat island effect	BAU-R-2	Green roofing of federal buildings (new in 2019)
BAU-I-3	Cooling degree days (new in 2019)	BAU-R-3	Specific energy consumption for space-heating by private households
BAU-I-4	Heavy rain in residential areas (new in 2019)	BAU-R-4	Funding for building and refurbishment adapted to climate change

Impact-Indicators – Effects			Response-Indicators – Adaptations	
BAU-I-5	Claims expenditure for property insurance (modified in 2019)		BAU-R-5	Insurance density of extended natural hazard insurance for residential buildings (modified in 2019)
Action area Energy industry (conversion, transport and supply				
EW-I-1	Weather-related disruptions of power supply		EW-R-1	Diversification of electricity generation
EW-I-2	Weather-related unavailability of power supply		EW-R-2	Diversification of end energy consumption for heating and refrigeration
EW-I-3	Reduced power generation due to ambient temperature in thermal power plants		EW-R-3	Electricity storage options
			EW-R-4	Water efficiency of thermal power plants
Action area Transport, transport infrastructure				
VE-I-1	High-water closures to shipping on the Rhine (modified in 2019)			
VE-I-2	Low-water restrictions to shipping on the Rhine (modified in 2019)			
VE-I-3	Heavy rain and roads (new in 2019)			
VE-I-4	Weather-related road traffic accidents			
VE-I-5	Impacts on roads from extraordinary weather events and disasters (case study, new in 2019)			

Cluster 'Economy'

Impact-Indicators – Effects			Response-Indicators – Adaptations	
Action area Trade and industry				
IG-I-1	Heat-related loss in performance		IG-R-1	Intensity of water consumption in the manufacturing sector
Action area Tourism industry				
TOU-I-1	Coastal bathing temperatures			
TOU-I-2	Bed nights in coastal tourist areas			
TOU-I-3	Heat stress in spas used for their healthy climate			
TOU-I-4	Snow cover for winter sports			
TOU-I-5	Bed nights in ski resorts			
TOU-I-6	Seasonal bed nights in German tourist areas			
TOU-I-7	Holiday destination preferences			
Action area Financial services industry				
FiW-I-1	Claims ratio and combined ratio in homeowners' comprehensive insurance			
FiW-I-2	Incidence of storms and floods			

Cluster 'Spatial Planning and Civil Protection'

Impact-Indicators – Effects			Response-Indicators – Adaptations	
Action area Spatial planning, regional and urban development				
			RO-R-1	Priority and restricted areas reserved for wildlife and landscape conservation
			RO-R-2	Priority and restricted areas for groundwater conservation or the abstraction of drinking water
			RO-R-3	Priority and restricted areas for (preventive) flood control
			RO-R-4	Priority and restricted areas for special climate functions
			RO-R-5	Land used for human settlements and transport infrastructure
			RO-R-6	Settlement use in flood-risk areas
Action area Civil protection				
BS-I-1	Person hours required for dealing with damage from weather-related incidents		BS-R-1	Information on how to act in a disaster situation
			BS-R-2	Precautionary measures for protection of the public
			BS-R-3	Training exercises
			BS-R-4	Active disaster protection workers

Cross-sectional Indicators

Response-Indicators – Adaptations	
HUE-1	Manageability of climate change impacts
HUE-2	Usage of warning and information services
HUE-3	Federal grants for promoting research projects on climate change impacts and adaptation
HUE-4	Adaptation to climate change at municipal authority level
HUE-5	International finance for climate adaptation

Development of Germany's climate

The development of Germany's climate since the end of the 19th century

A climate can be described in terms of the average condition of the atmosphere, characteristic extreme values and in terms of the frequency curve of meteorological phenomena such as air temperature, precipitation and wind in a specific location. A climate is the outcome of complex interactions among all components that make up the system of land, atmosphere and oceans. Also part of this system are the biosphere with seasonal changes in vegetation, the hydrosphere, the soil and the cryosphere (ice). The fact that climate changes in the course of time is known at least from our knowledge about the last ice age which covered major parts of present-day Germany with a thick blanket of ice. The evaluation of observational data since the mid-19th century indicates progressive global warming which cannot be attributed to natural causes, and today it is considered an established scientific fact that further temperature increases are to be expected. The mean value of average temperatures on the surface of land and water has steadily increased in the course of recent years. Since the 1960s, each decade was warmer than the previous one, and the data available so far for the current decade indicate that the decade from 2011 to 2020 will be marked by a new maximum level. According to the analyses carried out by the American research organisations NASA and NOAA, the global average temperature is currently around 1 °C above the level prevailing in the mid-18th century (Fig. 2). It should be noted that most of the warming occurred in the course of the past 35 years: 15 of the 16 warmest years in global records were recorded in the years since 2001, with 2016 being regarded globally as the warmest year so far, and the past few years from 2015 until 2018 were, in global terms, the four warmest years since systematic records began.

For Germany sufficient data exist from 1881 onwards enabling us to identify detailed climate changes nationwide. However, this can be said only for variables such as monthly observations of temperature and precipitation. The relevant daily data as well as other measured variables such as sunshine duration are generally not available nationwide before 1951. It is possible, however, on the basis of available data to retrace at least the average conditions of the two most important meteorological variables up to the end of the 19th century and thus essentially also to the beginning of human impacts on the climate. While the impact of additional greenhouse gases on the development of temperatures in the course of the past 139 years is patently obvious, the correlation with changes in precipitation is less obvious. This is partly due to a change triggered by general warming in large-scale atmospheric conditions. Nevertheless, precipitation is a crucial factor in the availability of water and is of equally great interest as temperature itself. Other meteorological factors were not illustrated in this context because they were considered to be of somewhat minor importance. Besides, these time series, as they are shorter by 50 %, allow only a limited comparison with temperature and precipitation processes. The latter is basically also true in respect of the examination of extreme events, as daily measuring values are required for such examinations. Nevertheless, owing to their high damage potential, it is precisely these events which represent the greatest threat to our society. It was therefore decided to carry out an analysis of changes observed so far, despite the limited availability of data.

Average climate changes

The assessment of mean values for atmospheric conditions was based on summarising the monthly data available for seasonal and annual mean values. In addition, the data collected at selective points in meteorological stations were applied scientifically to Germany nationwide.

Temperature

The annual air temperature as an aggregated mean for Germany between 1881 and 2018 was determined statistically to have risen by 1.5 °C[I] (see figure 2). This value is by 0.5 °C higher than the global temperature throughout the same period of time. Apart from such long-term evaluations, it is customary, in line with recommendations by the World Meteorological Organisation (WMO), to collect mean values for a period of 30 years in order to ascertain the nature of the climate and its changes. This makes it possible to eliminate the influence of short-term atmospheric fluctuations from a statistical appraisal of the climate, at the same time making it possible to trace the ups and downs of the climate as a whole. To this end, the WMO has suggested to focus on the period of 1961-1990. A comparison of the climate reference period (1961–1990) with the actual reference period (1981–2010) confirms that the air temperature mean in Germany rose from 8.2 °C to 8.9 °C.

A closer scrutiny of the temporal development shows that the rise in temperature did not take place evenly. In fact, there were phases of warming as well as periods of stagnation, interspersed from time to time with shorter periods during which temperatures tended to decrease slightly. One reason for this is the wide range of variations in atmospheric conditions from year to year with regard to, globally speaking, a relatively small region like Germany. Figure 2 demonstrates in fact that the variability of temperatures in Germany (bar) is much greater than the global temperatures (plane). However, in the course of periods extending over several decades, the so-called decadal climate variability also plays a crucial role. These are periodic variations extending over several years or even a few decades, which are closely linked with ocean currents. Dependent on temperatures on the surface of

I All statements made in the text regarding changes in temperature and precipitation, as well as the indices for extremes based on those variables, were calculated by means of (least square) linear trend; they are considered statistically sound provided they achieve a significance level of at least 99 %.

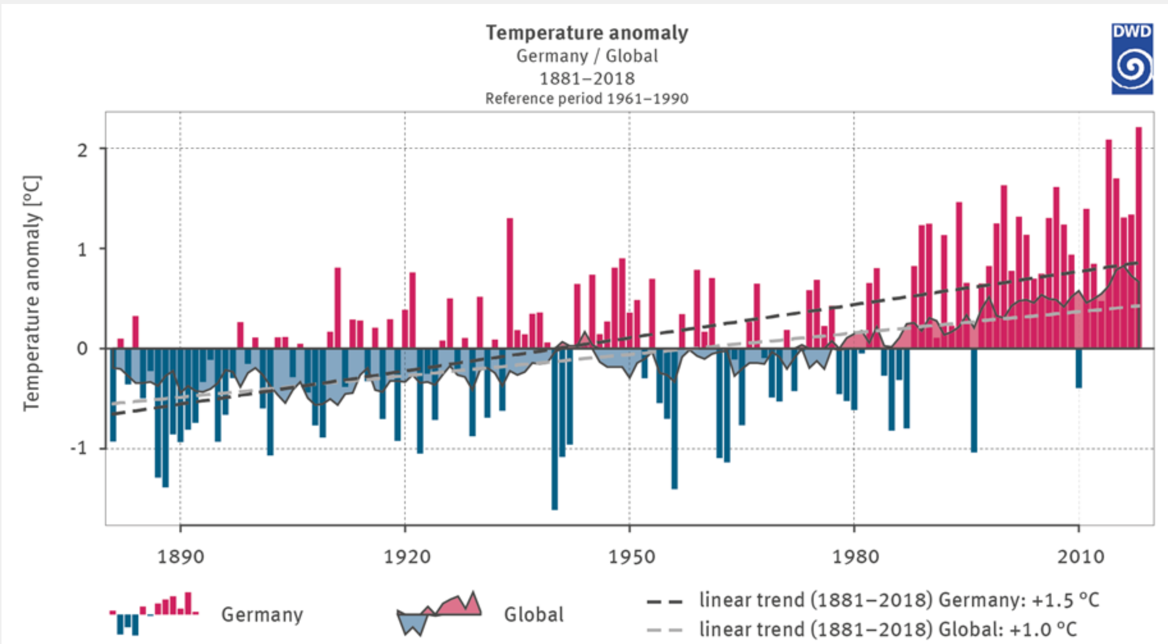


Figure 2: Deviation of temperature for Germany and globally from the long-term mean 1961–1990 (data: DWD, NOAA)

the oceans, there will be phases in which the atmosphere either warms up or cools down. These phases overlie the influence on the climate from external driving factors. However, apart from natural elements such as solar irradiation and volcanic activity, human influences have to be taken into account, such as changes in land use, air pollution owing to sulphur output from industrial plant as well as emissions of greenhouse gases such as carbon dioxide. Periods of a greater cooling effect exerted by ocean circulation on the atmosphere can therefore lead to a total concealment of the long-term trend, even at times when the total of extreme climate drivers alone would lead to warming. As soon as the oceans' influence is reversed, temperatures can be observed to increase.

In Germany the temperature rise observed hitherto seems to be homogenous throughout the country. In principle this applies also to the various meteorological seasons. Just in summer (June to August) the value for a surface area mean of 1.4 °C deviates slightly from the annual mean. For the other seasons the same temperature increase of 1.5 °C is the same as for the year as a whole. Roughly the same can be said for spatial differences. In this case, the annual mean temperature rise ranges from 1.3 °C to 1.6 °C, with the warming tendency in the western and southern Länder a little higher so far whereas in the northern Länder such as Brandenburg and Berlin, this tendency is a little lower than the Länder mean. Greater deviations from this general spatial distribution can be observed exclusively in the winter months. During the winter season temperature rise in the north-eastern Länder by values between 1.2 °C to 1.3 °C has so far been generally lowest whereas other Federal states such as Bavaria recorded a temperature rise up to 1.7 °C.

Precipitation

Contrary to temperature, there are distinct differences in changes to precipitation in Germany, especially by season but also in spatial terms. In summer the rainfall mean has remained largely unchanged whereas in winter especially, conditions have become significantly more humid. Likewise, the amounts of precipitation have increased at times of seasonal change, although this increase is distinctly lower and statistically unproven. Overall, the surface area mean for Germany since 1881 shows an increase in the annual mean precipitation of 8.7 %. However, there are major differences from a spatial point of view. Especially the states in the north-west of Germany show distinct increases in wet conditions of up to 16 % in Schleswig-Holstein, whereas precipitation figures from Mecklenburg-Vorpommern to Saxony-Anhalt and Thuringia show only a slight increase in the annual mean (less than 10 %). In Saxony

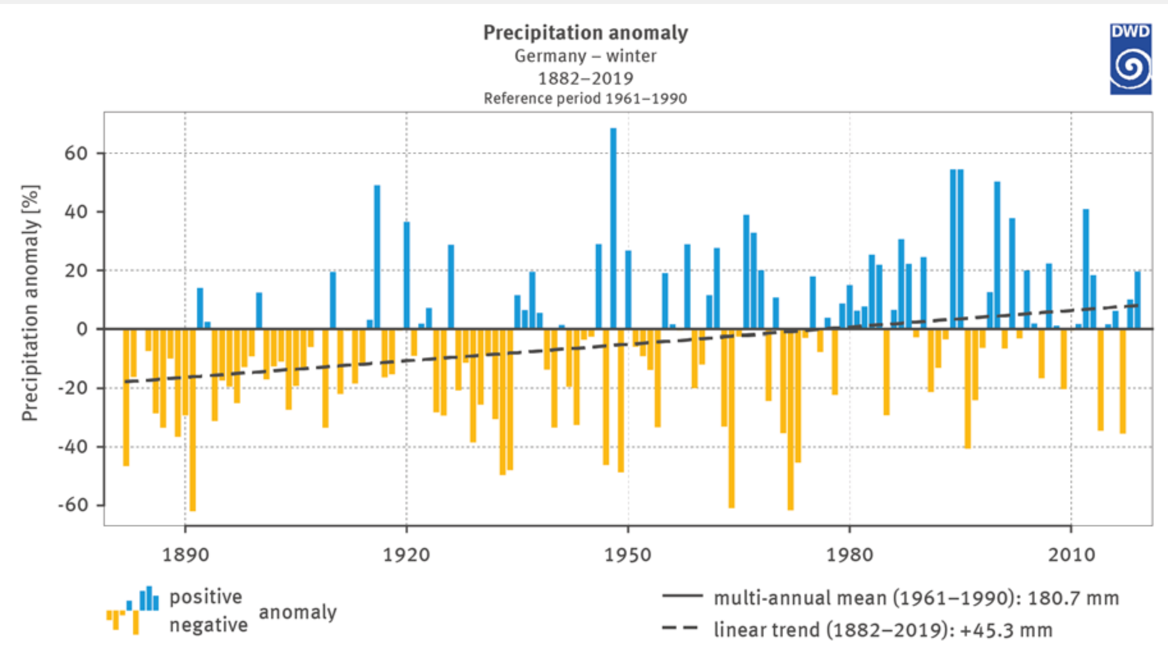


Figure 3: Percentage of deviation of winter precipitation (December, January, February) for Germany from the multi-annual mean of winter precipitation totals 1961–1990

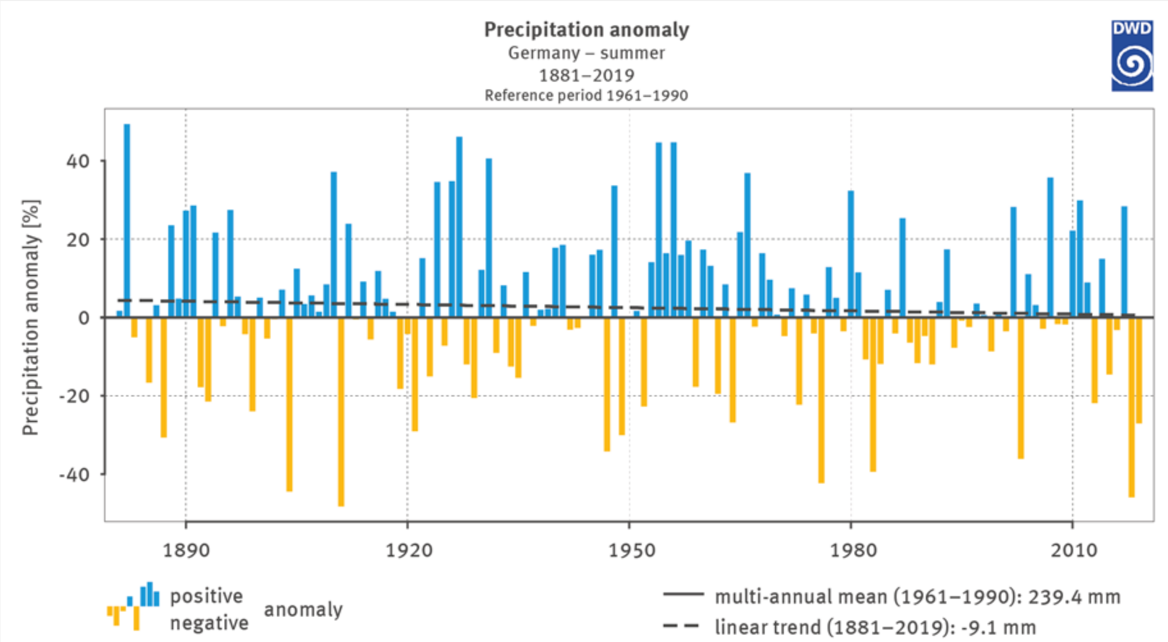


Figure 4: Percentage of deviation of summer precipitation (June, July, August) for Germany from the multi-annual mean of summer precipitation totals 1961–1990

conditions have actually become slightly drier during the same period. Spatially the picture is basically similar for the transitional seasons of spring and autumn.

The most distinct changes have so far been observed for the winter season. As demonstrated in Fig. 3, the surface area mean for average precipitation levels has increased by 25 % since winter 1881 / 1882. The spatial distribution of changes is obviously similar to that of temperature at this time of year. In other words, the least increases i.e. values of less than 25 % have so far been recorded in the north-eastern states of Germany. In the other German Länder the rainfall has increased more than can be said for the nationwide average. In the light of these spatially differing variables for warming and increases in precipitation, it can be said that the differences in the continentality of regions, i.e. in relation to the influence of land and sea on the climate at a specific location, show a slight rising tendency in the course of the 20th century. With regard to the summer months, there has been hardly any change so far. While it is true that the precipitation mean at that time of year has decreased by 3.8 % since 1881, it must also be said that the overall minimal decrease, which is within the range of natural variability, does not allow any conclusions even regarding tendency (see Fig. 4).

Changes in extreme situations

As the term implies, extreme situations are rare in that they deviate strongly from usual situations. Consequently, statistical analyses are less resilient than evaluations of average situations. So-called once-in-a-century events (i.e. extreme events which statistically occur once in 100 years) have to be determined e.g. on the basis of series of measurements which typically extend to a little more than a hundred years. A relatively easy and very descriptive method of determining changes in extreme events are so-called climatological key days on which threshold values are recorded, i.e. so-called threshold value events. This is, in fact, an evaluation of days on which e.g. the maximum temperature exceeds a specific threshold value, as e.g. the number of hot days with a maximum temperature of at least 30 °C. Apart from key days, it is possible to utilise other indices which can also be used for recording extreme climate events such as heat or drought periods. Listed below are various indices for the analysis of changes in extreme events regarding temperature and precipitation levels.

Statistically backed statements on changes in the frequency of cases where threshold values have been exceeded are already available: The frequency of hot days has increased in Germany nationwide, whereas ice days (days with maximum temperatures of < 0 °C) have become more and more infrequent during the past 60 years. At the same time, the frequency of intensive hot periods has increased, and the heat intensity has increased nationwide in Germany since 1951.

It is more difficult, however, to make reliable statements regarding trends of heavy precipitation events.. On one hand, such events display great variability both spatially and temporally. On the other hand, especially during summer months, convective events (the development of showers and thunderstorms) are considered relevant in cases where they occur either within the space of an hour or less. Although it is possible to observe tendencies towards a greater frequency of heavy precipitation events in the course of the past 65 years, it has so far not been possible, owing to the lack of available data, to make any statistically backed climatological statements on changes in heavy precipitation events.

Temperature

For the analysis of temperature extremes the amount of hot days and ice days was taken into account. Furthermore, the most intensive annual 14-day heat period with a daily maximum of at least 30 °C air temperature for the period 1951–2018 was evaluated for eight German cities.

Since 1951 there has been an increase in the number of hot days in terms of the surface area mean for Germany from a mean of approximately three days per annum to a current mean of approx. ten days per annum (see Fig. 5, left). More than ten hot days have never been recorded in Germany before 1994. The years with the most hot

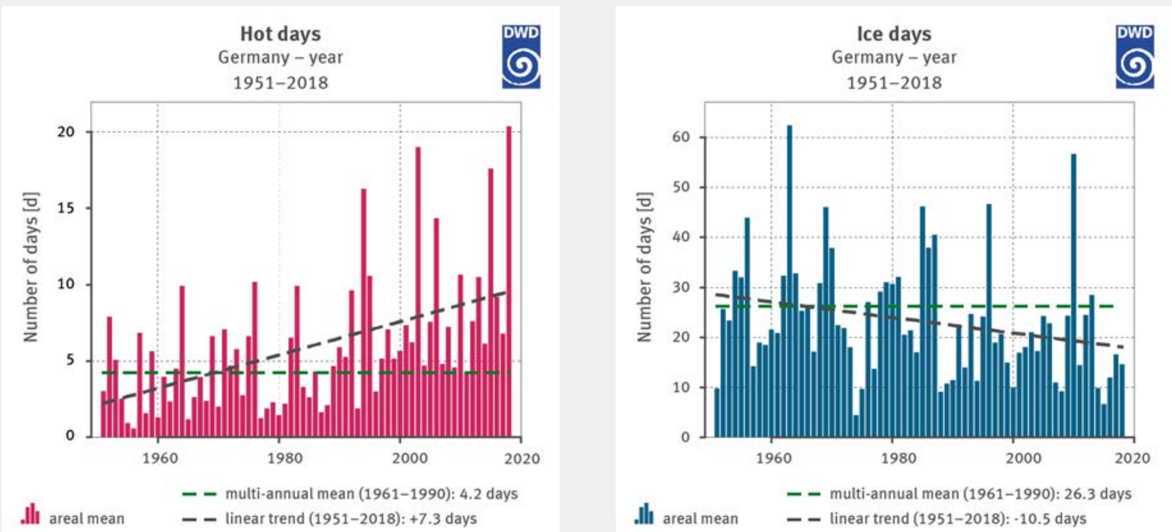


Figure 5: Number of hot days (left) and ice days (right) for Germany 1951-2018

days were 2018, 2003 and 2015. This increase is backed up by statistics, notwithstanding great variability of this index from year to year. In contrast, the decrease in the mean of ice days by approximately 27 days per annum to currently approx. 28 days per annum is much less distinctive and statistically not proven (see Fig. 5, right).

Figure 6 shows the most intensive annual 14-days heat period for several cities, with a daily maximum air temperature mean of at least 30 °C for the period 1950–2018. Regarding the cities examined, it is clear to see that the frequency and intensity of the intensive heat periods examined in this context show a rising tendency from north to south. Generally speaking, the highest daily maximum temperature mean in heat periods in the more northerly cities lies below 33 °C, although this value is often exceeded in southern cities. There are fewer recordings for Munich than is typical for the south, because the recording station is located at a relatively high altitude (515 m). Furthermore, it can be seen that such extreme heatwaves have occurred more frequently since the 1990s; e.g. Hamburg never experienced such events between 1950 and 1993, whereas five extreme heatwaves have occurred there since 1994.

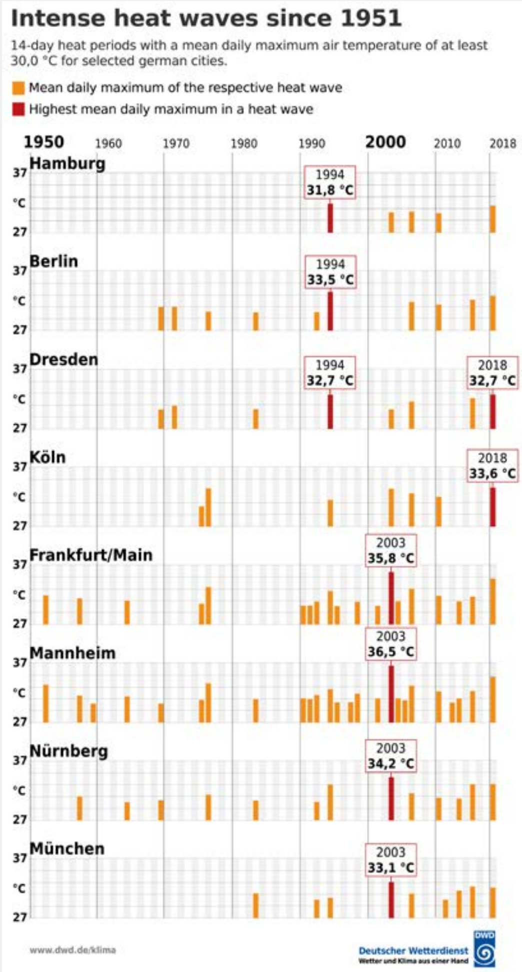


Figure 6: Mean value of the warmest 14-day period per annum for eight German cities (the height of a bar indicates the 14-day mean calculated, while the red bar indicates the year with the most intensive heat period so far)

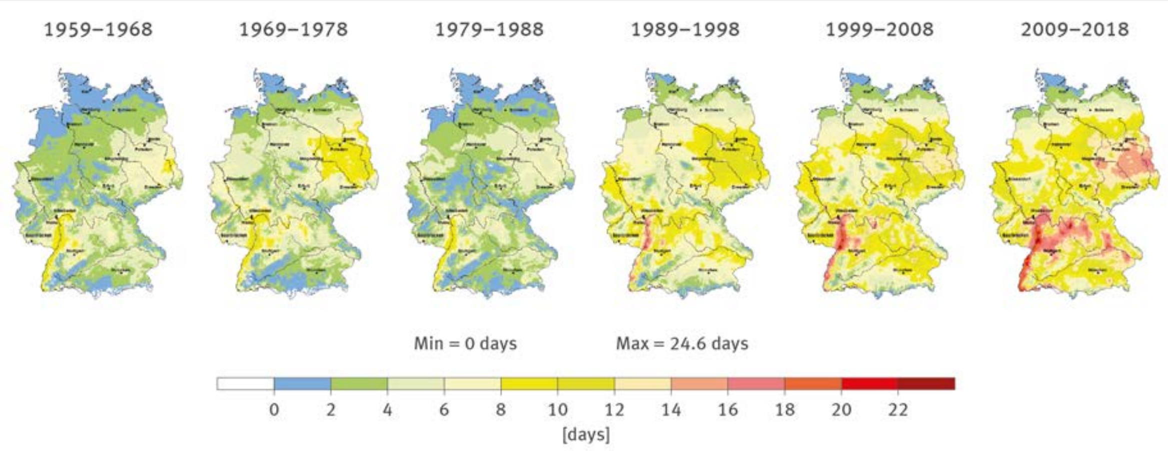


Figure 7: Annual mean number of hot days

The temporal development of surface area mean values contained in temperature indices is clearly reflected in their spatial development. Likewise, the major spatial differences between individual German regions are clearly visible. Between 1959 and 1968 the mean of hot days was predominantly between zero and four days per annum. Just along the Rhine trough and in north-east Germany south of Berlin between four and eight such days occurred, while in parts of the southern Rhine trough up to ten such days occurred (see Fig. 7). Until the decade of 1999–2008, the number of hot days increased on average by up to 18 days per annum. The extreme north of Schleswig-Holstein was the only area where that decade again showed fewer than two hot days per annum. In the course of the past ten years the number of hot days, especially in eastern Germany and in the Rhine-Main area, has again increased markedly. As a result, the multi-annual mean in large areas of the south and east shows more than ten such days per annum.

Precipitation

Relatively warm air is able to absorb more water vapour than relatively cold air. This is why principally, consistent relative air humidity is expected to coincide with greater precipitation. Besides, it can be assumed that, especially on the so-called convective scale, i.e. the development of showers and thunderstorms, an intensification of processes leading to the development of clouds and precipitation can be expected as a result of changes in meteorological conditions. The heavy precipitation occurring under such conditions would then even increase disproportionately compared to the increased content of water vapour in the air. The term heavy rain is used for major precipitation amounts per time unit. It typically results from convective clouds (e.g. cumulonimbus clouds). Heavy rain can lead to a fast rise in water levels and flooding which are often accompanied by soil erosion. The three warning stages operated by the DWD for different durations are illustrated in Table 1.

	Heavy rain		Continuous rain	
Duration	1 hour	6 hours	24 hours	48 hours
Remarkable weather	15 bis 25 l/m²	20 bis 35 l/m²	30 bis 50 l/m²	40 bis 60 l/m²
Severe weather	25 bis 40 l/m²	35 bis 60 l/m²	50 bis 80 l/m²	60 bis 90 l/m²
Extremely severe weather	> 40 l/m²	> 60 l/m²	> 80 l/m²	> 90 l/m²

Table 1: DWD's warning stages for various duration levels of heavy and continuous rain

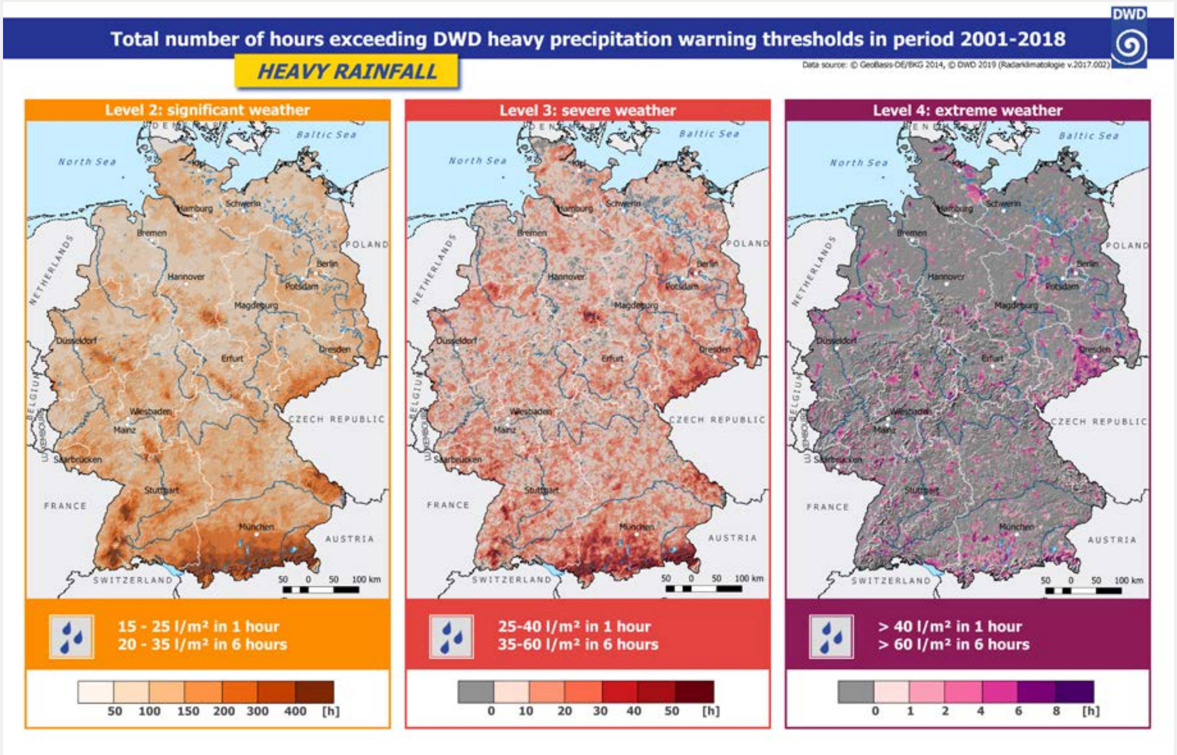


Figure 8: Total of precipitation hours within a period from 2001 to 2018, during which the DWD's warning thresholds were exceeded (the database is founded on the quantified precipitation analyses of data collected by the Wetterradarverbund (association of weather radar stations in Germany), as well as from the automated ombrometer and from any associated measuring network partnerships operated by individual states of Germany (source: DWD))

It must be borne in mind, however, that several other factors and processes play an essential role in the development of precipitation, thus leading to regional differences. Precipitation will not increase evenly in all areas, and in some areas conditions might become drier.

Depending on prevailing measuring conditions, a differentiation is often made between daily precipitation totals and shorter intervals down to durations of 5 minutes. However, many investigations are limited to a minimum temporal resolution of 60 minutes. The frequency of heavy precipitation at a duration stage of 24 hours (see also table 1) in Germany has already increased by approximately 25 % in the winter months of the past 65 years. In contrast, no distinct trend was identified for the summer months. Generally speaking, the intensity of heavy precipitation at this timescale can be described as similar.

In contrast, there are relatively few findings available for heavy precipitation of short duration occurring predominantly in summer in Central Europe. Admittedly, there are some indications for an increase in the intensity of convective events as temperatures rise. However, there is a distinct requirement for further research regarding this timescale. Trend analyses of heavy precipitation are principally hampered by the fact that not all particularly intense precipitation events of limited spatial extent are necessarily captured by meteorological stations. It is true that, in addition, there are radar data for contiguous areas, but such timescales are too short to permit making any robust trend statements.

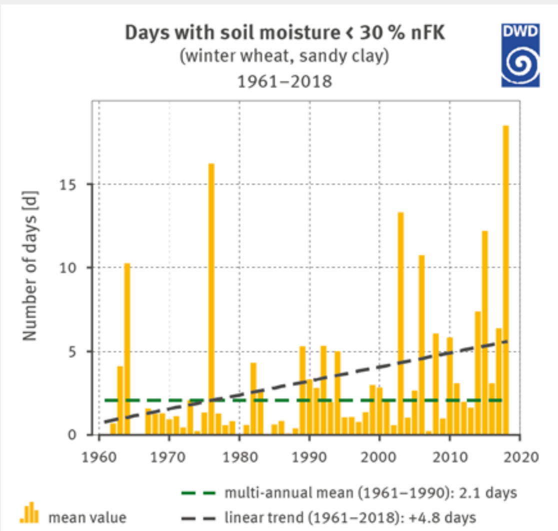
Nevertheless, radar data have, for the first time, made it possible to capture and enumerate the occurrence of heavy rain for contiguous areas. Figure 8 shows for the first time that the hours of heavy precipitation of particularly high intensity amounting to more than 25 l/m² in 1 hour or more than 35 l/m² in 6 hours respectively in Germany (see Fig. 8, middle) are more evenly distributed than the total hours of moderately heavy rain (see Fig. 8, left) where the spatial distribution is distinctly linked to Germany's topography. This showed for the first time that spatially extremely small-scale heavy rain of short duration and with high damage potential can occur anywhere and affect anyone in Germany; in other words, these conditions constitute a risk which is not limited to the southern states of Germany. A temporal extension of this kind of heavy rain analysis will in future allow a trend analysis for the related frequency of events where threshold values are exceeded.

Drought

Apart from the issue of changes in heavy precipitation events it is crucial, especially in summer, to what extent warming is accompanied by additional soil dehydration. Agriculture is particularly vulnerable to drought. In agriculture the term drought always refers to the condition of plants which owing to lack of water resources, either have to limit their photosynthesising activity or even die. Inadequate availability of water in the soil can be caused either by the absence or lack of precipitation or by high evaporation rates of plants; these rates are higher in dry and warm weather than under cold and humid conditions.

An ideal indicator for the degree of water supply available to plants is the soil humidity which is expressed in percent of usable field capacity (% nFK). The nFK is a relative measurement for the amount of soil water available for absorption by plants. When soil humidity drops to beneath 30% to 40% nFK, the plant's photosynthetic output diminishes and consequently its growth declines sharply. The longer a plant remains in this condition, the more severely it can be damaged. It was therefore considered essential to examine the number of days on which the critical soil humidity values of 30% nFK for the cultivation of winter wheat were not reached. The examination was focused on the main growth period of winter wheat, which will typically last from March until July or August. The type of soil also has a major influence on soil humidity. Heavy soil (such as sandy clay) is able to store more water for plants than light soil (such as clay-rich sand); that is why the former is able to bridge longer droughts than the latter.

As shown in Figure 9, the mean number of days with soil humidity values of less than 30% nFK has increased significantly in Germany since 1961, both for heavy soil (left) and for light soil (right). Owing to the lower water storage capacity of light soil, the number of days on which the critical threshold value is not reached is generally greater for light soil than for heavy soil. Eastern Germany and the Rhine-Main area are particularly affected by increasingly dry soil (see Figure 10).



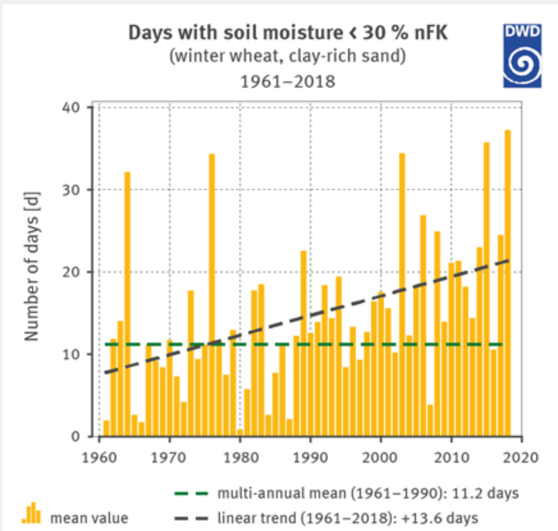


Figure 9: Annual number of days with soil humidity values below 30% nFK for winter wheat on heavy soil (sandy clay, left) or light soil (clay-rich sand, right)

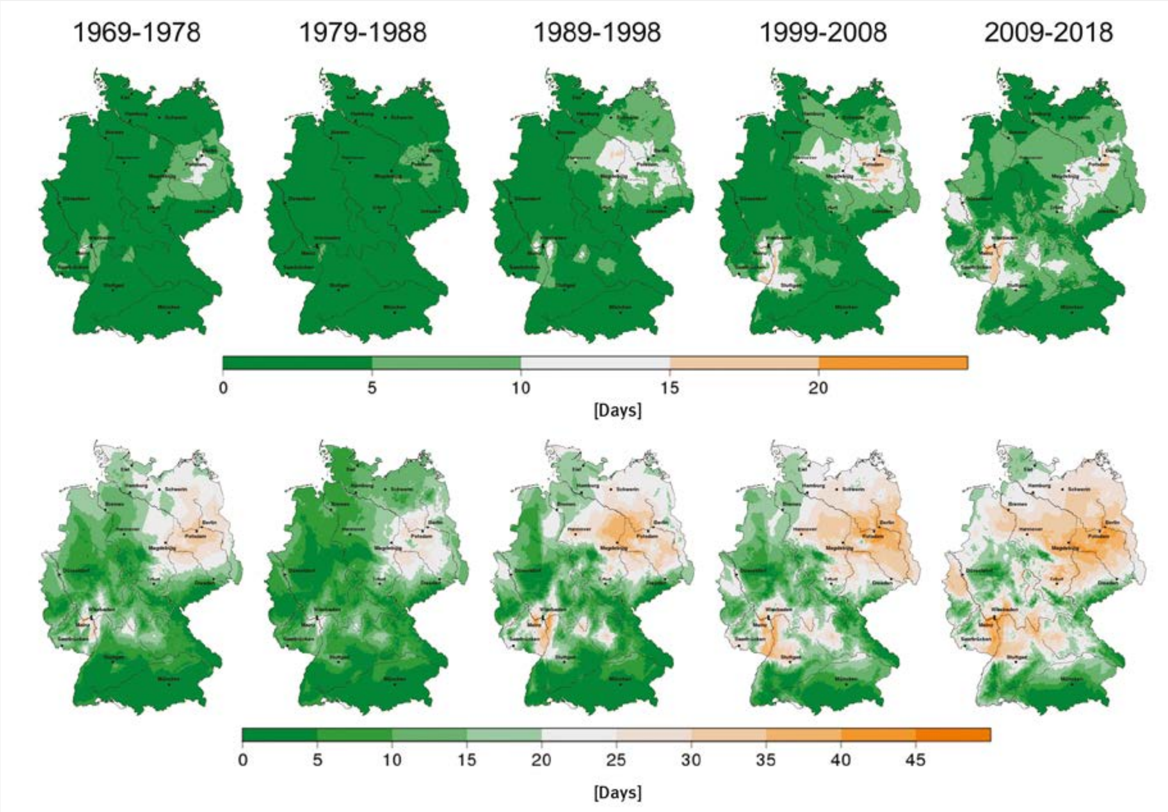


Figure 10: Annual mean number of days with a soil humidity of less than 30 % nFK for winter wheat on heavy soil (above, sandy clay) and light soil (below, clay-rich sand)

Indicators of climate change impacts and adaptation

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Human health

The human organism is constantly dealing with climatic conditions in its environment and reacts to these stimuli with its own adaptation responses. In particular, extreme weather situations can affect the health, efficiency and wellbeing of humans.

Even nowadays climate change has multiple direct and indirect effects on health. Weather and climate changes can lead to increases in infectious diseases and non-communicable illnesses such as allergies; they can also lead to an intensification of symptoms related to cardio-vascular and respiratory complaints. Extreme events such as storms, floodwater, avalanches or landslides pose unmediated risks to life and limb. Moreover, they can lead to social and psychological pressures as well as disorders such as stress, anxiety attacks and depression. It is worth remembering that climate change goes hand in hand with demographic and societal changes. Increased life expectancy increases the risk of chronic diseases. It can cause people to live solitary lives and develop feelings of loneliness. In view of such uncertainties, it seems appropriate at this stage, to give priority to considering the changing risks to human health which result from climate change.

Preventive health care plays a central role in adaptation efforts. Well founded and truly accessible information helps to motivate citizens to lower their personal health risks by adapting their behaviour. At the same time, active medical and care support are required for particularly vulnerable population groups in respect of health hazards such as heatwaves.

Effects of climate change

Adaptations

Heat exposure raises health risks

Increasingly, climate change will, apart from rising average temperatures, entail heat exposure events thus affecting health. Looking back it is possible to discern a trend since the 1970s towards an increase in hot days on which the daily maximum temperature amounts to 30 °C or more. In 'tropical nights', temperatures do not fall below 20 °C which means that recovery at night, especially after very hot days, is limited.

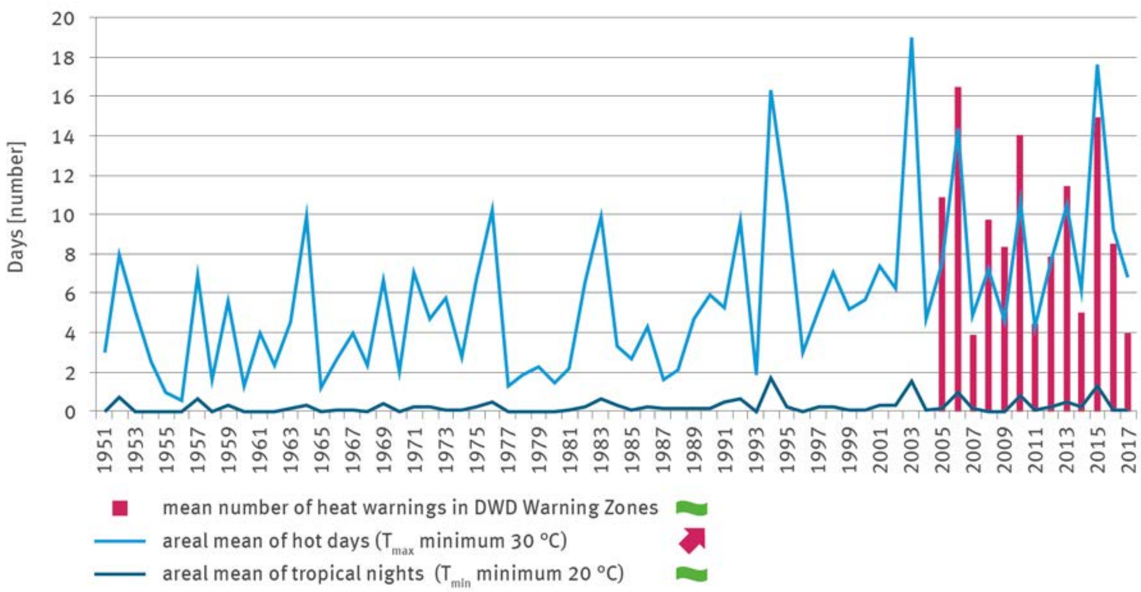
Contrary to hot days, tropical nights have not occurred frequently in our climes. It can be stated, however, that years with distinctive heatwaves have also regularly led to the development of tropical nights.

Strong correlations with the development of hot days are indicated by the number of heat warnings issued by DWD since 2005 as part of its heat warning system. Warnings are issued when 'major heat exposure' of at least 32 to 38 °C 'perceived temperature' is forecast and night temperatures lead to inadequate cooling. If extreme heat exposure at temperatures of 38 °C and more are expected, these warnings are certain to be issued; this is also normal procedure when such events are of shorter duration (see GE-R-1). Ever since the heat warning system came into operation, there have been weather–dependent fluctuations in the annual mean number of heat warnings in the so-called warning zones which follow the general outlines of administrative districts. After 2003 there were, in 2006, 2010, 2013, 2015 and also in 2018, according to the mean value calculated across the districts, on more than ten days, hot days and temperatures above 30 °C. Prior to 2000 the ten-day-mark was reached only in 1976 and 1995 and exceeded only in 1994. In terms of the nationwide annual mean, more warnings were issued in southern Germany, i.e. approximately on three more days, compared to four days fewer warnings issued in northern Germany.

The hot days and tropical nights as well as heat warnings indicate weather situations injurious to health; however, they do not allow any conclusions as to how many people's health will actually be affected. Heat exposure affects in particular older people, the chronically ill, young children and individuals who live alone. People

GE-I-1: Heat exposure

Apart from the increases in annual mean temperatures, the past forty years also show a trend towards rising heat extremes. Especially the number of hot days has increased significantly. As far as tropical nights are concerned, it has so far not been possible to discern a trend. The same is true for the number of heat warnings.



Data source: DWD (heat warnings, German climate atlas) who enjoy good health are in a better position to adapt and counteract the consequences of heat exposure more effectively. Health problems are usually caused by high fluid and electrolyte losses through sweating and inordinate stress on the cardio-vascular system owing to high amounts of heat transfer required.

In recent years, public awareness of health impacts from periods of extreme heat has increased. This is demonstrated by the outcomes of a representative survey of the German population, entitled 'Umweltbewusstsein in Deutschland' (Environmental Awareness in Germany)"[I] carried out in 2016[1] for the purpose of comparison with surveys from previous years. In 2016 50 % of respondents stated that they expected that heatwaves would have either very strong or strong effects on their own physical wellbeing. Compared to 2012 only 30 % of respondents made similar statements[2]. By comparison, in 2016 just 12 % considered themselves not affected in any way, whereas in 2012 33 % of respondents had expected to be affected.

I The representative population survey (of German-speaking residents aged 14 or more years) entitled 'Umweltbewusstsein und -verhalten in Deutschland' (Environmental Awareness and Behaviour in Germany' has been carried out every two years since 2000 on behalf of the BMU and the UBA. Since 2012, questions were incorporated in the survey which would supply data for the DAS monitoring indicators; from 2016 onwards, these questions were asked every four years in the environmental awareness surveys.

Interfaces

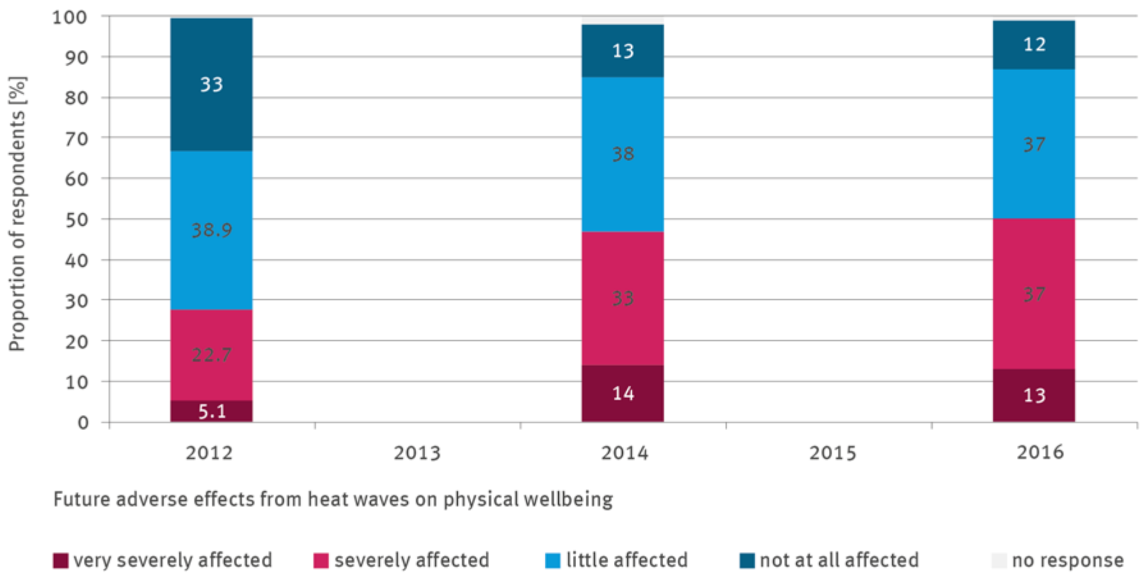
GE-R-1: Heat warning service

Objectives

Right to life and physical integrity (German Constitution, Art. 2)

GE-I-1 (addendum): Public awareness of health problems due to heatwaves

In 2016 half of the respondents already anticipated a strong or very strong impairment of their future physical wellbeing due to heatwaves. In 2012 this had been true for just a third of respondents.



Data source: BMUB & UBA (Umweltbewusstsein in Deutschland)

Heatwaves cause additional mortalities

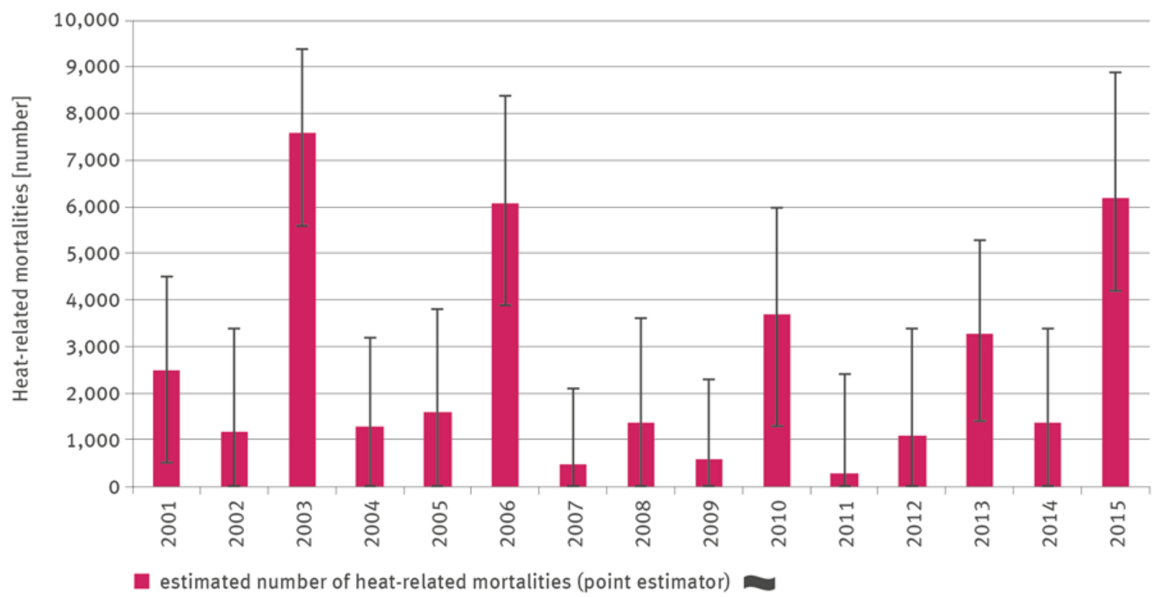
Since the beginning of the current millennium, there has been a succession of intensive heatwaves in Germany and most other European countries. Between 2000 and 2018 eight of eleven hottest years were observed since weather records began in 1881. An exceptionally high number of hot days was recorded in 2003, 2006, 2010, 2013, 2015 and 2018. In 2018 there were on average more than 20 hot days in Germany; this is the greatest number of hot days recorded since 1881. In 2003 there were on average 19 hot days and in 2015, on average 17 hot days were recorded nationwide.

Heat exposure causes the body to lose more fluid than under normal conditions. This fluid loss can lead to dehydration (lack of water in the body) and may also entail diminished viscosity of the blood. These phenomena increase the risk of thromboses and other cardio-vascular conditions. When thermoregulation (the mechanism of the human body which maintains a constant body temperature of approx. 37 °C) is restricted, this can bring about disorders in the human water and electrolyte balance which may result in life-threatening impairments of the cardio-vascular system. In particular older and frail people are very vulnerable to heat stress; this also applies to patients with chronic diseases such as cardio-vascular or respiratory conditions[3]. Furthermore, environmental conditions have a bearing on health risks. As demonstrated by studies, in built-up urban areas[4], where so-called urban heat islands develop and where increased ozone and fine particulate values occur[5] health risks are increased.

In mortality statistics, mortalities related to heat effects are typically attributed to other causes of death (e.g. conditions of the cardio-vascular system). If the amount of mortalities exceeds the seasonally typical and thus expected values, this is taken as an indication that there are extraordinary events involved. In determining the indicator ‚heat-related mortalities, aggregated mortality data from the Statistische Bundesamt (StBA/Federal Statistical Office) were used which describe the weekly total mortality per Federal State and per age cohort for the period from 2001 to 2015.

GE-I-2: Heat-related mortalities

In years with an above-average number of hot days, there are more mortalities than expected in the absence of heatwaves. In 2003 an additional 7,500 individuals died, while for 2006 and 2015 research indicates approximately 6,000 additional mortalities.



Data source: RKI (own calculations)

The mathematical model employed describes the non-linear link between high temperatures and mortality rate. Within a range of between 10 °C and 20 °C of a weekly mean temperature, mortality is relatively constant, whereas at a weekly mean temperature of more than 20 °C, it rises distinctly. This increase is particularly pronounced in age cohorts of 65–74, 75–84 and 85+. The weekly mean temperature indicates the mean value of all hourly values within a week while taking special note of day and night temperatures. Weeks with mean temperatures exceeding 20 °C typically also contain one or more hot days.

The number of heat-related mortalities is estimated as the difference between the modelled mortality and a hypothetical mortality regime which would prevail where weekly mean temperatures did not exceed 20 °C.

The precise method of estimation is described in a special issue of the Bundesgesundheitsblatt entitled 'Gesundheitliche Herausforderungen des Klimawandels' (particular challenges involved in climate change)[6]. The outcomes show that in 2003 the number of people who died was higher by 7,500 mortalities than would have been expected in the absence of a heatwave. For the years 2006 and 2015 respectively, approx. 6,000 additional mortalities were recorded.

These mortalities occur especially in age cohorts 75–84 and 85+, while the rate per 100,000 inhabitants is particularly high in cohort 85+. In the period between 2001 and 2015, weekly mean temperatures exceeding 20 °C occurred less frequently in the north of Germany, which means that most of the heat-related mortalities occurred in the centre or the south of Germany.

Extreme heat and long periods of persistent heat affect older people in particular.
(Photograph: © chingyunsong / stock.adobe.com)

Interfaces

GE-I-1: Heat exposure
GE-R-1 Heat warning service

Objectives

Right to life and physical integrity (German Constitution, Art. 2)

Allergenic plants gaining ground

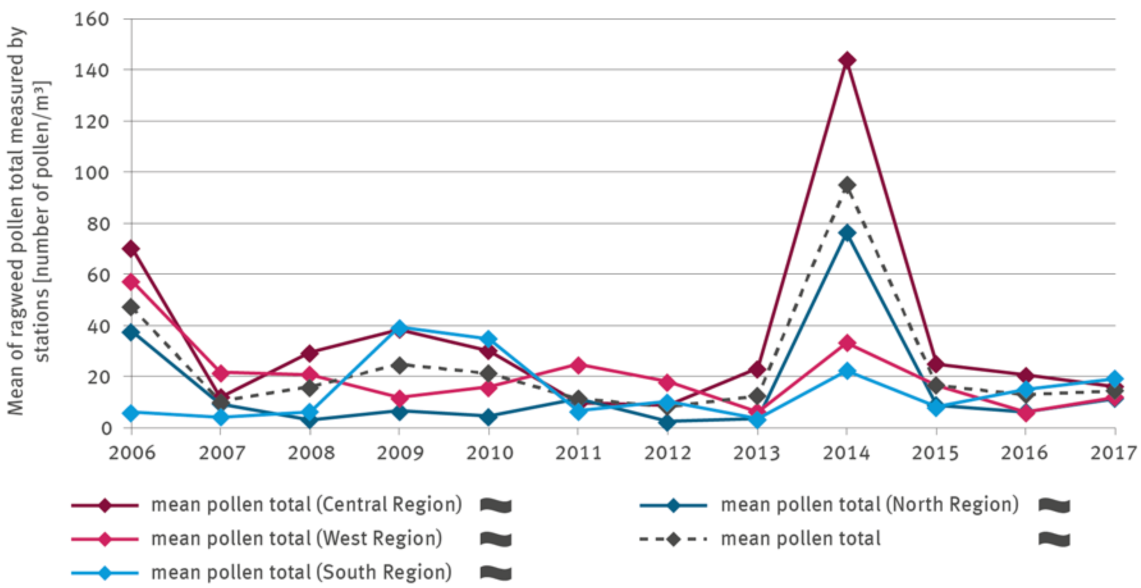
In Germany some 15 % of adults suffer from hay fever at least once in their life (lifetime prevalence) and 9 % from Asthma bronchiale. Allergenic pollen are primary triggers for hay fever, and several clinical studies have indicated a connection between the occurrence of airborne pollen and the occurrence of hay fever. Notably, the occurrence of pollen is heavily dependent on the weather or the climate. An overall milder climate with longer growth periods favours pollen being airborne for longer; it therefore favours higher pollen concentrations. It is also conceivable that the allergenicity of pollen allergens may increase as a function of temperature rise. In a warming climate, thermophilic plants may immigrate which were hitherto not endemic to Germany, including plants with high allergenic potential.

Common ragweed which emanates from North America (Ambrosia artemisiifolia) had for a long time been a comparatively rare and inconsistent weed. Its occurrence did not start to increase until the beginning of the 1990s. Nowadays common ragweed occurs in all Länder, and especially in southern and eastern Germany, it has started to form extensive, well established localised patches containing thousands of plants. This plant thrives in gardens, on uncultivated or fallow ground, in arable fields and cut-flower fields, in set-aside areas, on building sites as well as road and path verges. Causes for the spreading of this species are, for instance, the importation of bird food or seed material for deer and wildlife food plots, where these seeds are contaminated with ragweed seed. Other causes are the transportation of soil from affected areas in connection with building projects as well as the adhesion of seeds to agricultural machinery or mowers used on road verges. An EU Directive came into force in 2011 with the objective of restricting the contamination of feedstuffs with ambrosia seed.

The fact that ragweed is able to spread and establish itself in Germany is, however, also attributed largely to climate change because the annual plant can only achieve the seed maturity required for dispersal when the climate is warm or moderate with mild autumn weather. Unfortunately, it was not possible to find any systematic scientific evidence for this relationship. Similar concerns

GE-I-3: Contamination with pollen of ragweed

The spreading and establishment of ragweed is presumably favoured by climate change. However, so far the results of pollen measurements do not indicate any significant trends.



Data source: PID (pollen traps)

regarding variables such as the spreading and establishment exist with respect to other highly allergenic thermophilic plants such as lichwort or asthma weed (Parietaria officinalis, P. judaica) or the olive tree (Olea europaea).

Ragweed pollen is considered highly allergenic. In sensitised people even minor pollen concentrations, i.e. some ten percent pollen per cubic metre of air can trigger hay fever and, in the case of allergy sufferers, can also trigger asthma. Besides, there are reports of skin reactions after skin contact with the flower head or other components of this type of plant. Another contributing factor to the spreading of ragweed is the fact that it is one of the late-flowering plant species, which extends the period in which its pollen is airborne to the end of October. For sensitised allergy sufferers, this entails additional exposure to pollen owing to the extended period when it is airborne while undergoing the splaying process, thus prolonging the time when affected individuals suffer from related complaints.

For the time being mean ragweed pollen concentrations in Germany are still on the low side although concentrations vary from region to region. Moreover, long-distance transportation of goods from more strongly affected neighbouring countries can lead to heavy pollen burdens in some areas. Any trend statements on the development of pollen totals measured in Germany are still subject to uncertainties as they are based on relatively short time series. With respect to exposure situations in the four major regions of north, west, centre and south of Germany there is no distinct pattern discernible. The nationwide high contamination with ragweed pollen in Germany in 2014 was caused by long-term wind dispersal of pollen from the Hungarian basin during the plant's flowering period. Ragweed is particularly wide-spread in Hungary and surrounding countries, especially Slovakia, Romania, Serbia, Bosnia-Hercegovina and Croatia; wind dispersal can thus emanate from those countries on 'long-haul' flights.

Total pollen count measurements do not permit any conclusions as to the risk of the population actually coming into contact with this type of pollen or in respect of developing sensitisation or allergic reactions. Nevertheless, for precautionary reasons every effort should be taken, subject to the rules of proportionality, to curb the further spread of this plant in Germany.

Climate change favours the spreading and establishment of highly allergenic species such as ragweed.
(Photograph: © Elenathewise / stock.adobe.com)

Interfaces

GE-R-3: Information on pollen

Objectives

Examining measures to curb the spreading of ragweed throughout Germany's Länder (DAS, ch. 3.2.1)

To keep Germany as far as possible free from the occurrence of this species (Action Programme Ragweed by the Julius Kühn-Institute – ongoing since 2007)

Exotic mosquitoes bear new health risks

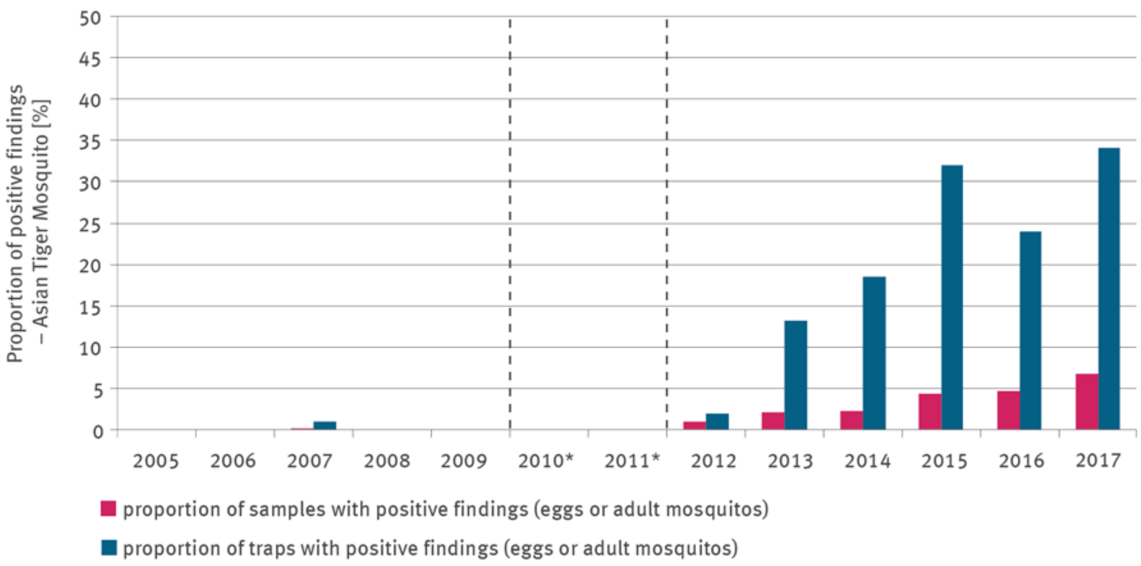
Worldwide we are confronted with new and recurring fomites (infection agents) which in many cases can be transmitted between animals and humans; owing to their increasing global mobility they are able to spread very fast. Both long-term climate change (temperature, precipitation) and the increase in extreme weather conditions play important roles in this process. In vector-transmitted infectious diseases such as malaria, dengue, leishmaniosis, zika, chikungunya or early-summer meningoencephalitis (FSME) there is the risk that in Germany changed climatic conditions will enhance favourable conditions for animal vectors such as mosquitoes or ticks, thus increasing the risk of infection for humans and animals. This goes to show the close links between the health of humans, animals and their environments (One Health).

The mechanisms of absorption, development and reproduction of pathogens in vectors, and the transmission to animals and humans remain to be clarified in the majority of cases. Changed climatic conditions can influence this interaction of pathogens and vectors in various situations. Changed climatic conditions can entail changes e.g. in the reproduction rate of animal vector organisms, their lifespan, their behaviour or their population density. Their efficiency in transmitting pathogens can also be affected. Short winters may entail that the animals are active for longer in the course of the year, reproduce faster and produce more generations. This can cause vector species previously not indigenous to Germany, introduced from warmer countries, to get established here and disperse widely.

The examination of relationships between climate change and vector or pathogen dispersal is still in its infancy. The recording of most infectious diseases associated with vectors is already carried out systematically and in most respects on a nationwide basis, but owing to the regulations laid down in the German Infection Protection Act (e.g. compulsory registration), there is nonetheless a shortage of data on occurrence and distribution of vector species and their infection with these pathogens. The illustration is therefore limited to the example of one vector, i.e. the Asian Tiger Mosquito (Aedes albopictus), a mosquito species that was originally introduced from Southeast Asia. It

GE-I-4: Pathogen carriers – case study

Warmer climatic conditions can favour the establishment and spread of the Asian Tiger Mosquito in Germany. This has created the basic prerequisites for this pathogen to extend its range here in Germany provided it is introduced by infected individuals. The evidence of eggs and mosquitoes caught in traps as well as positive samplings in the Upper Rhine area have shown a distinct increase.



Data source: Kommunale Aktionsgemeinschaft zur Bekämpfung der Schnakenplage KABS e.V. (mosquito monitoring)
*) No data available for 2010 or 2011; from 2012 onwards, sampling was continued using different types of traps.

is considered a highly efficient vector which can transmit more than 20 different viruses.

The Tiger Mosquito which emanates from a species variant successfully adapted to non-tropical conditions in USA has meanwhile achieved wide distribution in southern Europe and also in parts of Central Europe. In recent years there have been frequent finds of eggs, larvae and adult individuals of this species in Germany. According to the current state of knowledge, the introduction takes place by means of vehicular traffic from the south (e.g. Italy). In areas where the Tiger Mosquito comes upon favourable conditions, it is able to establish and spread. Of particular benefit to the establishment of the Tiger Mosquito is its release in areas where the immediate environment offers adequate breeding sites, blood hosts and safe havens such as allotment garden areas and housing zones with a high proportion of garden space.

In respect of the chikungunya virus it has been possible to show already that transmission by Ae. albopictus is, also in Germany, not much limited by external temperatures but especially by an adequate occurrence of mosquitoes[7]. For the zika virus laboratory tests have shown that the vector competence of Ae. albopictus is distinctly boosted by temperatures of 27 °C as against lower temperatures of 18 °C[8]. The establishment of these mosquitoes has created the basic prerequisites for this pathogen to spread widely in Germany too, provided it is introduced by infected individuals.

The Rhine Plain in Germany is favoured by warm climatic conditions. It also plays a major role as an important entrance point to Germany of vehicular traffic for thermophilic species from neighbouring countries (e.g. Switzerland and Italy). There has been ongoing recording of the occurrence of Tiger Mosquitoes in the Upper Rhine area since 2005. Evidence was first found in 2007. This was done by examining 105 traps when evidence was found for five Tiger Mosquito eggs in more than one thousand samples. After a break in monitoring in 2010 and 2011, followed by the installation of new types of traps in 2012, findings were again positive: a total of eight individuals were found which means that one percent of all trap samplings were positive. From 2012 on, the number of samplings was expanded, leading to annually c. 1,500 samplings in the Upper Rhine area from 2014 onwards. As early as 2013 13 % of all traps and c. 2 % of all samplings resulted in evidence of eggs or adult mosquitoes. Subsequent years produced further increases in the number of positive findings. Already in 2014 approximately in 18 % of traps and in 2017 approximately in 34 % of traps along motorways evidence was found for Ae. albopictus. Besides, in Baden-Württemberg there are reports of at least four established populations. In locations such as Heidelberg and Freiburg evidence has been found for three consecutive hibernations from 2015 to 2016, 2016 to 2017 and 2017 to 2018. Since 2015 efforts have been ongoing to develop and enhance a monitoring system for mosquitoes[9].

The Asian Tiger Mosquito is able to transmit numerous pathogens. (Photograph: © emodeath / stock.adobe.com)

Nevertheless, the infestation with Ae. albopictus is lower in Germany than in southern Europe. Likewise, the warm-weather periods are still shorter in Germany. Even in southern Europe, only rare individual cases and small clusters of transmissions of dengue and chikungunya virus were identified apart from two chikungunya virus outbreaks, It is therefore considered that although the risk of individual transmissions in Germany cannot be dismissed, there seems to be limited danger of major outbreaks.

Objectives

At both Federal and Länder level, additional data ought to be collected and analysed in order to recognise epidemiologic developments in Germany in time, to understand their causes and relationships, to improve risk assessments and to develop preventative and intervention strategies. (DAS, ch. 3.2.1)

Cyanobacteria – impairment of recreational bathing waters

If temperatures rise in future summers, the desire of humans for a cooling bath in lakes or rivers and the sea will increase. At the same time however, climate change can affect the quality of recreational bathing waters. A much discussed health risk in connection with climate change is the contamination of recreational waters with cyanobacteria, commonly known as blue-green algae.

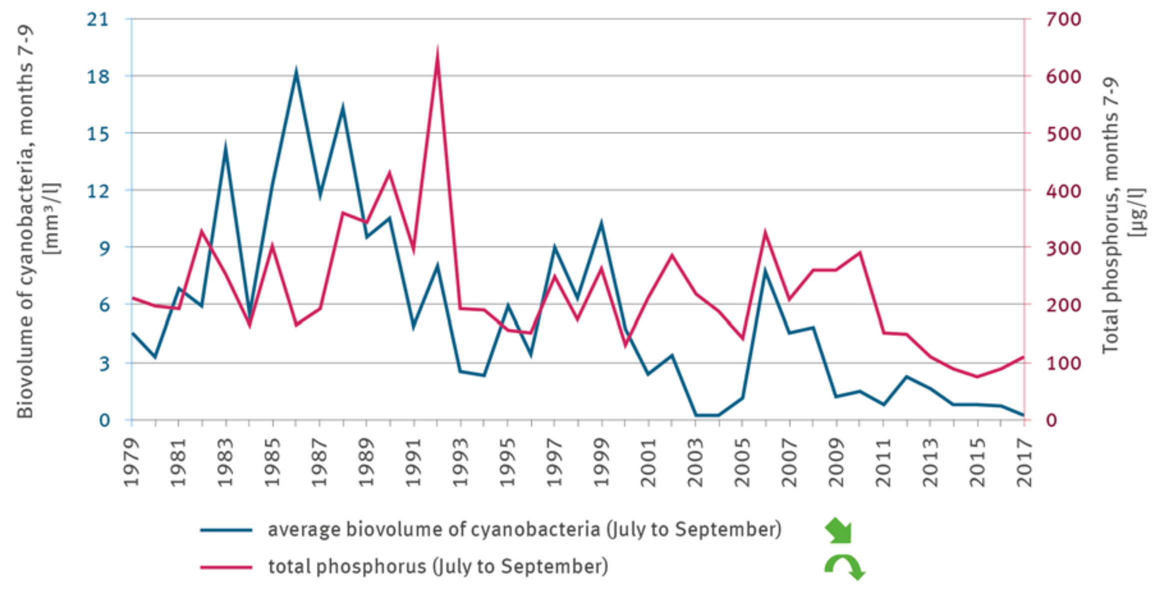
Increased concentrations of blue-green algae occur particularly in waters which are rich in plant nutrients, especially total phosphorus. In waters only moderately contaminated with nutrients, cyanobacteria have to compete for available nutrients with both higher water plants and with other phytoplankton, thus rarely achieving dominance. However, if there is heavy contamination with nutrients, this often results in mass reproduction of cyanobacteria, so-called ‘algal bloom’. This is exacerbated by stable thermal layering of waters which develops especially at high temperatures and stable weather conditions. Stable layering also leads to the deposition of some cyanobacteria at the surface thus potentially resulting in further localised accumulations of cyanobacteria.

In view of increased algal bloom owing to weather conditions, the possibility of a relationship between climate change, water warming and health impairments caused by cyanobacteria is discussed.

It has been observed that bathing in waters heavily contaminated with blue-green algae has led increasingly not only to symptoms such as irritations of the skin and mucous-membranes as well as allergic reactions, but also stomach, intestinal and respiratory illnesses. Whether these are ultimately caused by toxic cyanobacterial substances (cyanotoxins) or by accompanying bacteria has not yet been clarified. The absorption of major quantities of cyanotoxins can lead to serious impairment of the liver, kidneys and nerves. The risk is particularly high for young children and children at primary-school age who are apt to swallow unintentionally large amounts of water while crawling about or frollicking in shallow water. The same risk factor applies to inexperienced water sportsmen or women who do not just swallow water but also absorb it into their respiratory system when surfing or water-skiing in water contaminated with cyanobacteria.

GE-I-5: Contamination of recreational bathing waters with cyanobacteria – case study

Subject to weather conditions during the bathing season, health risks can develop in bathing waters owing to high concentrations of cyanobacteria. Surveys of the Müggelsee in Berlin have shown that a major reduction in nutrient inputs from the end of the 1980s resulted in a marked decrease in contaminations.



Data source: Leibniz-Institut für Gewässerökologie und Binnenfischerei IGB (lake monitoring)

If water looks distinctly turbid owing to the presence of cyanobacteria or especially if there are streaks forming on the surface, it is advised not to enter the water for bathing. The same precautions should be taken for dogs.

Observations have shown that the relationships in the course of contamination with cyanobacteria are complex; any generalisations would therefore be fraught with extraordinary problems. Depending on nutrient availability, size, depth, wind exposure and type of water use, the development in different waters can differ a great deal. In order to be able to make statements that apply nationwide, it would be necessary to carry out more observations of waters used for recreational bathing. It must be said, however, that currently research into the occurrence of blue-green algae in waters varies considerably. In view of the currently available data, it is not possible at present to make any statements regarding the question whether in recent years there has generally been an increase in contamination with blue-green algae of recreational bathing water in Germany.

Nevertheless, the data on developments in the Große Müggelsee lake over the past almost forty years can serve as an example. This largest of the lakes around Berlin has considerable recreational value, especially for the eastern parts of the city. The biomass of blue-green algae has decreased since the 1980s. The marked decrease from the end of the 1980s until the beginning of the 1990s is primarily due to the reduced input of nutrients via the Spree river after German unification in 1989. Since the mid-1990s, however, there have been no discernible trends, for contamination either with phosphorus or with blue-green algae biomass. This is due in part to the fact that contamination with phosphorus is still exceeding the critical threshold above which blue-green algal bloom can develop. Besides, rising temperatures repeatedly cause extended periods of more stable layering in water bodies. These layerings are particularly apt to favour the development of cyanobacteria which in those phases can also produce very high proportions of the total phytoplankton biomass.

The sometimes remarkable fluctuations of contamination with cyanobacteria between years are essentially due to variations in the layering events which occurred in those years. For example, in the hot summer of 2003 the layering was less stable than in summer 2006 – a year in which comparatively high amounts of cyanobacteria biomass and a cyanobacteria content of 80 % were measured in the phytoplankton biomass. A more frequent occurrence of stable layerings may in future counteract the positive effects of reduced nutrient inputs on contamination with cyanobactera, provided the nutrient concentration in the water is not at levels that would clearly limit the growth of cyanobacteria (<30 µg total phosphate per litre).

Bathing in waters contaminated with cyanobacteria presents health risks. (Photograph: Ingrid Chorus / Umweltbundesamt)

Interfaces

WW-I-6: Start of the spring algal bloom in standing waters

Objectives

In cases of mass reproduction of cyanobacteria and health risks, appropriate management actions to be taken without delay in order to prevent exposure to these risks. In addition, information to be disseminated among the public (EU Bathing Water Directive, Art. 8)

Early heat warning – prerequisite for effective prevention

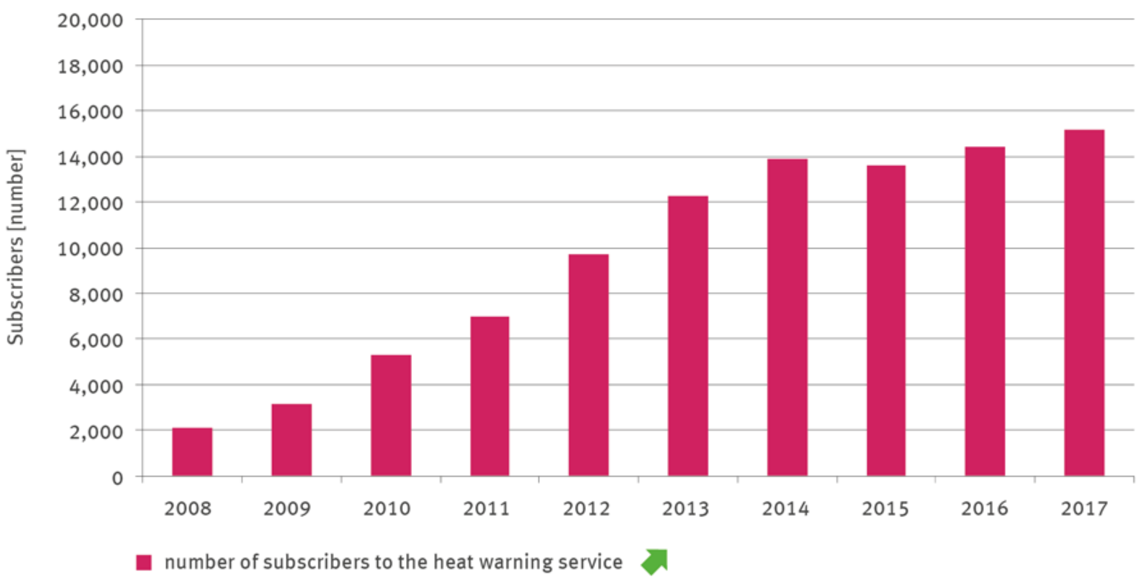
Especially in residential homes dedicated to the care of the elderly and people with disabilities, the hot summer of 2003 led to increased hospitalisations of residents as a result of dehydration or to increased mortality rates owing of hyperthermia. In order to enable residential homes and individuals with solitary lifestyles to prepare for heatwaves and to take timely precautionary and protective measures, the DWD introduced a heat warning system in 2005. Customised for individual warning zones which largely follow the outlines of administrative districts, daily heat warnings are issued for both the current and the following day, as soon as the perceived temperature reaches defined threshold values and when other factors such as in-door temperatures and certain heat stresses for the elderly as well as specific thermal situations in urban environments arise.

Heat warnings are issued in various ways, e.g. by internet, by subscription to the Newsletter 'Hitzewarnungen' (heat warnings) or, since July 2013, also via smartphone apps. Until the end of 2010, health service centres were informed actively by e-mail, ftp or by fax. In 2011 the DWD converted its system for communications with health service centres with the intention to establish the newsletter as the only communication channel. In the course of 2011, the conversion to newsletter subscription was almost fully completed. Increasingly, also private individuals make use of the newsletter. The number of subscribers has increased continuously in the course of recent years. However, in order to be really effective, heat warnings have to be followed up by concrete actions. This includes the prevention of major physical exertions, drinking enough fluids, ensuring proper electrolyte balance as well as actions to ensure both active and passive cooling of rooms. Residential homes for the care of the elderly and people with disabilities are inhabited by people who are not necessarily able to take such measures unaided. Both, care and nursing staff are called upon to provide active support, i.e. to take appropriate precautionary measures once heat warnings are received.

It has so far not been examined systematically nationwide as to which actions are actually triggered by heat warnings. However, in the state of Hesse, the authority supervising care and nursing services has carried out random sample inspections in residential homes on hot days since 2009.

GE-R-1: Heat warning service

The DWD's Newsletter 'Heat Warnings' provides information when for the current and the next day Severe Heat Stress is to be expected, typically with values of 32 to 38 °C Perceived Temperature (heat warning stage I) or Extreme Heat Stress of more than 38 °C Perceived Temperature (stage II) is to be expected. In the course of previous years, the number of subscribers (residential homes and private individuals) to the newsletter has increased steadily.



Data source: DWD (heat warning service, records of newsletter subscribers and warnings issued)

The authority checks whether preventative measures are taken appropriately; it also gives advice in case of inadequacies and, where necessary, issues instructions for corrective actions. Since 2009 the inspections have covered approximately 10 to 25 % of all residential homes. In years with numerous hot days such as 2010, 2013 and 2015, more extensive inspections are made. Inspections are carried out in accordance with a uniform catalogue of criteria. When residential homes offer their employees soft drinks free of charge on hot days, it can be concluded that they have been sensitised to the detrimental effects of heatwaves. After all, if a residential home enables staff to maintain their efficiency levels, this will ultimately also ensure appropriate care and provision for residents. Regarding the dispensing of free soft drinks to its residents, the residental homes are obliged to supply these on the basis of reasonable demand. In 2017 the dispensing of free soft drinks to employees was taking place in almost 98 % of all residential homes. In recent years a distinct improvement has been achieved.

Interfaces

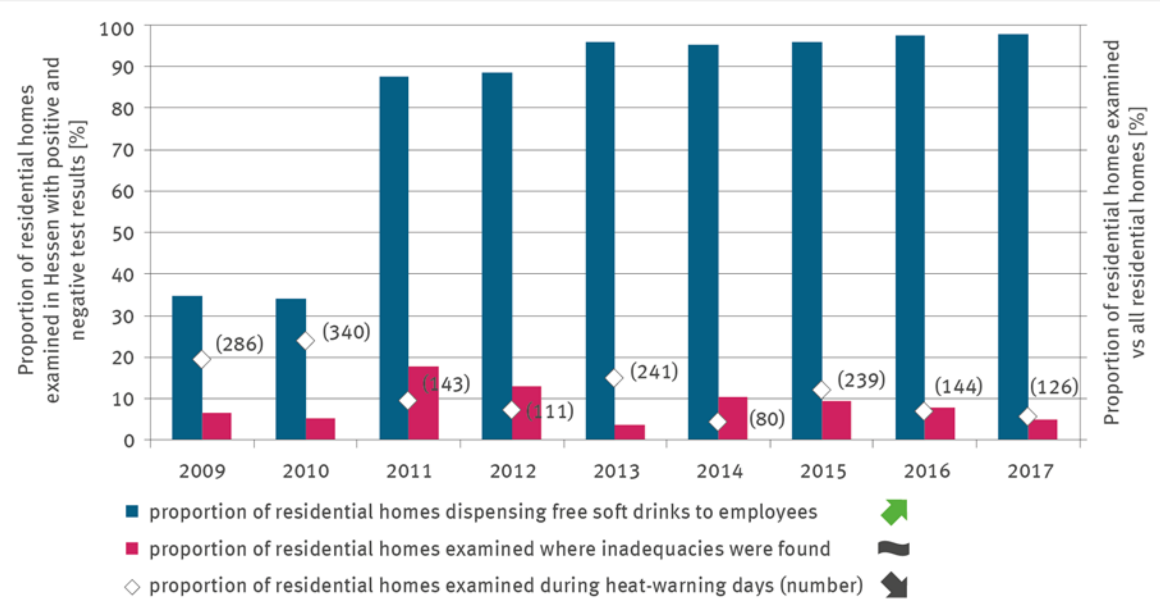
GE-I-1: Heat exposure
GE-I-2: Heat-related mortalities

Objectives

Promoting the provision of targeted, matter-of-fact explanations and information to the public, at-risk groups, multipliers such as staff in the health service and civil protection; better networking between the DWD, the informed agencies at Länder and municipality level, health service institutions, civil protection agencies or institutions such as schools and nurseries, in order to be able to take preventative and topical measures in affected locations (DAS, ch. 3.2.1)

GE-R-2: Successes of the heat warning system – case study

In the residential homes for the elderly and for people with disabilities e.g. in Hesse, heat warnings trigger preventative measures. While random sample inspection of residential homes on hot days will continue to uncover inadequacies, these were found to be diminishing in the course of the past four years.



Data source: Hessische Betreuungs- und Pflegeaufsicht (residential home inspections)

People with pollen allergies need information

'Hay fever' is the colloquial, as well as trivialising term for a condition which is induced largely by allergenic pollen. However, hay fever is by no means harmless; it can be accompanied by major losses in quality of life and serious health impairments. Especially in cases where the allergic inflammation of nose and eyes extends to the bronchia, this can lead to chronic breathing difficulties and irreversible restructuring processes in the bronchia and lungs. One in three hay-fever sufferers will develop, in the course of their life, asthma that is related to the pollen season but which can later become asthma that prevails all-year round.

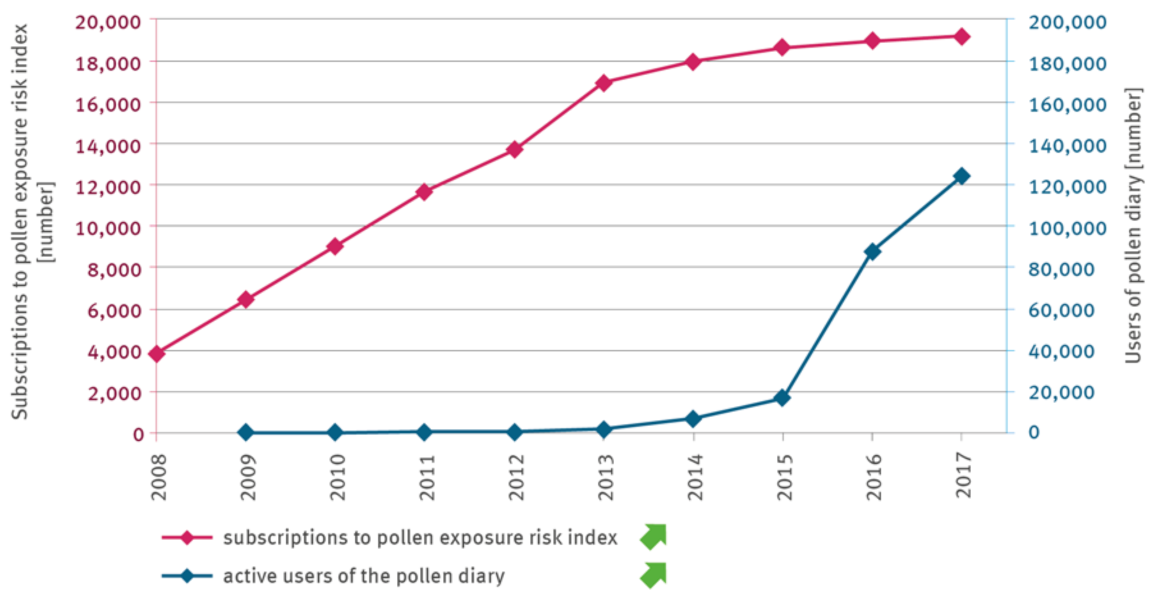
Coming into contact with allergenic pollen in the environment is in many cases unavoidable or difficult to control. It is therefore absolutely essential to give patients a chance to better understand the nature of their condition and of any underlying causes thus enabling them to develop avoidance strategies. The following applies: the more allergy sufferers understand their condition, the less they suffer.

To provide allergy sufferers with better information, the DWD jointly with the Stiftung Deutscher Polleninformationsdienst e. V. (PID/German foundation for pollen information services) publish, as and when required, a pollen exposure risk index. During the season when pollen is airborne, this index regarding the intensity of exposure to the eight allergologically most important types of pollen (hazel, alder, ash, birch, sweet grasses, rye, mugwort and ragweed) expected for the current and the next day. The high degree of actuality of these forecasts enables people who suffer from pollen allergies to arrange for targeted prophylactic actions in terms of adapting their behaviour and obtaining appropriate medication.

Information on the current and predictable exposure risks can be downloaded direct from the internet. Alternatively it is possible to subscribe to a newsletter which provides subscribers with a direct warning in case of exposure risks. Further information on the subject of allergies is provided via an online portal operated by the Helmholtz-Zentrum München for the prevention and treatment of allergies (www.allergieinformationsdienst.de).

GE-R-3: Information on pollen

There is a notable increase in the use of available information contained in the pollen exposure risk index and the service of the pollen diary or smartphone apps by individuals helping them to understand their own hayfever symptoms. The amount of newsletters distributed and also the use of the services offered by the PID and Techniker Krankenkasse are increasing significantly.



Data source: DWD (pollen exposure risk index), PID (pollen diary)

In addition to the pollen exposure risk index, the PID has since 2009 been developing further services offered for the support of allergy sufferers. They started by offering the online pollen diary which enables people with hayfever to make connections between their current problems in eyes, nose and bronchia as well as their current medication, with the values of pollen activity in the location where they happened to be at any particular time (even if they were in another European country). The daily records entered into the internet-based pollen diary helps allergy sufferers to analyse, quickly and independently, the intensity of their condition and the degree of current exposure to air-borne pollen. In addition, the users of this diary are provided with an individual evaluation of their pollen season. The pollen diary can also serve a patient's GP as a useful aid in making a diagnosis and planning a therapy. In line with technological advances, a pollen app (Pollen App 5.0) was developed for smartphones in 2013. This app makes it possible to record the individual symptoms and their severity, at the same time as providing individual forecasts regarding likely medical complaints for the subsequent two days.

The forecasts provided by the pollen exposure risk index enables allergy sufferers to take targeted precautions.
(Photograph: © Jürgen Kottmann / stock.adobe.com)

Since 2015 the Techniker-Krankenkasse (a health insurance) in co-operation with the PID has offered an app entitled 'Husteblume' (a pun on a children's name for the seed heads of dandelion). The contents of this app is identical with the Pollen App 5.0. The Husteblume, in addition to the general and individual pollen exposure forecast and recording of symptoms, also provides generic therapy tips. For the 2019 pollen season, the app was thoroughly revised and expanded by several new functions. The user numbers for the pollen diary contained in the two virtually identical apps (pollen app and Husteblume) have increased substantially in recent years. Almost 200,000 users are entering records regarding their medical complaints in nose, eyes and bronchia as well as records of whatever medication they are using. In view of the fact that the Pollen App 5.0 is used in five European languages, this opens up opportunities for scientific studies in terms of comparisons.

The increase in subscriber numbers noticed in recent years indicates a mounting interest in the pollen exposure risk index issued jointly by the DWD and PID and also in the services offered by the PID Techniker Krankenkasse (insurance company). So far there have been no systematic evaluations of the positive effects of the pollen exposure risk index or the pollen diary published by the PID including the smartphone app, regarding the quality of life of allergy sufferers. A survey on the 'Husteblume' app published by the Techniker Krankenkasse indicates however that 56 % of users feel that they are now better informed about their allergy, while 34 % state that they have been coping better with their allergy since using the app. 27 % of users report that the app has improved their quality of life. Every eleventh user even states that their allergy has improved in general[10].

Interfaces

GE-I-3: Contamination with pollen of ragweed

Water regime, water management, marine and coastal protection

Precipitation processes and the temperature regime have a decisive influence on the natural water cycle – both globally and regionally. Any changes in climatic conditions will also entail changes to the water regime and thus the water management framework.

It is not just a matter of chance that Germany's water industry has for many years grappled with the impacts of climate change on water regime and water quality. Important issues are the long-term protection from extreme floodwater events and the appropriate handling of low water levels. Maintaining a sufficient and sustainable supply of drinking water and service water in all parts of Germany has become an increasingly important issue in view of the drought year of 2018. Water is indispensable for many types of use, e.g. as drinking water, cooling agent in the energy industry, as raw material and process material in industrial applications, as mode of transport in the shipping industry, for the irrigation of agricultural fields or simply in recreation and leisure. In order to be able to meet the wide variety of demands, water must meet certain requirements in terms of volume and quality. Even in a basically water-rich country like Germany, dry summers can lead to regional difficulties regarding adequate supplies of water. A sparing use of water reserves and the balance between water supply and utilisation therefore play important parts in adapting to climate change.

Likewise, adequate supplies of water are vital for all water-dependent ecosystems. The water industry therefore deals increasingly with ecological issues. The EU Water Framework Directive requires that surface waters and groundwater be kept in, or restored to, a condition which is both ecologically and chemically sound, and that their function as habitat for animals and plants be safeguarded in pertuity. The task is to achieve these objectives despite climate change.

Effects of climate change

Adaptations

Increased occurrence of low groundwater levels

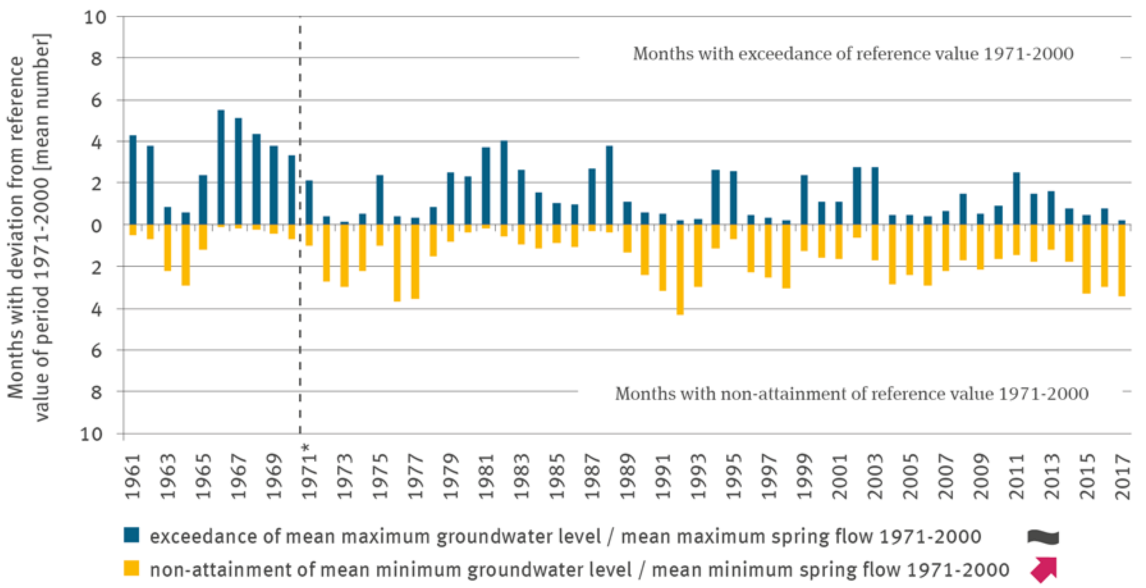
The extent to which groundwater can replenish itself in a location and the amount of groundwater levels that can develop, are dependent on a variety of influencing variables. Some of these variables include the distance between the aquifer from the top of the ground surface, the characteristics of the upper layers above the aquifer, the size and shape of rock cavities and the subterranean in- and outflow of groundwater. Above all, it must be remembered that the groundwater formation in any area is dependent on precipitation and surface run-off as well as evaporation. If the climatic conditions change, this will affect the formation of groundwater.

Rising temperatures act as triggers for a potentially higher evaporation overall, which means that less water will trickle down to infiltrate the groundwater. Years with lower total precipitation do not immediately affect groundwater levels. Contrary to surface water, groundwater reacts rather slowly to any changes in the precipitation regime. The situation can escalate in areas where in future, the availability of water will be restricted – on one hand owing to decreasing precipitation and on the other owing to an increased evaporation demand of the atmosphere. Both, changes in temperature and in precipitation affect the surface run-off, with knock-on effects on the groundwater. Although precipitation amounts increase in the winter months, the precipitation tends to fall on saturated or frozen ground and therefore cannot seep in. In the summer months, soils tend to dry out more owing to higher temperatures and lower amounts of precipitation. Precipitation which in future may more frequently occur as heavy rain, can either not or barely be absorbed by dry soil, thus trickling away largely above the surface.

In order to obtain an overview of the development of groundwater levels in Germany, 136 groundwater measuring points and spring flow points were selected across all federal states and hydrogeological environments, for which data are available from 1971 onwards; in respect of 96 measuring points the observation time series even date back as far as 1961. All these measuring points are in the uppermost aquifers and they are, as far as possible, unaffected by anthropogenic influences. In other words, there is no groundwater abstraction or irrigation taking

WW-I-1: Groundwater level

Compared to the long-term mean, the frequency of months with low groundwater levels below-average is on the increase. In particular, precipitation deficits occurring several years in a row, lead to falling groundwater levels or reduced spring flows.



* measuring point collective expanded from 1971 onwards

Data source: groundwater monitoring networks of federal states place, the degree of soil sealing is low and there have been few changes in land management in the area. This makes it possible, to a considerable extent, to make connections between any changes observed at these measuring points and changes in the temperature and precipitation regimes.

Looking at the entire time series, it becomes clear, as shown by the mean value of all measuring points observed, especially in the course of the past decade, that there has been an increase in the occurrence of extremely low groundwater levels and very little spring flow. The number of months per year in 1971 to 2000 in which the mean of lowest groundwater levels or spring flows measured were not reached, has increased significantly since 1961. At the same time, the number of months in which the mean of the highest groundwater levels or spring flows measured long-term were exceeded, has decreased. Statistically speaking, however, this trend is not significant. It is also evident that owing to weather conditions there were cyclical changes in groundwater levels at least as late as the 1990s. Such changes can no longer be found to the same degree since the 1990s.

Developments vary across Germany even though the patterns show similarities. A particularly strong trend can be seen towards low groundwater levels in the low-precipitation areas of north-east Germany, i.e. in areas where annual precipitation amounts to less than 700 mm. This situation prevails especially in Brandenburg, Sachsen-Anhalt and Mecklenburg-Vorpommern. However, even in regions with particularly high precipitation (annual precipitation of more than 900 mm), i.e. in the uplands and in the alpine regions, it can be said that groundwater levels were clearly low. These findings would seem to require further research. Groundwater levels and spring flows were conspicuously low in the years 2013 to 2017. In view of a distinctly dry period, the data for 2018 point to the likelihood of a similar, presumably even more extreme situation arising.

In Germany also three quarters of drinking water is abstracted from groundwater. The formation of adequate volumes of high-grade groundwater is therefore a fundamental requirement for a sustainable supply of drinking water, also and especially in times of climate change. In the DAS Monitoring Report for 2015, just under 96 % of groundwater bodies were found to contain satisfactory volumes of water, i.e. the formation of groundwater was found to be in balance with the extent of groundwater abstraction.

An extensive network of groundwater measuring points has been established which regularly provides data on groundwater levels. (Photograph: Christiana Mühlner)

Interfaces

WW-I-2: Mean run-off
WW-I-4: Low water
BO-I-1: Soil moisture levels in farmland soil

Objectives

Groundwater management in a way to ensure the prevention of a deterioration in the volumes available and to ensure that satisfactory volumes are maintained or achieved (WHG § 47 (1))

Promoting decentralised infiltration of precipitation in order to contribute to the formation of groundwater; making increased use of spatial planning to safeguard water resources and using planning processes to aim for adapted consumption of water at a time of diminishing formation rates of groundwater (DAS, ch. 3.2.14)

Demand management as well as application of technological methods and improvements for a more efficient use of water, in order to avoid, at times of extended and more frequent regional drought phases and low-water periods, regional conflicts of use [...] in respect of groundwater extraction close to the surface (DAS, ch. 3.2.3)

The availability of water is changing

In the greater part of Germany, the natural run-off regime of watercourses is determined by precipitation. During the warm season, the degree of evaporation also plays a role. This leads to high mean values of run-off in winter and early spring, compared to low run-off values in late summer and autumn. Especially in the southern parts of Germany, winter snow cover plays a crucial part alongside run-off and rain volumes. In alpine catchment areas with major rivers such as Iller, Isar, Lech and Inn, winter precipitation often accumulates as snow; therefore run-off is lowest at that time of year. As a result of snow melt in spring and early summer, often accompanied by rainfall, the run-off maximum occurs in the middle of the year. This is termed a nival run-off regime.

Apart from precipitation, the catchment area's topography plays an important role; it is crucial for the speed at which precipitation actually affects the run-off regime.

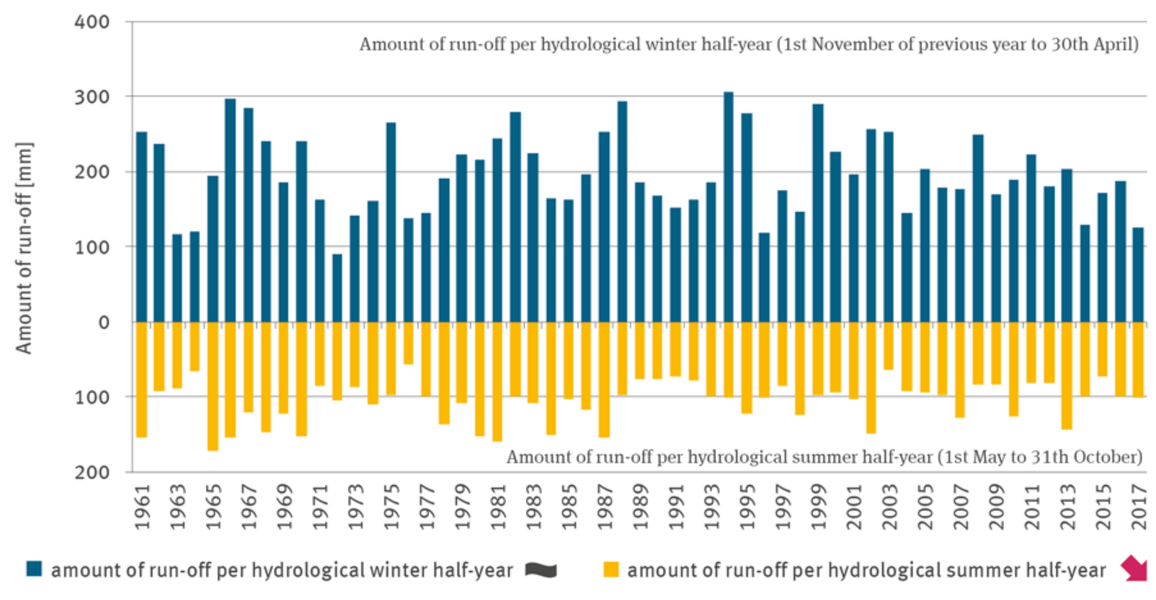
Where climate change affects the precipitation and temperature conditions, it will also affect the run-off regime. This may include impacts on the volume of the total run-off of water and on the seasonal distribution of run-off.

For an analysis of run-off regimes and their development, a total of 80 levels across Germany's river catchment areas were selected. They represent mean catchment area sizes at a scale of 250 to 2,500 km². These are levels which are, as far as possible, unaffected by anthropogenic influences, i.e. where run-off levels were observed which are not strongly marked by, for instance, water transfer or water retention systems.

The mean water run-off (MQ) or the annual run-off volume (Ah) derived in relation to the size of the catchment area concerned acts as an indicator for the availability of water. This indicator shows the availability of water in principle, including water which is available for cultivation and for a variety of surface water applications such as cooling water or shipping. Changes in the mean run-off values can also entail changes in groundwater levels in riparian areas, thus affecting supplies of drinking water and process water.

WW-I-2: Mean run-off

The average run-off value across 80 levels measured in German river basins show clear variations from year to year. The amount of run-off during the hydrological winter half-year has been decreasing, albeit not significantly, since 1961 However, a significant decline in the mean run-off value for summer has been observed, which suggests a change in the availability of water in summer.



Data source: run-off measurement of federal states

Although the time series from the 1960s onwards shows a slight decline in the mean run-off value for the hydrological half-year period from early November to end of April, this cannot be regarded as a statistically significant trend. However, during the hydrological summer half-year, i.e. from early May to end of October, a significant falling trend can be discerned. This is due to reduced precipitation in summer and temperature-related higher evaporation during those months. This development suggests that changes in the fundamental availability of water in both half-years, i.e. winter and summer, are already beginning to take place.

The mean value calculated across Germany, as well as – owing to the effects of precipitation and evaporation – the winter run-off values, are clearly higher in general than the run-off values for the summer half-year. The low-water year 1972 is the only year in the time series observed where summer run-off was higher than winter run-off. Since then there has not been one year when this happened again. Nevertheless, the relationship between medium run-off in the summer half-year and the winter half-year does not suggest any changes that can be described as statistically significant.

In the Danube river basin where the run-off regime is characterised by a predominantly nival run-off, there have been – from 1960 until the late 1980s – just as many years in which the values for summer run-off were higher, as there were years where the winter run-off values were higher. Since 1990 the years in which winter run-off values exceeded summer run-off values, have increased in frequency nationwide. This suggests that the influence of the snow cover on the run-off regime is diminishing.

The values for summer run-off are in decline. This reflects a diminished availability of water.
(Photograph: © Jodocos / stock.adobe.com)

Interfaces

WW-I-1: Groundwater level
WW-I-3: Floodwater
WW-I-4: Low water

Repeated floodwater events

Compared to the fluctuations and changes in mean run-off values, there is greater awareness among the public of floodwater events because they have an immediate impact on human activities as they can cause personal injury and material damage.

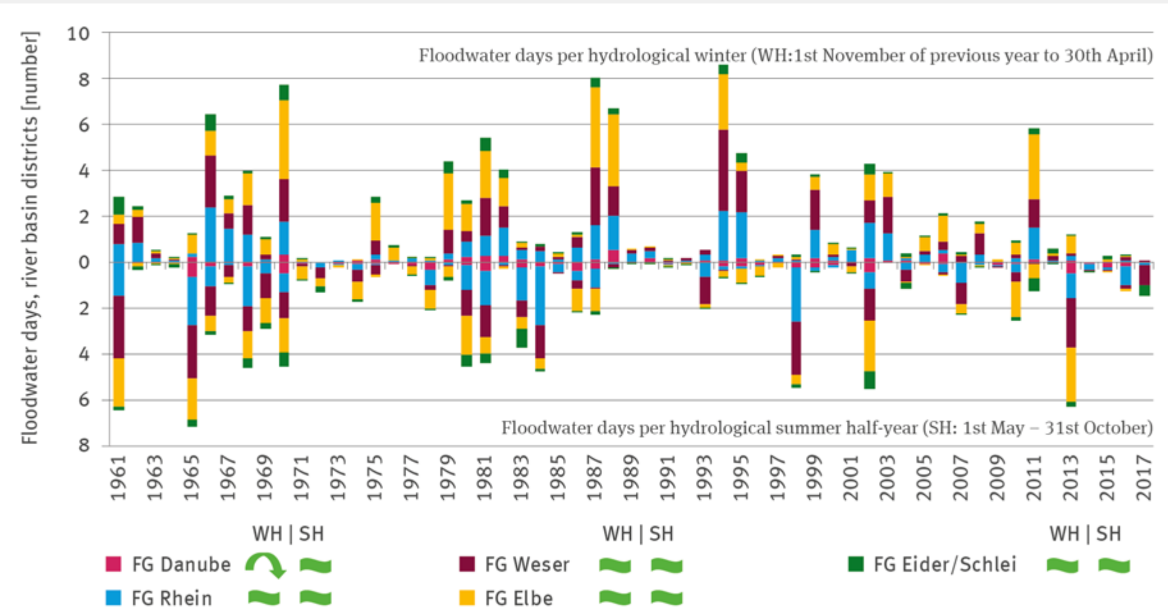
The time series starting in 1961 clearly indicates that the floodwater regime varies from year to year. This is true for both the extent of floodwater events and for seasonal distribution. Floodwater days distributed across 79 of Germany's river basins were subjected to evaluation. Floodwater days are days on which the mean daily run-off value is higher than the mean floodwater run-off (MHQ) calculated for the reference period 1961 to 1990. The MHQ is calculated separately for the hydrological winter half-year (November of the previous year to April) and the summer half-year (May to October) on the basis of the highest run-off values (HQ) respectively.

When averaging the number of floodwater days for all levels observed in a river basin, it becomes clear at which locations the floodwater events were concentrated in which years. Floodwater events can be triggered by regionally limited weather constellations. For the summer season this typically refers to rain that continues for several days and to heavy-rain events which can be very localised. In the winter season floodwater is frequently caused by thaw in connection with rainfall, because under these circumstances run-off from major amounts of meltwater may occur within a few hours.

As far as summer floodwater events are concerned which occurred since the turn of the millennium, the years 2002 and 2013 stand out. In August 2002 floodwater in Germany was particularly prevalent in the Elbe and Danube areas. These events were caused by extreme rainfall continuing for days, which resulted in weeks of emergency operations in order to overcome the ensuing flood disaster. Likewise, floodwater events at the end of May and in early June 2013 were triggered by several days of rainfall. Apart from Germany and Austria, other countries in central and eastern Europe were particularly badly affected. The month of May 2013 is considered to be one of the periods in which precipitation was highest

WW-I-3: Floodwater

The time series for the floodwater regime is characterised by individual repeated floodwater events both in the winter half-year and in the summer half-year. It was not possible to discern any significant trends. Subject to weather constellations, there are spatial focal points where floodwater occurs. However, as a rule several river basins are affected.



Data source: run-off measurement of federal states

since meteorological records began. In 2017 the low pressure front Alfred led to several days of rain resulting in floodwater in the region of the Harz mountains and foothills. Likewise, the Weser river basin was one of the most heavily affected.

The most recent high floodwater event occurred in January 2011, with focal points again in the Elbe and Main areas, but other river basins were also affected. The floodwater was preceded by a December month with comparatively high precipitation while, at lower geographical level, substantial amounts of snow accumulated. This meant that considerable amounts of water equivalent were stored in the blanket of snow when suddenly a low-pressure area coming in from the Atlantic triggered a strong thaw in the second week of January, which led to rapid melting of the snow cover, even in the mountains. This period of thaw was immediately followed by several rain fronts with prodigious precipitation.

As indicated by the time series so far, the development of floodwater days does not show any significant trends either for the summer or for the winter season. The development of floodwater is always related to specific combinations of weather conditions which have so far not occurred either systematically, regularly or repeatedly. The distribution of floodwater days impacting the hydrological winter and summer seasons has so far not indicated a trend either. The events occur in both half-year periods, albeit a little more frequently in winter.

Climate change cannot be accounted for by a single floodwater event. Atmospheric conditions and large-scale weather patterns which favour the occurrence of floodwater suggest a wide-ranging variability. Warming enables the atmosphere to store fundamentally more water vapour, i.e. absorb moisture, thus increasing the potential for heavy rainfall. Westerly winds might increase in winter; likewise the frequency and intensity of so-called Five B (Vb) weather front trajectories might increase in summer. Under these kind of weather conditions, low-pressure areas shift to Central Europe from the Mediterranean where they are charged with water vapour. Often these low-pressure areas bypass the Alps und then deposit their rain in the eastern uplands and the eastern foothills of the Alps. The weather conditions which cause the Five B trajectories can remain stationary for a long time causing continuous rain and even heatwaves.

Apart from climate change, there are however numerous other developments which affect the phenomenon of floodwater events. Increasing sealing and compaction of the soil in catchment areas, as well as barriers to natural flood plains and embankments result in higher run-off into rivers.

Floodwater results from heavy or long-term rainfall or snowmelt. (Photograph: © mb67 / stock.adobe.com)

Interfaces

VE-I-1: High-water closures to shipping on the Rhine
FiW-I-2: Incidence of storms and floods

Objectives

Protection from increasing floodwater risks in river basins (DAS, ch. 3.2.14)

Designation of floodwater areas and creation of retention areas (WHG, §§76 (2), 77)

Low-water events – no climate-change related clusters found

Low-water events, in the same way as floodwater, are part of a natural run-off regime. In alpine catchment areas low-water events may occur in winter owing to the storage of precipitation as snow. However, in river basins in upland areas and in the case of rivers in lowlands and plains, low-water levels occur especially in summer and early autumn owing to high evaporation compared to the precipitation. Prolonged meteorological droughts, i.e. periods of low or no precipitation, tend to exacerbate seasonal low-water levels, especially during the summer months.

Changes associated with climate change may influence the time, duration and intensity of low-water events in many ways. The projected decrease in precipitation in the summer half-year and a higher evaporation requirement of the atmosphere may lead to a decrease in run-off in the summer half-year.

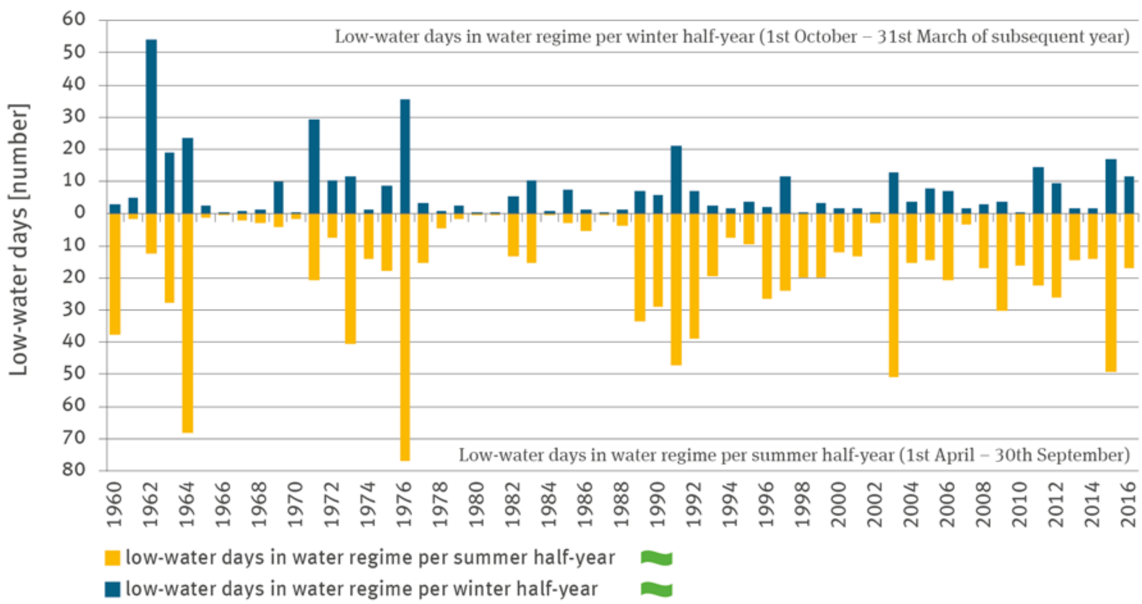
The consequences of low-water events influence both the ecology of waters and their utilisation. Owing to low flow rates at low water levels, the water warms up faster. This entails increased plant growth, especially in terms of algae, thus causing reduced oxygen concentrations, especially in river lakes. Moreover, if run-off decreases, inputs into the water bodies are diluted to a lesser degree thus leading to higher concentrations of nutrients or harmful substances. Both processes have far-reaching impacts on aquatic creatures as well as on water quality.

For various types of use, sufficient run-off or adequate supplies of water are fundamental prerequisites. In the absence of adequate amounts of water, which is specific to each river, the potential for shipping is restricted. Furthermore, lack of run-off can jeopardise the abstraction of water for cooling purposes or for agricultural irrigation. It can also lead to quantity restrictions being imposed on the discharge of wastewater.

For the time series illustrated, the run-off values for 80 levels of German rivers were examined in order to

WW-I-4: Low water

In recent years, the low-water regime in Germany's river basins was characterised to a considerable degree by distinct low-water years. Especially in the years 1991, 2003 and 2015 and latterly in 2018, prolonged drought periods have led to a strong decline in water levels of Germany's rivers.



Data source: run-off measurement of federal states

establish in respect of the water regime, on how many days in the summer half-year (1st April to 30th September) and in the winter half-year (1st October until 31st March) of the subsequent year, low-water levels were recorded. A low-water day is defined as a day on which the mean annual daily run-off is lower than the mean low-water run-off (MNQ) calculated for a level in the period of 1961 to 1990. The MNQ is calculated on the basis of the lowest run-off rates of individual water regime years (NQ). When the number of low-water days is averaged across the levels recorded, it becomes clear that again and again there have been individual years with an extreme accumulation of low-water days. In the course of the past 30 years, such accumulations occurred in particular in the years 1991, 2003 and 2015. This affected in particular the river basins of Rhine, Elbe and Weser, and, to a lesser extent, also the Danube. Regarding the river basin districts of Eider/Schlei, Schlei/Trave and Warnow/Peene, the water regime years 1996 and 2008 recorded a high number of low-water days. Owing to the fact that low-water events can usually be attributed to stable high-pressure fronts, the ensuing consequences typically extend over wide areas.

In 2015 low-water levels prevailed for more than six months. The impacts on eastern Germany were particularly severe and prolonged, as here the summer drought lasted well into autumn whereas the situation in parts of the south-western catchment areas of Rhine and Danube were mitigated by considerable precipitation in the Swiss Rhine area and in the south of the Upper Rhine. Although the summer of 2015 was generally less extreme than the summer of 2003, the drought period lasted for an extraordinarily long time. On several reaches of the river shipping was considerably restricted in 2015.

2018 was another extreme low-water year with impacts on all German river basins. In the Rhine area, owing to months of drought, low-water levels and run-off rates were reached which had not been recorded for many years, consequently exposing rock formations and gravel banks in the river basin which had not been seen in living memory. Very low-water levels were also recorded for Elbe, Danube and Weser. All German waterways experienced shipping restrictions some of which lasted for some considerable time.

For the entire time series no significant trends are discernible either for the winter or the summer half-year. This may be due partly to the fact that the extreme low-water situations in the 1960s and 1970s are still exerting considerable influence on developments.

Low-water levels occur especially in summer and early autumn when there are extended periods with lack of precipitation. (Photograph: © Comofoto / stock.adobe.com)

Nevertheless, the seasonal distribution of low-water days indicates a significant trend. Compared to the low-water days in winter, there is a noticeable decline during summer. As in the case of mean run-off values, this suggests that there are changes taking place in the seasonal availability of water.

Interfaces

EW-R-4: Water efficiency of thermal power plants
VE-I-2: Low-water restrictions to shipping on the Rhine

Clear trend towards higher water temperatures in lakes

Water temperature is one of the pivotal cause variables for processes occurring in lakes, which also makes it an important factor which determines their utilisation and the framework conditions regarding their ecosystems and for managing their water regime. In turn, water temperature is directly dependent on air temperature and its daily and seasonal progression. Consequently it is plausible to assume that climate change has direct impacts on water temperature and ecosystems in standing water bodies.

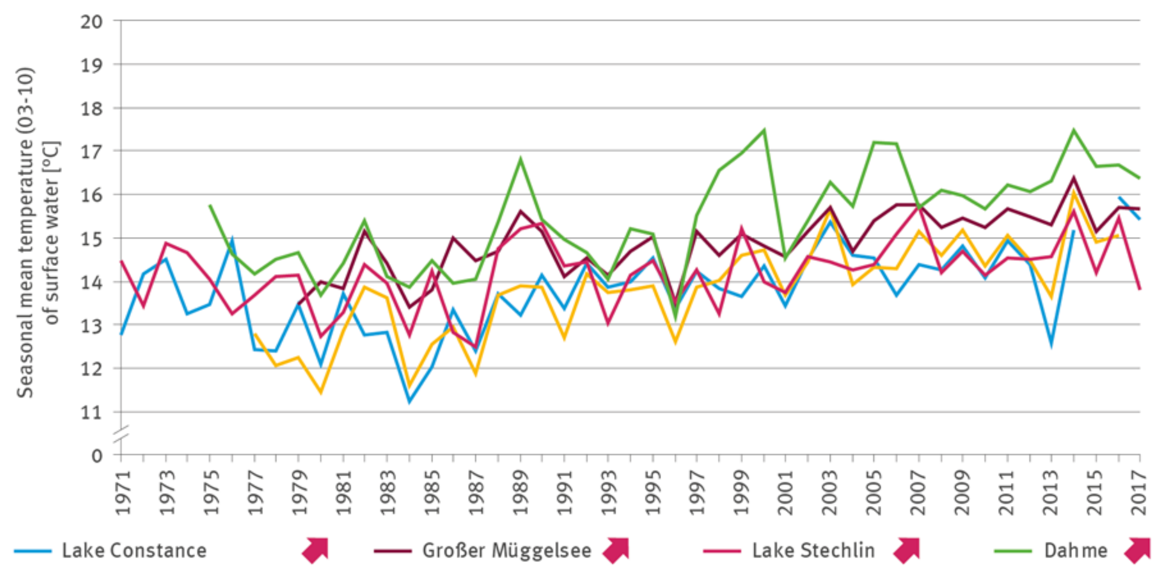
Many creatures occurring in water bodies are adapted to specific temperature conditions. Therefore, even minor changes can entail shifts in the species composition in standing water bodies. This may result in the displacement of originally occurring organisms by other species. The incoming species may very well be non-indigenous species which benefit from higher temperatures. Furthermore, these circumstances can also lead to changes in the cycle of the seasonal development of creatures which belong to lake ecosystems.

The temperature and thermal regime of a water body control fundamental physical, biological and chemical processes. This explains why the response rate of numerous chemical and bio-chemical processes increases with rising temperatures; substances such as naturally occurring minerals dissolve more readily in warmer water whereas gases such as oxygen dissolve less readily. Some organisms can cope with oxygen content decreasing or mineral concentrations increasing whereas others are dependent on excellent water conditions. Likewise, material changes triggered by increases in temperature have a substantial effect on plants and animals in these water bodies.

It is difficult to attribute any noticeable changes in the species composition to climate change, as several impact factors interact, especially those related to the utilisation of water bodies and their peripheral areas. As things stand at present, we only have the changing temperature regime for deriving probable impacts on the composition of species in lakes. Uncertainties also exist in terms of climate change impacts on the types of utilisation feasible in lakes and on the challenges evolving in terms of water

WW-I-5: Water temperature of standing waters – case study

Water temperatures rose significantly in the course of the observation periods. This is true for both the annual mean temperature and the seasonal mean from March to October. The temperature increase applies to both, the lakes in the Alps and foothills (Lake Constance), the upland lakes (Saidenbachtal Reservoir) and different types of lakes in the North German Plain (Großer Müggelsee, Dahme and Lake Stechlin).



Data source: LUBW/ISF (Lake Constance), TU Dresden/Ökolog. Station Neuzehnhain, LTV (Saidenbach Reservoir), IGB (Großer Müggelsee, Lake Stechlin), SenUVK Berlin (Dahme) management. In this context, other impact factors also play an important role.

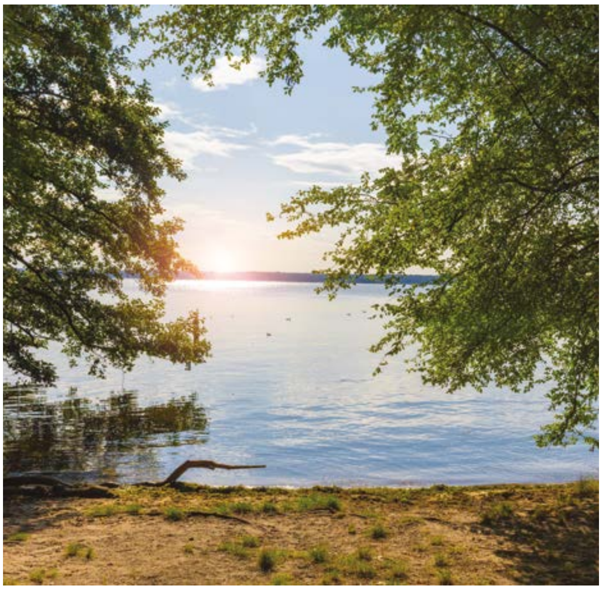
The situation prevailing in highland or lowland areas changes the characteristics of water bodies/water courses. In particular, there are changes in lime content as well as in the water passage and frequently also in the depth of water. Consequently, water temperature is also very dependent on the geographical location of the lake in question. An essential variable which allows the illustration of climate-change dependent changes is used for illustrating the development of water temperature in terms of lakes representative of various habitats.

Lake Constance is a lake typical of biomes found in the Alps and their foothills. It receives its water largely from its alpine catchment area via inflows from the alpine Rhine and the Bregenzer Aach. Besides, summer water levels of alpine rivers are essential in controlling the lake's temperature. Lake Constance is the third-largest lake in Central Europe; consequently, it is characterised by a very distinct layering of temperatures.

The Saidenbach Reservoir is representative for the group of layered, calcium-rich upland lakes which have a relatively extensive catchment area. Owing to the prevailing regular operation of this reservoir, it is possible to exclude any relevant anthropogenic, i.e. operational effects on its surface temperature. The Saidenbach Reservoir can therefore be used in principle to illustrate climate-change dependent temperature changes.

The lakes of the North German Plain are characterised by warmer and calcium-rich inflows. There are some very shallow river lakes such as the Dahme, a tributary of the Spree, and numerous polymictic lakes such as the Große Müggelsee, which owing to their relatively low depth do not show any prolonged thermal layering phases. On the other hand, there are lakes shaped by glacial periods which are distinctly deeper. Lake Stechlin, with a depth of 70 metres, is the deepest lake in Brandenburg. This is why stable layering takes place in the course of the year. When illustrating the temperature progress for Lake Stechlin, it was taken into account that until 1990 the lake was to a great extent affected by the cooling cycles of the Rheinsberg Nuclear Energy Plant. The temperature chart was adjusted accordingly.

The water temperatures of all lakes analysed here show significant increases during the observation periods, for both the annual mean and the seasonal mean between March and October. In contrast with the 2015 Monitoring Report in which the indicator was calculated on the basis of the mean of the two warmest months, the mean temperatures here indicate a very clear trend. In respect of Lake Constance the seasonal increase between 1971 and 2017 for instance amounted to two degrees, while in the Saidenbach Reservoir an increase by as high as three degrees was calculated.



Rising water temperatures in lakes have fundamental impacts on water ecosystems.
(Photograph: © Maurice Tricatelle / stock.adobe.com)

Interfaces

WW-I-6: Start of the spring algal bloom in standing waters
FI-I-2: Occurrence of thermophilic species in inland waters

Objectives

Management objectives for surface waters: good ecological and chemical condition / good ecological and chemical potential (WHG, § 27)

Algal bloom in spring – major fluctuations from year to year

Apart from direct and indirect impacts of water temperature on the material balance of lakes, as well as their species composition and utilisation potential, changes in the water temperature also change the layering of water bodies which, in turn, entails impacts on the pivotal processes in water ecology.

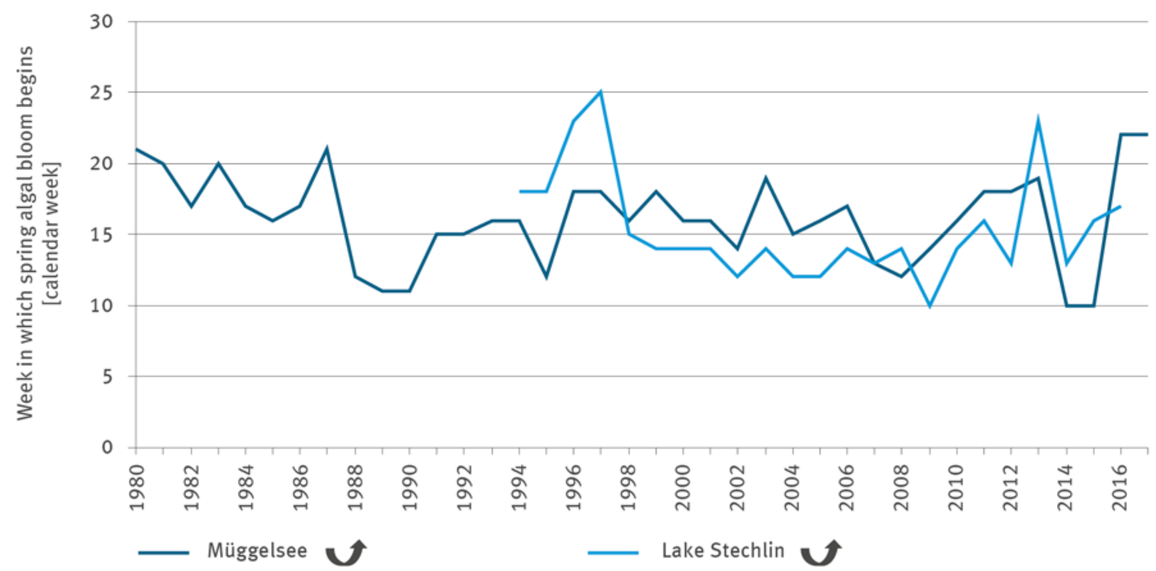
Especially in sufficiently deep lakes the phases of layers mixing and phases of temperature layering alternate. While solar radiation will warm up the surface water, it will not penetrate to water layers further down. The variety of water temperatures results in more or less stable layering of the water body – the so-called summer stagnation – which prevents the exchange of oxygen and nutrients among the layers.

Summer stagnation stops when in autumn the circulation regime restarts owing to falling surface temperatures. The cooling of surface water in winter resulting from the development of stable layers as a function of air temperature in winter and spring, is rapidly impeded again by spring circulation. Thanks to this circulation process, nutrient-rich water from the depth is transported to the lake surface where it furthers the growth of algae in this phase. The milder the winter and the higher the spring temperatures, the earlier algal bloom begins in spring; this triggers a phase of algal growth which subsides once the available nutrients have been used up and strong feeding pressure from zooplankton sets in. The clear water phase begins.

In principle, the temporal process of circulation and layering is different for each lake, depending on variables such as lake size, water depth, type of circulation and the regional climate. Deep lakes such as Lake Stechlin in Brandenburg typically form a more stable layering than shallow lakes such as the Große Müggelsee in Berlin. ´The latter can occasionally be subject to complete mixing of layers owing to windy conditions in summer. In Germany there is very limited availability of long-term time series of temperature measurements using depth profiles which might indicate the annual progress. It is therefore not possible to provide valid illustrations of time series of layering conditions in typical lakes.

WW-I-6: Start of the spring algal bloom in standing waters – case study

The time of onset of spring algal bloom depends on the temperatures prevailing in late winter and spring. Particularly mild winters such as 2001/2002 or particularly cold winters such as 2013/2014 influence the processes taking place in the course of the time series. It would therefore be inappropriate to over-interpret the square trend calculated statistically.



Data source: Leibniz-Institut für Gewässerökologie und Binnenfischerei IGB (lake monitoring)

The shallow Große Müggelsee and the deep Lake Stechlin illustrate that from year to year algal bloom starts at different times of spring. As far as the Müggelsee is concerned, in the years 2011 and 2014 spring algal bloom started at the earliest in the beginning of March whereas in 2016 and 2017 spring algal bloom did not start till late May. For the 70 m deep Lake Stechlin the range of fluctuations is even greater: in 2009 spring algal bloom started already in early March whereas in 1997 and 2014 it did not start until mid or early June. The 1990s experienced a number of mild winters which led to a comparatively early onset of spring algal bloom. Between 2008/2009 and 2012/2013 all winters were colder than calculated for the long-term mean thus leading to a later onset of spring algal bloom.

When the water warms up in spring, phytoplankton can proliferate very suddenly.
(Photograph: © Dudarev Mikhail / stock.adobe.com)

Interfaces

WW-I-5: Water temperature of standing waters
GE-I-5: Contamination of recreational bathing waters with cyanobacteria
FI-I-2: Occurrence of thermophilic species in inland waters

Objectives

Management objectives for surface waters: good ecological condition and/or good ecological potential as well as good chemical condition (WHG, § 27)

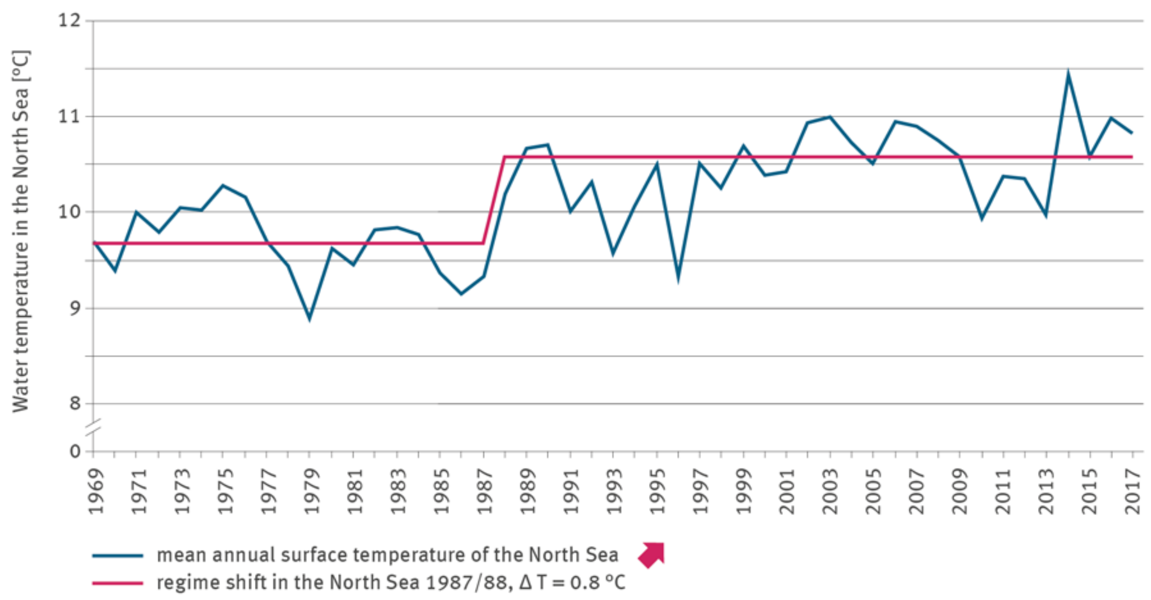
The North Sea is warming

The heatwave of summer 2018 was not limited to Germany; in fact, it extended to large parts of the land mass in the northern hemisphere. On German coasts water temperatures of 25 °C reached Mediterranean proportions. In July 2018 the mean surface temperature of the North Sea missed the record temperature of 17.4 °C of July 2014 by just 0.1 °C. The 'marine heatwave' also extended over the entire Baltic Sea where the mean temperature for July amounted to 20.0 °C thus exceeding the previous record temperature, measured in 2014, by another 0.5 °C. It seemed obvious that the cause was an almost stationary distribution of high and low pressure areas – a prolonged stagnation period which was favoured by the diminishing temperature contrast between polar and mid-latitudes[11].

More than 90 % of excess heat caused by the anthropogenic greenhouse effect is stored in the ocean. Between 1960 and 2015 the heat energy contained in the upper 2,000 m of the earth's ocean increased by 304 sextillion Joules (304 x 1021 J). For the entire earth's surface the warming rate mean calculated amounted to 0.33 Watt per square metre (W/m2), which latterly (1992–2015) almost doubled reaching 0.61 W/m2[12]. Consequently, the heat energy absorbed annually by the ocean currently amounts to 9.8 x 1021 J which is 17 times higher than the world energy demand in 2017 (equivalent to 13,511.2 billion tonnes of oil)[13]. If you imagine this amount of heat energy distributed exclusively over the upper 5 m of ocean, this would result in a temperature rise of 1.3 °C per annum. In fact, between 2000 and 2015 the ocean's surface temperature rose at a rate of 0.013 °C per annum[14]. Accordingly, 99 % of the energy increase must be 'concealed' in lower layers of the ocean. It therefore follows that to measure global warming primarily in terms of the globally calculated surface temperature (GMST) is tantamount to a 100-fold underestimation and misperception of this complex issue. In fact, global warming came into question when the GMST more or less stagnated (global warming hiatus) between 1998 and 2013. Climate change indeed manifested just superficially in terms of GMST. A hiatus in global warming is, however, out of the question, because the heat content of the ocean (and also the sea level) did increase faster in the so-called hiatus phase.

WW-I-7: Water temperature in the sea

The mean surface temperature of the North Sea has increased in the period from 1969 until 2017. The abrupt temperature jump in 1987/88 manifested in a regime shift and mean value shift by 0.8 °C.



Data source: BSH

A direct consequence of heat storage in the ocean is the expansion (increase in volume) of seawater – one of the crucial causes of sea level rise. In 2017 the global sea level was 77 mm above the 1993 level (when satellite measuring began) thus reaching a record level[15]. Just under 40 % of this increase is due to the thermal expansion of sea water, most of the rest of the increase in mass is due to melt water inflows.

Evidence for the warming of North Sea and Baltic Sea is found in the large-scale analyses of surface temperatures which have been carried out in the North Sea for over 50 years by the Bundesamt für Seeschifffahrt und Hydrographie (BSH/Federal Maritime and Hydrographic Agency). Annual mean temperatures were calculated on the basis of aggregated measurements. Formally, a significant linear trend of 1.3 ± 0.6 °C (95 % confidence interval) is stated for the entire period in question. The slow and gradual rise in temperature suggested does not, however, adequately describe the regime character of the historic development. This development is characterised by a cold regime which lasted until 1987; it ended abruptly with the temperature jump in 1987/88 and was replaced by the current warm regime. The regime change is manifested in starkly contrasting long-term means of 9.7 °C until 1987 and 10.5 °C from 1988 onwards. This development shows similarities with the hiatus phases of the GMST cold regimes (–0.5±1.0 °C) and of the warm regimes (until 2013: 0.3±0.7 °C) trend-free. Whether the temperature jump which occurred in 2013/14 initiated a more extreme warm regime remains to be seen. In terms of quality, the time series of air temperature in Germany shows a similar development (see Figure 1, p. 19).

The highest annual mean temperatures of the North Sea, typically resulting from extreme warming in the summer months, amounted to 11.0 °C (2003, 2006, 2016) and above (11.4 °C, 2014) The cumulative occurrence of such events during the warm regime does not come as a surprise. The regime change was not observed for North and Baltic Sea alone; in fact it was observed globally in a multitude of variables[16,17]. The ecological consequences of warming in both North and Baltic Sea were documented for instance by Beaugrand (2004)[18] and Alheit et al. (2005)[19].

The increasing sea temperatures have far-reaching impacts on the entire marine ecosystem. Species either adapt their range of distribution or become extinct (either locally or regionally) while other species come in to occupy these ecological niches. Indirect side effects of climate change such as lack of oxygen and the acidification of the seas contribute to changes in the diversity, composition and distribution of species thus changing the entire food web prevailing in marine habitats. Likewise, the economic consequences for marine fisheries are difficult to assess. Along German coastlines high seawater temperatures have made headlines in recent years, whenever the bathing tourism was affected by blue-green algal bloom; such processes are provoked additionally by the over-fertilisation of the seas.

Water temperatures in the North Sea are rising.
(Photograph: Peter Löwe, BSH)

Interfaces

FI-I-1: Distribution of thermophilic marine species
TOU-I-1: Coastal bathing temperatures

Objectives

Limitation of all factors which lead to warming and acidification (DAS, ch. 3.2.3)

The sea levels of North Sea and Baltic Sea are rising

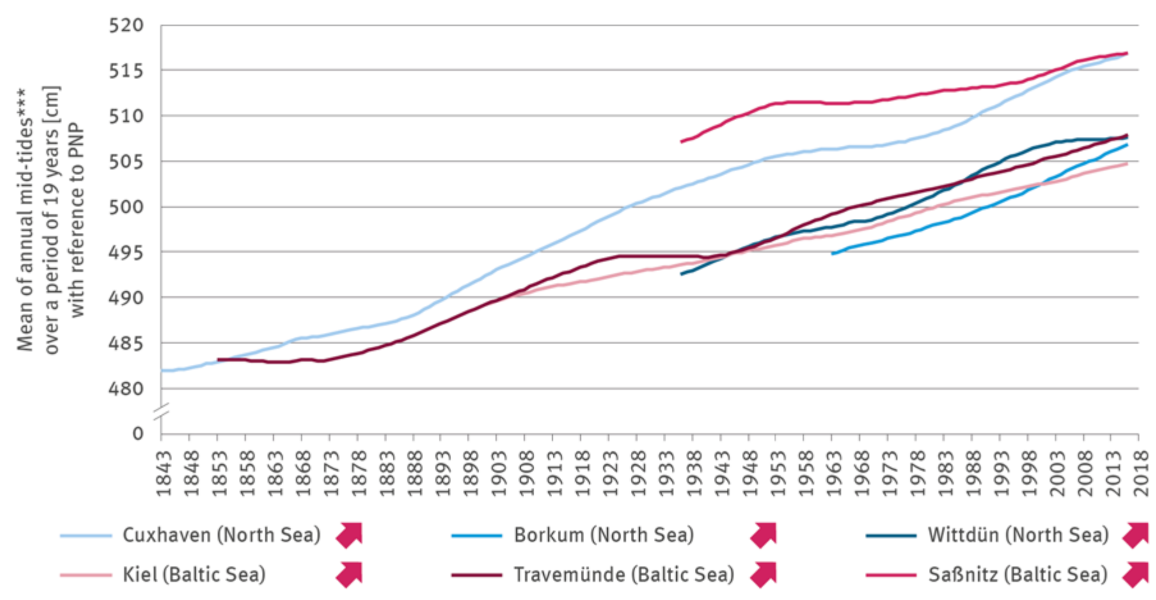
The glaciers and ice sheets on the poles are melting thus providing the seas with large quantities of meltwater. At the same time rising water temperatures make the sea water expand. Consequently, this leads to global rise of sea levels. The Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC) published in September 2019 by the Intergovernmental Panel on Climate Change (IPCC) provides projections of earth system models for mean global sea level rise and for extreme values and their frequency, based on scenarios of socio-economic development. The probable bandwidth of mean global sea level rise for the end of this century compared to the year 2000 is between 61–110 cm, while the median is estimated as 84 cm. These values are higher than stated in the previous IPCC case report published in 2013, because new findings suggest a higher contribution of meltwater from the antarctic ice sheet. The SROCC also demonstrates that, as a consequence of sea level rise, storm surge water levels be higher than before. It is expected that sea levels will continue to rise beyond the year 2100 and that they will remain high.

However, increases in sea levels occur in very different ways regionally and locally; this also applies to the North Sea and the Baltic Sea. Water levels along the German coastlines have been measured regularly for over 150 years. This makes it possible to state concrete figures regarding the changes. In the southern part of the German Bight the mean sea level rise in the course of the past 100 years amounted to 1.1–1.9 mm per annum – not including land subsidence effects. This means that the rates of increase for the North and Baltic Seas are just slightly below the values for global sea level rise. However, if the influence of land subsidence is taken into account, the rates of increase in some German coastal zones reach values of 1.6–2.9 mm per annum.

The North Sea is subject to tidal changes. The mean value of mid-tide (MTmw) is therefore of crucial importance. In contrast, the Baltic Sea – owing to its geographical location and tenuous link with the oceans – is subject to comparatively weak tidal influence; this is why in this case the annual mean water levels (MW) are relevant. For these coefficients of water level, a moving average across

WW-I-8: Sea levels

The calculated mean values of selected sea level measurements recorded in the North and Baltic Seas in the course of 19 years illustrate the rise in sea levels. In most cases, these increases in sea level are significant.



Data source: BfG (Level database of the Federal Waterways and Shipping Administration)

19 years was calculated. For the selected North Sea levels at Cuxhaven as well as Borkum and Wittdün on Amrum, the mid-tide levels suggest significantly rising values. The Baltic Sea levels at Kiel, Travemünde and Saßnitz also show a significant rise in sea level. Differences between the rate of sea level rise in the North Sea and the Baltic Sea are due to differences in vertical land movement.

For coastal regions, in particular estuaries and low-lying coastal zones, rising sea levels signify a very slow increase in risks from storm surges. Estimates for the development by end of this century vary.

Another consequence of rising sea levels is progressive coastal erosion which affects sandy coastal zones exposed to sea surges, thus also affecting many popular bathing beaches. Such coastal sections are the foundation of tourist development in the North Sea and Baltic Sea areas. This confronts coastal protection authorities with additional challenges. Likewise, the operation of waterways is expected to face additional challenges, e.g. in terms of sediment management.

Sea level rise puts the coastlines at risk.
(Photograph: © jomo333 /stock.adobe.com)

Interfaces

WW-I-7: Water temperature in the sea
WW-I-9: Intensity of storm surges
WW-R-3: Investment in coastal protection

Objectives

Designing integrated development strategies for ecosystems in coastal zones including estuaries. Establishing sanctuaries for ecosystems affected by sea level rise. Making use of synergies between nature conservation and coastal protection (DAS, ch. 3.2.5)

Examining and documenting any changes in currents, erosion or sedimentation in estuaries and shipping routes, arising from the predicted sea level rise (DAS, ch. 3.2.11)

For existing or planned industrial sites, consideration must be given, both nationally and internationally, to the impacts of climate change such as the consequences of the expected sea level rise in areas near a coastline. (DAS, ch. 3.2.12)

Sea level rise and the related groundwater level rise as well as the increase in coastal erosion tendencies call for extra efforts in the protection of coastal zones. This is required as a foundation for essential new focal points regarding the development of coastal landscapes. (DAS, ch. 3.2.14)

Increase in storm surges owing to sea level rise

When the water level on the North Sea coast is higher than 1.50 m above the average high-water level, this is referred to as storm surges. Storm surges occur when onshore wind categorised as storm or hurricane pushes large volumes of water towards the coast. If the resulting build-up of wind occurs during an astronomic high-water phase (such as MHW) on the North Sea coast, with a north-westerly wind force of Bft. 8-9 (on the Beaufort scale), this can lead to storm surges.

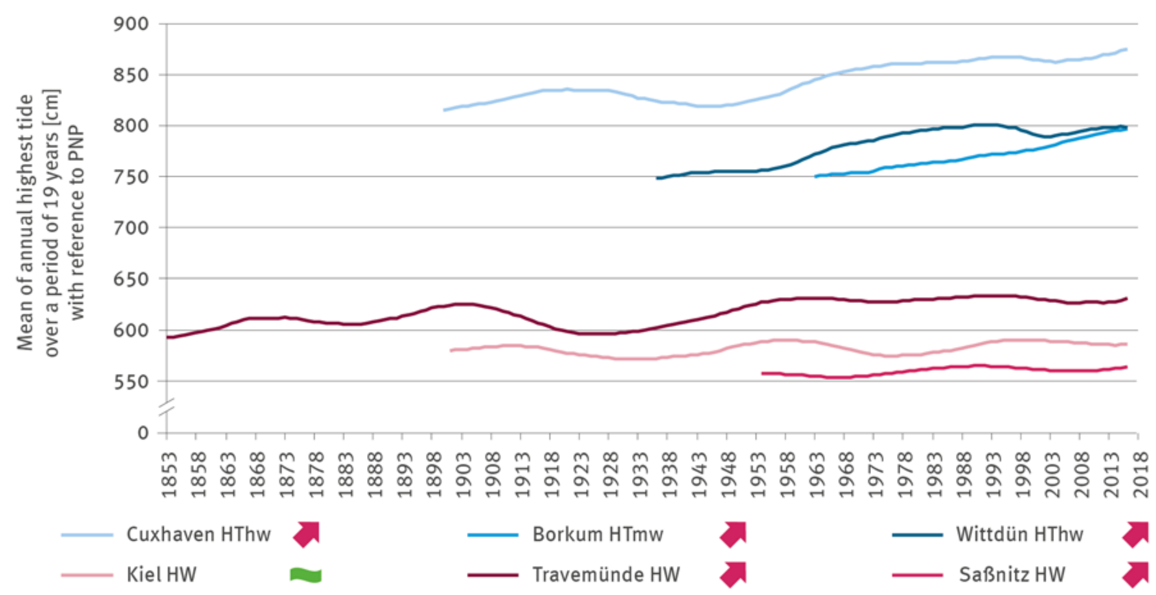
An additional increase in storm surges can result from external surges produced by wind fields in the North Atlantic which, similar to a tidal wave, traverse the North Sea in an anti-clockwise direction.

As a result of sea level rise in the North Sea in the course of the past one hundred years, storm surges start from a higher initial level and therefore cause waves to make landfall from a greater height. Apart from sea level rise, there is a problem, especially in estuaries, with increased storm-surge water levels owing to increased dyking and damming of the tributaries of Ems, Weser and Elbe. This means that the natural flood plains have been severely constricted.

In general, major storm surges entail damage to buildings and infrastructures near the coast. The North Sea coast in particular experienced major storm surges in the past. For almost 2000 years storm surges have been documented on German coasts. As early as 1219 the so-called 'Grote Mandränke' (the big drowning) caused the death of some 36,000 people. The storm surge of 16th February 1962 which affected the entire German Bight, and especially Hamburg, is deeply engrained in people's memory. The big storm surge in northern Friesland in November 1981 caused extensive damage, in particular on North Sea islands which were unprotected by dunes or dykes. In December 1999 hurricane Anatol reached storm peaks up to 200 kilometres per hour and briefly caused very high increases in sea levels throughout the North Sea area. In December 2013 the entire North Sea area was affected by hurricane Xaver and storm surges which were quite severe in some places. The dykes on the mainland managed to withstand the onslaught of water masses,

WW-I-9: Intensity of storm surges

The development of storm surges on North and Baltic Sea coasts shows rising trends for the five levels examined. The exception is Kiel where no significant trend has been discerned.



Data source: BfG (Level database of the Federal Waterways and Shipping Administration) whereas on the islands in eastern and western Friesland, dunes were severely breached in many places.

As far as the Baltic Sea is concerned, the tides are not of major importance; here it is the duration and the intensity of the wind which determine whether storm surges occur. Water levels of one meter and more above the average water level are considered as storm surges here. The Baltic Sea is also known for the occurrence of 'Seiches' (French for standing wave) where water is pushed back from the German part of the Baltic Sea coast by westerly or north-westerly wind. Once the storm abates, the water than swashes landward thus leading to storm surges on the western coast of the Baltic Sea. As things progress, the waves of the Baltic Sea enter a pendulum motion (alternately swashing landward and seaward) until the motion subsides. The same phenomenon can be observed during prolonged easterlies. Furthermore, changes in air pressure also contribute to water level fluctuations by producing natural oscillation in water masses.

In the beginning of 2017 and 2019 severe storm surges occurred on the German coast of the Baltic Sea. In Wismar a sea level of 1.83 m above average was reached in the evening of 3rd January 2017 which was exceeded in the same place with a sea level of 1.91 m above average two years later on 2nd January 2019. After these events had taken place, damage was recorded especially on the coasts and beaches.

The increase in intensity of storm surges caused by rising sea levels is illustrated by the annual maximum High Water (HW) for the North Sea levels and for the annual maximum High Water measured for the Baltic Sea levels. The indicator reflects the highest (tidal) High Water per annum for the North Sea and the highest High Water per annum for the Baltic Sea. For these coefficients of water level, a moving average across 19 years was calculated by BfG.

In the case of selected North Sea levels a trend can be derived regarding the magnitude of sea level rise. Likewise, regarding the Baltic See coast a cyclical pattern and a periodicity of 30 to 40 years can be observed which overlies the trend. The illustration based on average values measured across 19 years has not revealed any extreme individual events. It is only accumulations of such events which lead to increasing values.

Storm surges also pose threats to infrastructures close to coasts. (Photograph: © Wojciech Wrzesień /stock.adobe.com)

Interfaces

WW-I-8: Sea levels
WW-R-3: Investment in coastal protection

Objectives

Requirements of regional planning for the protection from increasing storm surges and floodwater risks (DAS, ch. 3.2.14)

Water usage clearly in decline

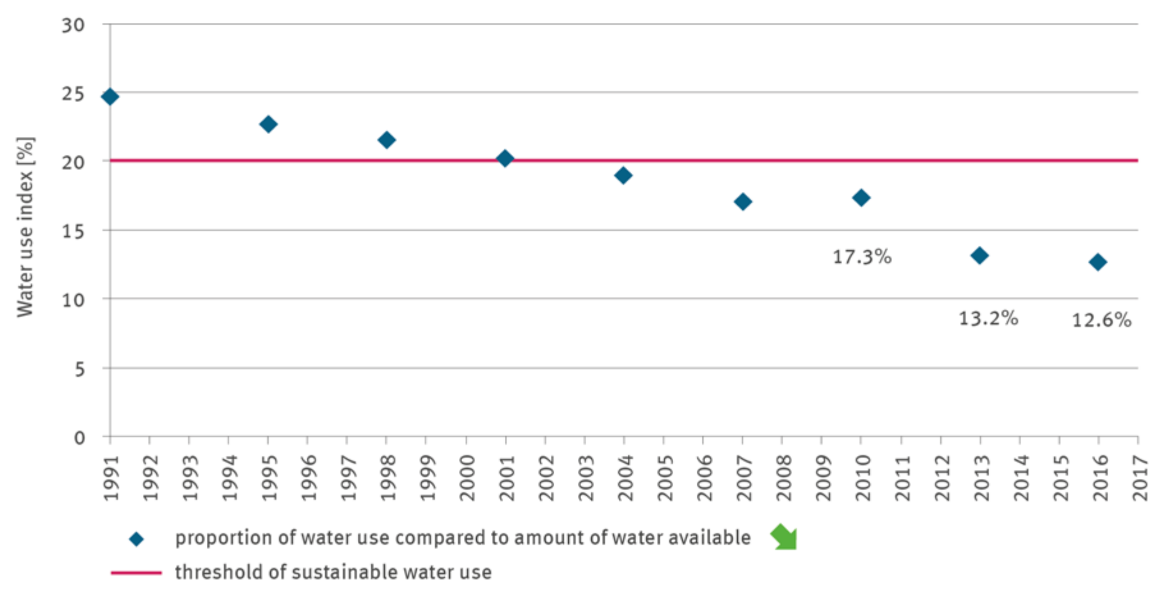
Germany is a country rich in water where in current circumstances there are only limited restrictions to water availability at a regional and seasonal level. The long-term average shows that approx. 188 billion cubic metres of groundwater and surface water are potentially available whereas only a fraction of this volume is being used. Nevertheless, extended and more frequent drought phases and low-water periods, brought about by reduced water supply, can result in regional conflicts of usage regarding surface water and especially with regard to groundwater abstraction close to the surface. This is true, in particular, for central parts of eastern Germany, the north-eastern German lowlands and the south-eastern German basin where unfavourable climate-related water regimes occur; in other words where comparatively little rain falls while evaporation of water is high owing to high summer temperatures.

The water use index provides basic clues as to whether the usage of water resources in Germany is sustainable or whether water shortages are developing. Water abstraction can be termed sustainable as long as it does not exceed the threshold of 20 % of available water supply. Notably, the 20 % threshold is an internationally valid benchmark. Once water usage exceeds this threshold, this is regarded as a sign of water stress. Values of 40 % and above are termed high water stress. The causes for exceeding this threshold can be sought in an increased water abstraction or scarcity of naturally occurring water supplies.

Owing to a decline in both the commercial and private water usage in Germany, this 20 % threshold has been undercut regularly since 2004. Overall the values recorded in the water use index have been declining significantly since 1991. It follows, therefore, that according to internationally valid benchmarks, the extent of water usage can be considered sustainable. Energy producers as well as industrial and mining operations have contributed to this distinct decline; as these companies clearly have the greatest share (80 %) in water usage. Coolant abstraction by thermal power plants accounted for the lion share of commercial water usage. Consequently, efficiency improvements in terms of recycling or cyclical usage, had

WW-R-1: Water use index

In the course of the past 25 years, water usage has experienced a significant decline. 2004 was the first year in which the water usage index of 20% considered critical was undercut, i.e. no more than 20% of the potential water supply has been used since. However, there are distinct regional differences in Germany, and climate change confronts water providers with new challenges, for instance, in terms of meeting the demand at times of seasonal consumption peaks.



Data source: UBA (based on data of StBA (water use) and BfG (water supply)) particularly favourable effects on the water regime, at least until 2007.

Likewise, water consumption by private households and by trade was reduced substantially since 1991 from 144 litres per person per day to 123 litres per person per day. It is nonetheless important to keep using drinking water sparingly.

The water use index used as an indicator so far does, however, have its limitations when it comes to illustrating the adaptation requirements and related activities in the water industry. An overview of the situation nationwide does not take into account any distinct regional differences within Germany. In future, the water regime may – owing to climate change and a further decrease in summer precipitation and increased evaporation e.g. in eastern Germany – become even more unfavourable thus reducing the availability of water in that area. At the same time, extended heat periods may lead to increased demand for water. With regard to private water usage it is to be expected that, especially in residential areas with a high proportion of detached houses and terraced houses which have their own courtyard or garden space, water consumption will soar in prolonged periods of heat without precipitation as major quantities of water will be used for garden irrigation.

The overall declining water usage on one hand and the climate-induced higher consumption peaks on the other as well as variations in regional distribution of water resources and water demand, confront water providers with certain challenges. In particular water providers in rural areas and in upland regions where largely decentralised and precipitiation-dependent water supply structures prevail, may be confronted with predicaments during prolonged drought periods. Nevertheless, with regard to central or pipeline-based supply, it has been possible so far to keep a balance in terms of regional and temporary differences in water availability and demand. In the case of several subsequent years of prolonged drought, it is important to ensure that there are always sufficient water resources available to meet the demand.

Summer temperatures can lead to drinking water consumption peaks in households. There are, however, distinct regional differences. (Photograph: © Sashkin – stock.adobe.com)

Interfaces

WW-I-1: Groundwater level
WW-I-4: Low water
EW-R-4: Water efficiency of thermal power plants
IG-R-1: Intensity of water consumption in the manufacturing sector

Objectives

As far as demand management is concerned, technical methods and improvements for a more efficient use of water can be applied and this should be taken into account in accordance with the principle of proportionality (DAS, ch. 3.2.3)

Back to natural structures of water bodies

Floodwater events are a natural phenomenon. Human interventions such as separating alluvial meadows from rivers, straightening rivers, clearfelling of alluvial forests and property development in flood plains entail that the topography of the landscape is less able to retain floodwater thus accelerating run-off into watercourses and standing water bodies. It is to be expected that progressive climate change will increase the flooding risks of flowing waters. This increases the importance of floodwater risk management as embedded in the European Flood Risk Management Directive (FRMD) enacted in 2007 thus giving it legal status.

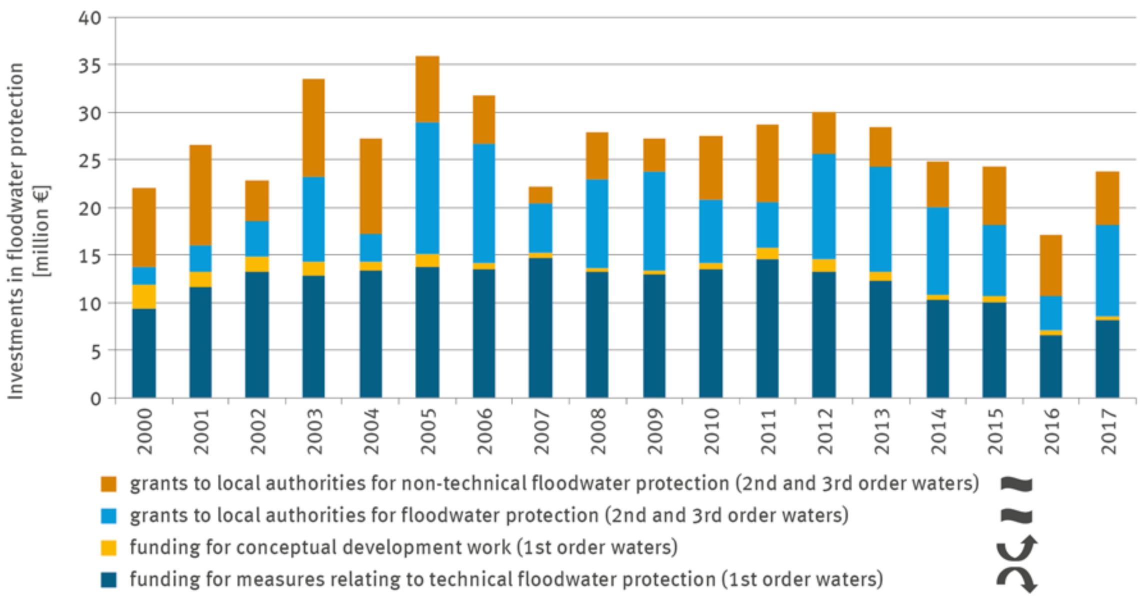
By late 2015 floodwater risk management plans, agreed and approved at national and international level, had been, for the first time ever, developed for all German river basins. Every six years, these plans have to be subjected to revision and updating by those Länder which are responsible for floodwater precautions; this work has to be done taking into account the anticipated impacts of climate change. To this end it is necessary to create or update maps for areas in danger or at risk, to lay down objectives for dealing with extant risks and to design and enhance action plans to achieve those objectives. Such plans contain measures for technical floodwater protection, restoration of retention areas and the rehabilitation of near-natural structures of water bodies/watercourses.

Additional measures such as demarcation and designation of floodwater areas or preliminary planning work for the implementation of operational measures for floodwater protection are embedded in the Wasserhaushaltsgesetz (WHG/Water Resources Act). In respect of such planning and conceptional measures for the state of Hesse alone the cumulative expenditure amounted to 6.85 million Euros in the course of the past ten years. Nevertheless, a holistic approach plays an important role in other areas too, such as behavioural precautions and precautions in the building sector, as well as development planning, improvements in floodwater forecasting, crisis management and risk-adapted reconstruction.

Technical flood protection defences such as dams, dykes and walls, rain and flood control reservoirs, barrages,

WW-R-2: Investments in floodwater protection for inland waterways – case study

In the course of the past ten years, 259.71 million Euros were granted to Hesse by the Federal Government and invested in flood protection. This figure does not reflect any investments by local authorities themselves. As far as Hesse is concerned, its obligation extends only to the maintenance of old meanders of the river Rhine (Old Rhines). Non-technical flood protection measures regarding 1st order waters in Hesse are therefore carried out to a limited extent only (not represented in the chart).



Data source: Hessisches Ministerium für Umwelt, Klimaschutz, Landwirtschaft und Verbraucherschutz (budget account) pumping stations and flood channels are employed for the retention, passage and redirection of water. Some Länder such as Baden-Württemberg or Bavaria are already basing their design efforts for flood protection defences on a 'Lastfall Klimaänderung' (potential climate-change related burden). In order to account for 'climate change factors' such as a hundred-year flood event, a safety margin is added to the currently valid design value as a safeguard against any rising floodwater risks in the future. In Hesse investments in technical flood protection have declined in recent years, because the prolonged dyke rehabilitation work in the areas of Rhine and Main are now essentially completed.

In addition to measures for technical flood protection, also non-technical measures are gaining in importance, because natural or near-natural structures of watercourses are able to retain water, stabilise the water regime and mitigate moderate flood events occurring in flowing waters. Restoration of natural or near-natural conditions is therefore promoted wherever possible. Meandering rivers and streams reduce flow rates and attenuate floodwater run-off peaks. Where the bed of a watercourse is permeable, consisting of types of sand and gravel, this enables the natural exchange between surface- and groundwater and is thus able to buffer, at least in part, floodwater peaks or water shortages. Cut-off meanders, alluvial meadows and flood plains in the vicinity of watercourses, are able to absorb part of the floodwater run-off. While many restoration or rehabilitation measures are often informed mainly by nature conservation objectives, they also help to reduce floodwater risks. Accordingly, the federal programme 'Blaues Band Deutschland' (Germany's blue ribbon) adopted by the Federal Cabinet in February 2017, made specific reference to the social benefits of rehabilitating watercourses for the purpose of adaptation to climate change impacts. One of the core challenges regarding non-technical flood protection continues to be the availability of additional retention areas which are safe to be flooded in a floodwater event.

Within the scope of the Joint Task entitled 'Improvement of Agrarian Structures and Coastal Protection' (IASCP), the Federal Government reimburses the Länder with 60% of their expenditure in respect of constructing new and reinforcing extant flood protection defences, for relocating dykes and for measures to develop near-natural watercourses/water bodies. The national flood protection programme was designed jointly at Federal and Länder level after the June 2013 floods in the areas of Elbe and Danube. Its purpose is to advance the implementation of supraregional measures for floodwater protection in river basins. The Federal Government uses the special framework plan (SRP) entitled 'Präventiver Hochwasserschutz' (preventative flood protection) to support the Länder in their implementation of measures for the realignment of dykes and the restoration of natural retention areas by means of flood control reservoirs and polders. For the first time ever, the Federal Government is promoting the purchase of retention areas. In order to implement flood protection measures in respect of 1st order waters, the Länder use further funds from their own budgets, in addition to the resources available under IASCP and SRP. Furthermore, individual Länder grant funding to local authorities within the framework of their responsibility for 2nd and 3rd order waters.

Flexibly designed technical and non-technical flood protection measures also assist the adaptation to climate change. (Photograph: © Ewald Fröch / stock.adobe.com)

Interfaces

WW-I-3: Floodwater
BD-I-3: Restoration of natural flood-plains
WW-R-3: Investment in coastal protection

Objectives

Restoration and redynamisation of alluvial meadows in river basins (DAS, ch. 3.2.3)

Protection from increasing floodwater risks by strengthening passive safeguarding measures (especially keeping land free from property development) and active run-off control, substantial expansion of retention areas (DAS, ch. 3.2.14)

Designation of floodwater areas (WHG, § 76)

More shading – better cooling of water structures

In principle, natural and near-natural water structures provide more favourable living conditions for aquatic organisms than water courses whose structure has been interfered with. The richer the structure of water courses, the greater the variety of different micro-habitats which enable aquatic creatures to take evasive action when living conditions change. In view of climate change and associated increases in water temperature, riparian vegetation plays an important role.

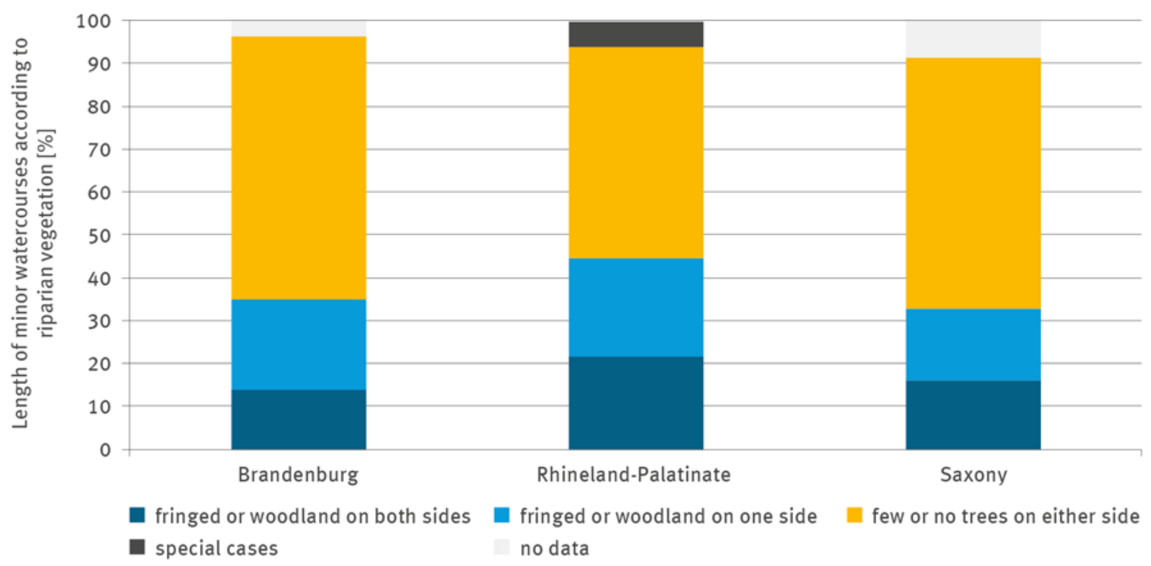
Especially in the case of small or medium-sized, hence narrower watercourses, shading by means of riparian woodland vegetation can help to prevent water from warming excessively. Herbaceous vegetation on the banks of smaller watercourses is, however, of minor importance for shading. It is true to say that in respect of larger rivers, the associated riparian vegetation has less influence on shading the entire cross section of the watercourse and also on cooling, but even in this case it produces diversification and creates cooler, shaded riparian zones which in warmer summer months serve as sanctuaries for sensitive species thus helping to improve their habitat conditions.

Under natural circumstances, the banks of nearly all small and medium-sized watercourses would be wooded with alder, willow and ash trees. However, property development close to and in watercourses, intensification of land use extending well into zones of water margins, as well as the use of hydropower resulting in numerous watercourses losing their natural riparian vegetation. These incisive changes are perpetuated by means of regular maintenance of watercourses in order to counteract natural succession. The restoration of riparian woodlands in particular is a form of adaptation to climate change, which can actively counteract further increases in water temperatures.

As part of mapping watercourse structures, the Länder of the Federal Republic carry out surveys of different water structure parameters in order to assess to what degree their condition can be described as near-natural. To this end, the Länder apply, for recording and evaluating woodland vegetation, a homogeneous methodology developed by the Federal/Länder Working Group Water. The mapping outcomes are fed into the assessment of the ecological condition of waters in accordance with the

WW-R-3: Riparian vegetation on the banks of small and medium-sized watercourses – case study

The associated shading effect of riparian woodlands help to counteract increases in water temperature. Watercourses with riparian woodland on one or both banks are now to be found only in a third or scarcely half the sections of small and medium-sized watercourses in examples from the Länder examined for the purpose of this analysis.



* owing to divergent data collection for Brandenburg, the water courses examined ranged from a water level width of 1 to 8 m

Data source: LfU Brandenburg, LfU Rheinland-Pfalz, LfULG Sachsen (watercourse structure mapping) implementation of the EU Water Framework Directive (WFD).

The latest outcomes from the mapping of the structure of water courses carried out by the environment authorities are illustrated in the indicator for Brandenburg, Rhineland-Palatinate und Saxony. The indicator is focussed on small and large streams as well as small rivers with an average water level width up to 20 metres, because in the case of this type of flowing waters, associated woodlands clearly influence the water temperature. The following percentages were found for riparian sections wooded on one or both banks: in Brandenburg 35.1 %, in Rhineland-Palatinate 44.6 % and in Saxony just under 32.9 % of the entire riparian section mapped. The reason for the distinctly higher percentage in Rhineland Palatinate is essentially that here 40.6 % of the terrain is forested compared to just under 35 % in Brandenburg and just 22.3 % in Saxony. Consequently, a greater proportion of streams and rivers flows through forested terrain.

In the case of woodland vegetation extending on only one bank of the watercourse, the orientation of this vegetation is crucial for the shading effect. Consequently, the existence of this type of vegetation does not necessarily constitute shading, either temporally or spatially. Several differentiated analyses would be required to clarify this. On the other hand, lack of riparian vegetation is not necessarily a clue for the absence of shading, for shade can also be cast by built structures on the margins of watercourses. Nevertheless, it can be assumed for such sections that the watercourse in question has been generally altered by anthropogenic activities.

Furthermore, it is debatable whether for a near-natural protective section of a watercourse it would be preferable to have gappy riparian vegetation alternating naturally between shaded and sunlit sections rather than having total shading (Grünverrohrung, roughly translated as a solid shield of dense green vegetation), in view of the fact that gappy vegetation is more consistent with the natural alternation of such structures. The mapping outcomes currently available do not, unfortunately, allow such differentiated evaluation.

The data obtained so far do not yet permit the illustration of time series which might show the progress achieved in rehabilitating watercourses by restoring the formerly associated near-natural riparian woodlands. For this purpose, regular consultation of water structure mapping databases would be required in future. Furthermore it will be necessary to enhance the indicator by involving and incorporating other Länder, and to collate the data,

Shading by riparian vegetation can help to prevent excessive increases in water temperatures.
(Photograph: © XtravaganT / stock.adobe.com)

where appropriate, ordered in categories of physiographic baseline conditions thus allowing the identification of any specific actions required.

It is to be expected that further renaturation efforts for the restoration of near-natural water structures will have positive impacts on water temperatures.

Objectives

Achieving good condition of surface waters (WFD, Article 4 (1))

Increasing the barrier-free condition and structural diversity of watercourses; restoring and redynamising alluvial meadows (DAS, ch. 3.2.3)

Prioritising actions under WFD which maintain or enhance the natural adaptability of watercourses as well as the biotope or habitat diversity of our watercourses (DAS ch. 3.2.2).

Coastal protection requires extensive investments

In view of rising sea levels and the expected increase in frequency and intensity of storm surges, the German coastal regions, too, are confronted with an increased risk of flooding. In Germany those areas are considered at risk if they are, on the North Sea coast, up to 5 metres above sea level, and on the Baltic Sea coast, if they are up to 3 metres above sea level. This covers an area of approximately 13,900 square kilometres with 3.2 million inhabitants; this area represents economic values of 900 billion Euros[20]. Cities close to the coast such as Hamburg, Bremen, Kiel, Lübeck, Rostock and Greifswald are particularly at risk.

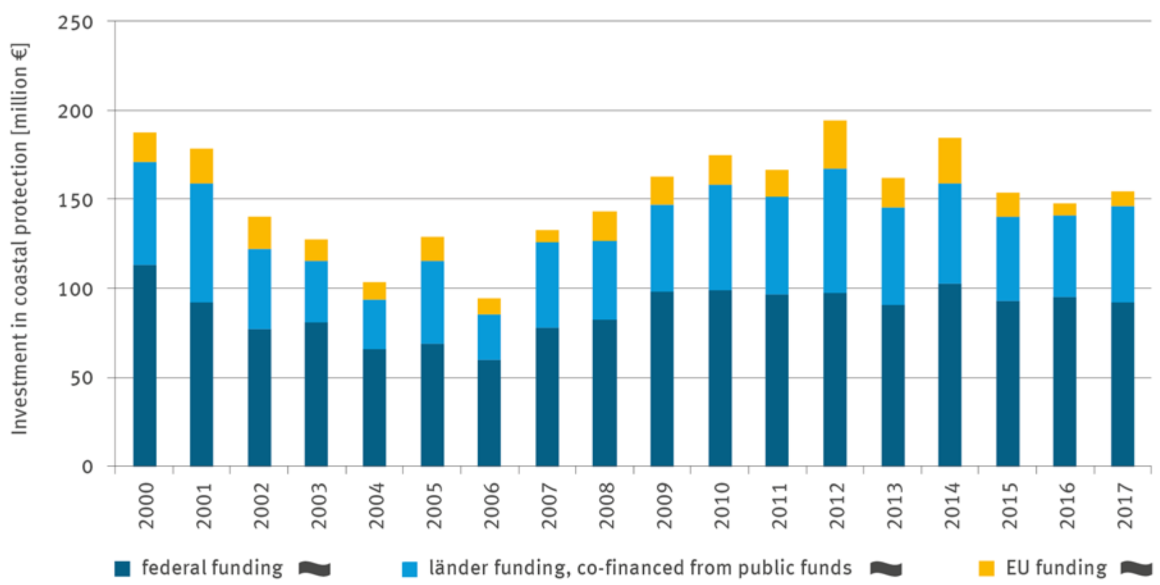
In order to protect the infrastructure, buildings and human life in those exposed coastal regions from increasingly intense floodwater events in future, the existing technical structures installed for protection from floodwater will have to be adapted to changed climate conditions.

Some of the coastal protection measures are e.g. the construction of new and the reinforcement and heightening of extant dykes, as well as the enhancement of embankment protection installations, the application of beach nourishment or the construction or reinforcement of storm surge barrages. Every one of those measures constitutes an intervention which has to be subject to authorisation, because they entail the impairment or irrevocable loss of mudflats, eelgrass beds, salt marshes or dunes. Another measure under discussion is the restoration of localised floodplains which were lost in the past owing to damming; this might be remedied by realigning or slotting dykes. The different coastal protection measures are accompanied by the designation of various priority and restricted areas for coastal protection and coastal floodwater protection respectively.

In 2011 the Länder of Schleswig-Holstein and Mecklenburg-Vorpommern amended their design methodology for coastal protection measures on the coast of the Baltic Sea. As part of the implementation of the FRMD which makes the consideration of climate-change related projections of sea level rise mandatory, a new guideline for designing coastal protection structures was introduced. This guideline now conforms, in principle, with the approach taken by those Länder which adjoin the North Sea coast. In this

WW-R-4: Investment in coastal protection

The funding made available by the Federal Government for the purpose of coastal protection declined between 2000 and 2006. After an increase in funding between 2006 and 2009, investments by the Federal Government have remained consistently at a high level.



Data source: BMEL (IASCP reporting)

light, owing to climate change it is estimated that sea levels will rise by 50 cm in the course of the next one hundred years. The new design method has a considerable impact on medium-term action planning. For dykes and steel structures or reinforced concrete structures this partly means heightening the structures, while for coastal protection dunes including their shore and shoreface areas this will potentially involve more frequent and, in terms of volume, more extensive beach nourishment operations. Moreover, in Schleswig-Holstein the construction of dykes has been changed in such a way that in future it will be relatively easy and inexpensive to heighten them further.

In Germany technical measures for coastal protection are financed predominantly by the IASCP. The EU's share of financing these measures amounts to between 5 and 13 %. The Federal Government and the Länder bear the bulk of the funding, sharing the investment cost at a ratio of 70 to 30. The objective is to speed up, or in individual cases, to supplement the ongoing reinforcement of coastal protection structures; the Federal Government therefore provides the coastal Länder with an additional 25 million Euros per annum via an IASCP special framework plan over the years 2009 to 2025 for coastal protection measures resulting from climate change.

These coastal protection measures which qualify for IASCP funding include for instance the construction of new, and the reinforcement and heightening of extant, coastal protection structures as well as dykes, barrages, groynes, breakwaters and other coastal flood defences. Likewise, operations in foreshores in front of dykes without embankment foreland up to 400 metres and beach nourishment qualify for funding. Other elements qualifying for funding include the essential acquisition of land as well as nature conservation actions and landscape maintenance necessitated by coastal protection measures.

After the investments in coastal protection made between 2000 and 2006 declined to about half, the expenditure has increased again since 2007, reaching just under 200 million Euros in 2012. Ever since, the annual expenditure from funds provided by the Federal Government, the EU and the Länder has oscillated around a total of 150 million Euros per annum. Investments by the Federal Government remained relatively consistent between 2009 and 2017 with just above 100 million Euros.

In 2012, the State of Schleswig-Holstein prioritised, within the general plan for coastal protection, funding for dyke reinforcement projects – a total of 93 kilometres. In this context, a total of just nine kilometres of dyke structures were reinforced by late 2017: on Nordstrand, on Sylt, in Büsum and in the Hattstedter Marsch. Those dykes were built on the basis of the so-called climate profile. In this process, the dykes were designed in a way to ensure that if required at a later date, they can be extended at the top in order to heighten the dyke by approximately 1 to 1.5 metres. Between 2012 and end 2017 approximately 292 million Euros were invested in coastal protection in Schleswig-Holstein. Apart from strengthening dykes, the funding was invested in the application of beach nourishment on Sylt and Föhr, construction of roads and paths along the dykes, revetments, groynes, breakwaters, reinforcement of barrages, work on the reinstatement of foreland areas, mound reinforcement; as well as measures taken by water and soil associations or municipalities.

Coastal protection structures have to be adapted to changed climate conditions.
(Photograph: © Deyan Georgiev / stock.adobe.com)

Interfaces

WW-I-8: Sea levels
WW-I-9: Intensity of storm surges
WW-R-2: Investments in floodwater protection for inland waterways
RO-R-3: Priority and restricted areas for (preventive) flood control

Objectives

Making additional efforts regarding the protection of coastal areas; developing new forms – including especially passive forms – of safeguarding measures for islands and coasts (DAS, ch. 3.2.14)

Strategic management of coastal areas (IKZM, page 6ff.)

Fisheries

In the same way as agriculture and forestry, fisheries are dependent on the availability and regenerability of natural resources. If there are changes in the size and location of fish stocks, and if there are changes in the plant and animal communities, this will directly affect the conditions prevailing in the fishing industry. In principle this applies equally – albeit in different ways – to both marine and freshwater fisheries.

As far as changes in marine fish stocks are concerned, there is an additional factor to be taken into account: Rising sea levels and frequent storm surges impact on coastal habitats thus affecting also the coastal opportunities for catching fish. In the case of freshwater aquaculture the debate starts with bottlenecks in the availability of water for managing fish ponds and extends to the adverse consequences of rising water temperatures as well as heavy precipitation events and floodwater, especially where salmonids such as trout and salmon are bred which depend on particle-free and oxygen-rich water.

So far, no specific adaptation measures have been described either for marine or for freshwater fisheries. In respect of marine fisheries, theme-specific discussions, especially regarding the call for a curb on overfishing, are often linked to adaptation measures, as it can be assumed that sustainably used fish stocks will be more resilient to climate-related changes than overfished stocks. And yet, in negotiating fishing quotas, climate change has so far been left out of the equation. So far, in freshwater fisheries, the debate has been dominated by other management challenges.

Effects of climate change

Thermophilic fish species in North Sea and Baltic Sea

Rising water temperatures, changed currents and rising CO_2 concentrations in sea water affect the living conditions for all marine organisms. It is worth remembering that water masses in the North Sea do not warm up in direction of north to south. In fact, the warming process takes place in complex spatial patterns. In the North Sea it has been observed that the stocks of psychrophilic (cold-loving) fish, molluscs and crustaceans have a tendency to move to cooler zones as warming increases. Their organism requires a specific range of temperatures, which is no longer available to them in a warming habitat. Besides, they follow plants, plankton and other marine organisms which they feed on and which prefer water at colder temperatures. At the same time, new species emanating from more southerly seas have encroached on the North Sea.

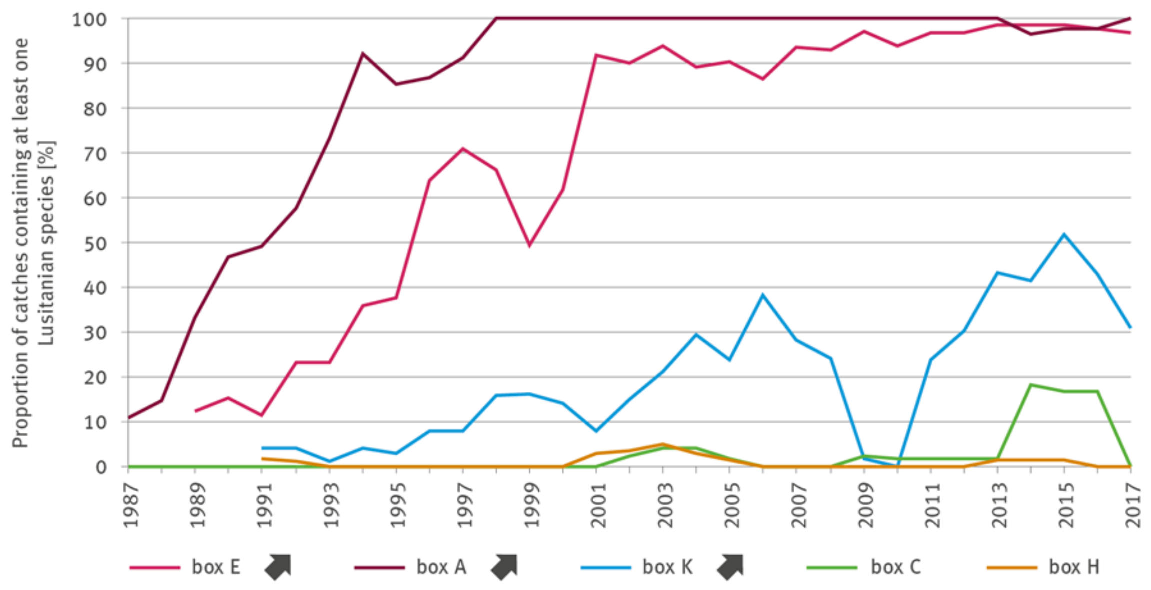
The brackish water of the Baltic Sea, with its mixture of freshwater and seawater, has given rise to unstable ecological equilibria. The high variability of environmental conditions offers only few, very tolerant fish species adequate conditions for living and reproduction. In view of the higher tolerance of species it is to be expected that the consequences of climate change in the Baltic Sea will have less pronounced impacts on species shift than in the North Sea. Nevertheless, changes to the productivity of fish stocks in the Baltic Sea are likely to occur.

Changes in the distribution of fish stocks and in species composition confront marine fisheries with new challenges. In this light, the spatial shift of North Sea fish populations towards cooler zones may entail economic losses to the fishery operators concerned, if new ranges of well-known species become harder to reach thus requiring much greater expense. It is hard to predict with any certainty to what extent such economic and ecological effects might be offset against the distribution and abundance of other species. At any rate, under current circumstances, it would not be worthwhile to target catches of these other species.

An important foundation for future adaptation of fishery management is the exact observation of the spatial shift in fish stocks and the observation of changes in the

FI-I-1: Distribution of thermophilic marine species

The effects of climate change on fish stocks are visible already today in the North Sea in terms of the encroachment of southern European thermophilic species on northern latitudes. In the most southern research areas nearest the German North Sea coast, almost every catch now turns up a southern species. Likewise, the most northern research areas show a similar increase.



Data source: Thünen-Institut für Seefischerei (GSBTS: German Small-scale Bottom Trawl Survey) species communities. Under the 'German Small-scale Bottom Trawl Survey' (GSBTS), standardised catches are carried out every year in designated areas of the North Sea. The objective is to assess the natural variability of fishing quotas for various species of fish and to record medium to long-term changes in the composition of fish species.

If you analyse the catch records of recent years up to 30 years ago in five research areas within the German Bight, you will see that more and more frequently specific south-European species originating in Portuguese seas have been identified in catches. Typical representatives of this group of species are for instance the tub gurnet (Chelidonichthys lucerna), the red mullet (Mullus surmuletus), the yellow sole (Buglossidium luteum) and the Mediterranean scaldfish (Arnoglossus laterna) as well as the anchovy (Engraulis encrasicolus) and the sardine (Sardina pilchardus). In the most southerly fishing zones nearest the German coast (Box A and Box E), every catch turns up at least one of these species, whereas in the late 1980s such catches would have been rare. Beginning in the mid-1990s, a little further north, approximately in the latitude of Denmark's Esbjerg (Box K), representatives of the above-named species appeared, and this subsequently happened with medium frequency, albeit not continuously. Likewise, there have been more and more catches, also in the northern North Sea (Box C) which suggest a potential distribution, also in these areas, that goes hand-in-hand with increasing temperatures.

Concurrently with the encroachment of southern European species, a decline in psychrophilic species has been observed. As a case in point, the codfish has almost completely disappeared from the southern North Sea. This is not just a consequence of intensive fisheries, but also – due to the detrimental effect of the seas warming in these latitudes – on the basic food source and the physiological processes this fish species undergoes.

Apart from climate change, there are other factors such as commercial fisheries responsible for the shift in fish stocks. However, the intensified warming does seem to play a vital role in the spatial relocation of fish stocks. Mild winters have enabled some southern fish species to survive winters and reproduce in the North Sea.

Thermophilic sardines are conquering the North Sea thus gaining in relevance to fisheries.
(Photograph: © ermess / stock.adobe.com)

Interfaces

FI-I-2: Occurrence of thermophilic species in inland waters
WW-I-7: Water temperature in the sea

Developments in freshwater fisheries still uncertain

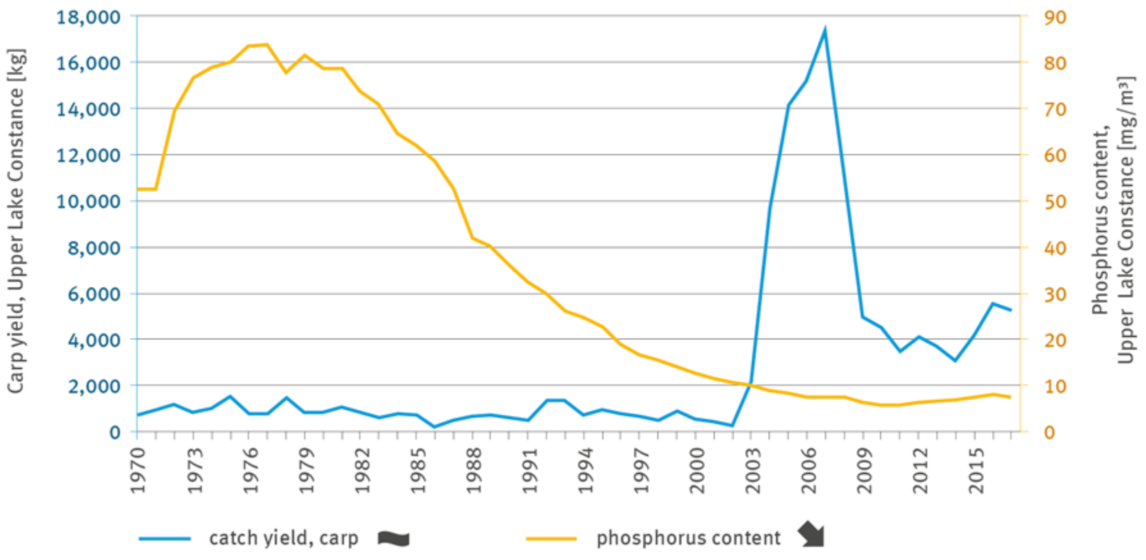
So far, the impacts of climate change are still playing a secondary role to other factors impacting on freshwater fisheries. As far as catch results of lake and river fisheries are concerned, these are subject to the general conditions governing fishing operations and cost-covering marketing opportunities as well as the availability of selected fish species of commercial interest to fisheries. This is why, rather than focussing on the potential impacts of climate change, the discussion is much more intense on conflicts arising from increasing tourist exploitation of lakes and rivers, losses of fish to hydropower plants, restrictions on fisheries from conservation-based constraints or changes in the nutrient contents of water. Protracted periods of drought, arising from advancing climate change, pose increasing and clearly visible threats to populations of mussels, crabs and small fish species which occur in small and minute lakes and rivers. The situation is similar in aquaculture, although in this case, the most important influencing factors impacting on production are water temperatures affected by climate change, the duration of ice cover on lakes in winter and water flow rates. Basically, fishermen tend to be more worried about the distribution of fish diseases and the presence of cormorants which has increased drastically in the course of the past two decades.

Generally speaking, decentralised production structures and small-scale enterprises predominate in freshwater fisheries. This explains why there is a dearth of nationwide data which would facilitate a systematic identification of climate-related changes regarding shifts in species composition of the fish fauna, not just in lakes and watercourses but also in aquaculture.

As for the future, experts do not rule out the possibility that climate change will have increasing impacts on fish stocks, income sources and proceeds in freshwater fisheries. For example, thermophilic species, distributed by shipping activities in canals, will have better opportunities to become established as water temperatures rise. Thermophilic species such as carp might benefit in terms of competing for habitats, whereas brown trout and other species which can exist only where temperatures are low, are likely to suffer restrictions to their habitats.

FI-I-2: Occurrence of thermophilic species in inland waters – case study

Despite a substantial reduction in the phosphorus content of Upper Lake Constance, the hot summer of 2003 led to an explosive increase in thermophilic carp. In particular during spawning and the development of larvae, warm weather conditions provide carp with competitive advantages. The warm summers of subsequent years bestowed record yields on commercial fisheries.



Data source: Landwirtschaftliches Zentrum Baden-Württemberg – Fischereiforschungsstelle (catch statistics, commercial fisheries Upper Lake Constance)

Using the example of Lake Constance for which long-term catch statistics exist from commercial fisheries, it is possible to demonstrate that particularly warm years can entail changes in the fish fauna. Upper Lake Constance and to some extent also Lower Lake Constance have in recent years become nutrient-poor again as a result of water pollution control measures. The phosphorus content of Lake Constance, which in the late 1970s and in the early 1980s amounted to more than 80 mg per cubic metre of water is now settling at around 6-8 mg. It is not to be expected that sizeable quantities of carp would exist in such lakes.

Therefore, the surprisingly strong presence of carp in 2003 is obviously due to particularly warm conditions in the summer of that year. Especially in Lake Constance it is rare to have early and prolonged warming of the lake water at the time of carp spawning and subsequent development of carp larvae. In most years, a warm period in early summer is followed by a cooler phase associated with the lake water cooling. Such conditions are not conducive to the emergence of young carp. As a result of those favourable conditions prevailing in 2003, subsequent years saw the highest carp yields ever recorded since the compilation of statistics on commercial fisheries in Lake Constance began. Between 1970 and 2003, carp catch results oscillated around 800 kg per annum, while in 2007 more than 17,000 kg were caught. After 2009, the yields have settled around a clearly higher level of approximately 4,000 kg, while the yield level rose again after the warm years of 2014 and 2015. As far as longer-term impacts are concerned, especially after the warm year of 2018, it is not possible to make any assertions at this point in time.

Fish species such as carp are more competitive under warm breeding conditions.
(Photograph: © Vladimir Wrangel / stock.adobe.com)

Interfaces

FI-I-1: Distribution of thermophilic marine species
WW-I-5: Water temperature of standing waters

Soil

Soils fulfil a great variety of tasks in nature which benefit humans either directly or indirectly. Soil properties such as humus content and soil structure are, next to climate, crucial for the fertility of soils. Fertile soils are essential for successful production in agriculture. Likewise, they are a basic requirement for producing victuals. In contrast, 'poor soils' often serve as havens or special habitats for rare plants and animals. Soils also play an important role in a landscape's water regime. They store and filter an astonishing amount of water. This makes them natural buffers warding off floodwater risks while providing us with clean groundwater. In Germany, the soil's functions have been protected since 1999 when the Federal Soil Protection Act (BbodSchG) was passed.

The climate influences numerous soil processes including a soil's formation, its properties and its functions. Soil processes such as weathering, formation of minerals, decomposition, development of humus and structure, take place over vast timescales and are strongly dependent on temperatures and availability of water.

The diversity of soils is great, and just as diverse are the impacts of climate change. In terms of surface area, agricultural use constitutes the most widespread intervention in natural soil structures, because more than half of Germany's surface area is used agriculturally. It is therefore important to make agricultural activities as sustainable as possible, using the soil's resources sparingly, in order to maintain and where possible enhance the natural resilience of soils in the face of adverse impacts from climate change such as summer droughts, waterlogging in winter and soil loss caused by water and wind.

For soils to fulfil their important functions in natural systems, they have to be protected from overbuilding and soil sealing.

Effects of climate change

Adaptations

Soil water supply – potential shortages

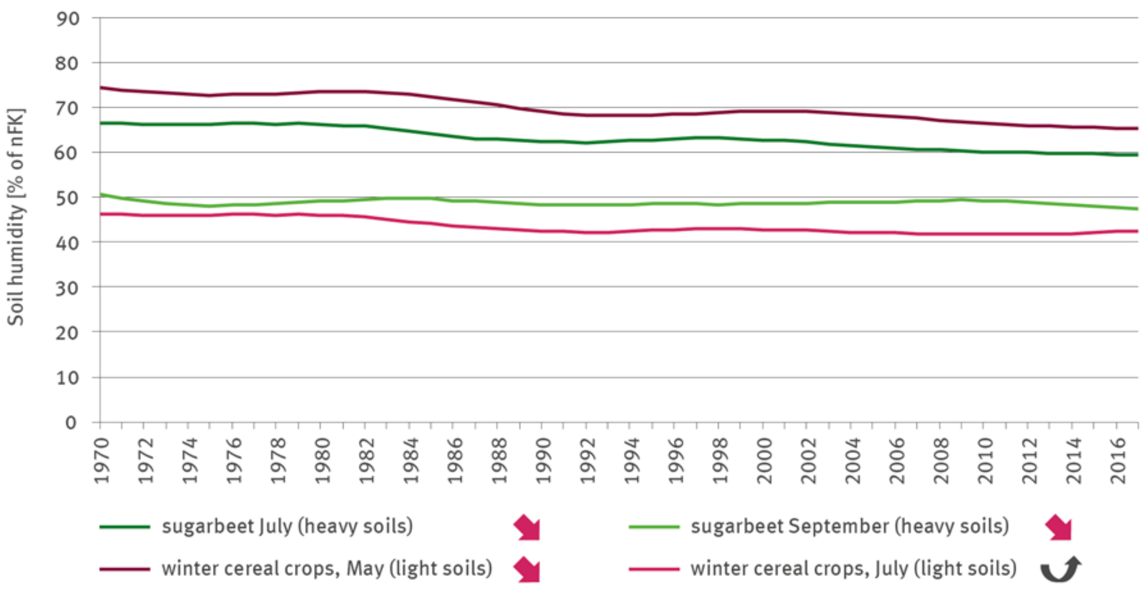
Precipitation and temperature are important contributing factors to the process of soil formation; they have direct influence on the water regime and mineral balance of the soil. If precipitation and temperature conditions change as a function of climate change, this will have consequences for soils, no matter whether soils are used for agricultural or forestry purposes, whether urban soils or soils with near-natural vegetation are concerned. An increase in soil temperature has consequences for crop cultivation (germination and growth of plants), life in the soil (activities of countless soil organisms) and for the soil structure. Soil development processes such as weathering, decomposition and humification are accelerated. An increase in soil respiration can lead to an additional release of CO_2 from the soils thus resulting in positive feedback accelerating global warming.

Subject to soil conditions it is expected that amounts of leachate are likely to diminish in summer owing to greater evaporation whereas it is expected to increase in winter owing to additional precipitation. On one hand, this results in consequences for groundwater formation. On the other, the actual amount of leachate governs the relocation of minerals such as nitrate in the soil. High precipitation in winter, especially when it falls on agricultural land with sparse vegetation cover, can result in repeated leaching of minerals. If clay-based soils dry out more in the summer months, the soil surface will harden, and water from precipitation will find it hard to seep in. In those cases repeated surface run-off will increase the risk of erosion.

For plant growth the availability of water in the soil is a crucial variable. When in the spring and summer months periods of high temperatures and low precipitation coincide with high water demand by vegetation, it can happen that the soil water available to plants is soon exhausted thus causing drought stress. For annuals which just like many agricultural plants (in particular cereal crops) flower mostly in the months of April till June when they grow fastest, restricted water supply in this phase can be critical. But also natural vegetation, for instance in wetlands, can be damaged by inadequate availability of soil water. Sandy soils, limited in their capacity to store water from winter

BO-I-1: Soil moisture levels in farmland soil

Adequate soil water reserves represent a crucial variable determining plant development. In farmland cultivation both under- and oversaturation during critical phases can adversely affect yields. In both light and heavy soils, soil water reserves available during the vegetation period have shown a significant declining trend during the past 50 years.



Data source: DWD (German climate atlas – agriculture) and spring precipitation, are particularly at risk. In later phases of the vegetation period water resources are usually exhausted. Likewise, the functions of dry soils are limited also in urban areas. The summer-related heat-island effect in urban areas can become even stronger where desiccated soils lose their cooling capacity.

The DWD operates a modelling service for soil water contents. Based on prevailing meteorological conditions (data collected by the nationwide network of measuring stations) and the development stage of plants, the current evaporation of selected agricultural crops is calculated, and the calculated amount of water is then abstracted from the soil water using mathematical formulae.

The soil humidity is stated as a percentage of usable field capacity (nFK) thus identifying the water reserves in a soil which are available for use by plants. The value of usable field capacity varies with the relevant soil properties, The soil humidity % nFK enables a comparison of different soils. Where water saturation drops below a value of 50 % nFK owing to low precipitation levels, water stress is bound to set in affecting numerous plant species. Values above 100 % nFK signify that soils are saturated with water. Therefore, seepage will take place into lower soil levels.

Nationwide evaluations of mean values should be approached with caution, because soil properties and precipitation conditions differ greatly, both regionally and locally. Nevertheless, they make it possible to draw inferences for long-term development trends. For example, if you consider soil water reserves in the months of May and July for light soils with high sand contents used for winter cereal crops, it becomes clear that the nationwide mean for roughly the past 40 years shows a declining trend. As far as winter cereal is concerned, the month of May coincides exactly with the regrowth phase when water demand is particularly high, which means that adequate supplies of water are crucial for plant development. In contrast, a poor water supply in July is less serious, as this is the time when the cereal ripens. Excessively high water contents in this phase might even have adverse effects on yields, partly because excessively high water contents might limit the use of vehicles on cultivated ground.

Trends towards lower soil water reserves can also sometimes be observed with regard to heavy soils rich in clay and loam. Likewise, if you analyse the conditions prevailing in these soils used for sugarbeet (as representative for root crops), you will find in this example that July – the mid-point of the regrowth period which determines yields – is marked by declining values. September too shows a trend towards lower values. This can have adverse consequences as sugarbeet depends on adequate water supplies in order to accumulate additional biomass shortly before harvest.

Desiccated soils impair the growth of both crops and wild plants. (Photograph: © Maurizio Targhetta / stock.adobe.com)

Even if soil water supply is primarily dependent on precipitation conditions, farmers nonetheless have the opportunity to respond to low water contents in soils during critical development phases of plant development. One of the options is to grow less water-hungry crop species or to adapt soil cultivation methods for instance to ploughless tillage or irrigation.

Interfaces

BO-I-2: Rainfall erosivity
LW-I-2: Yield fluctuations
LW-R-3: Adaptation of the variety spectrum
LW-R-6: Agricultural irrigation

Objectives

Protection of soil functions (DAS, ch. 3.2.4)

Loss of soil caused by water and wind impacts – painful losses

Soils are the result of development processes extending over thousands of years. It takes at least one hundred years, subject to adequate plant growth on weathered rock material, before one centimetre of vital humus-rich soil layer develops. Loss of soil owing to overbuilding or soil erosion therefore constitutes serious damage which is never wholly reversible.

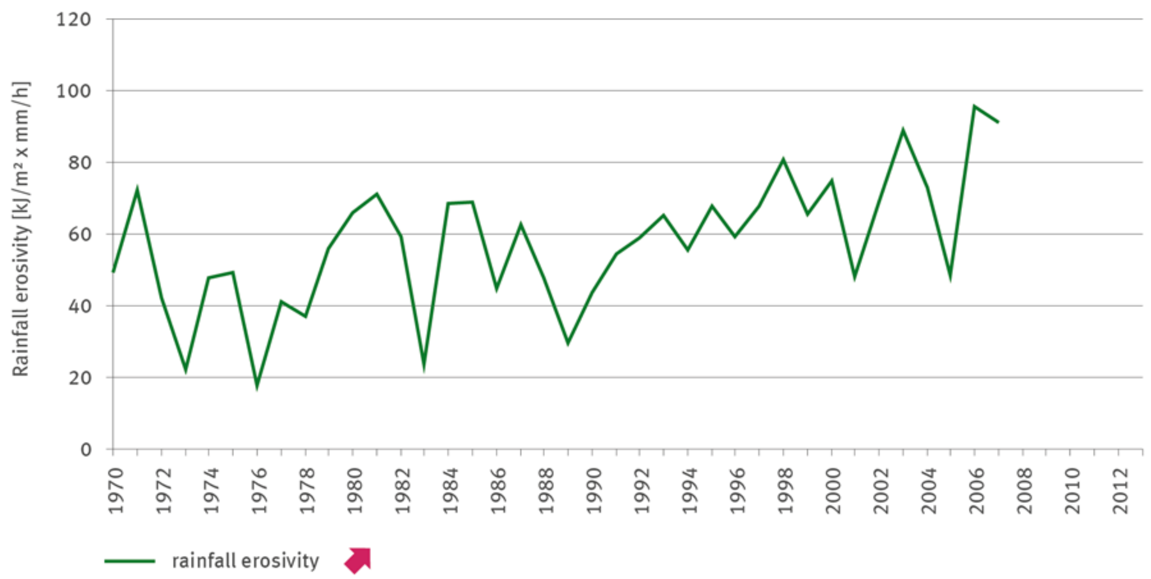
Soil erosion caused by water is one of several intensely discussed impacts of climate change on soils. Frequent heavy rainfall events and increases in summer droughts and winter precipitation are some of the causes of major erosion.

Winter precipitation that does not fall as snow and, in farmland soils usually falls on very gappy vegetation cover, can result in substantial loss of soil. This is aggravated by the fact that climate change and associated temperature rise are inclined to shift the development phases of plants including cultivated crop plants. Any resulting changes in ground cover are likely to increase erosion risks. At any rate, drought-related gaps in the vegetation and desiccated soil surfaces are bound to exacerbate erosion. Especially in northern Länder near the coast, wind is an additional cause of erosion on predominantly sandy soils. Increasing spring and summer droughts can only heighten the risks of wind erosion.

Soil erosion primarily signifies reduced efficacy of the soil and a loss of the topsoil rich in nutrients and humus. Eroded soil material is shifted horizontally across the surface and can end up in neighbouring water bodies. This is where diffuse mineral inputs, especially phosphorus, can cause undesirable eutrophication. Such processes are likely to counteract any efforts to enhance the condition of water bodies. Soil erosion is hardly visible; it is an insidious process leading to the impairment of important soil functions. Soil erosion can very quickly cause the loss of soils which have taken several centuries to develop.

BO-I-2: Rainfall erosivity – case study

High levels of rainfall intensity increase the risks of soil loss. In North Rhine-Westphalia rainfall erosivity in summer has increased significantly since the 1970s. In respect of sites with sensitive soils on major inclines this means that, especially in terms of agricultural use of soils, protection measures against soil erosion have to be taken.



Data source: Landesamt für Natur, Umwelt und Verbraucherschutz NRW (climate impact monitoring North Rhine-Westphalia)

Erosion monitoring that would cover the whole of Germany has yet to be invented. So far, soil monitoring conducted in existing permanent monitoring areas (BDF) is the only measuring network covering all of Germany's Länder for the purpose of long-term data collection on soil erosion nationwide. However, neither the procedures nor the intensity follow a homogeneous approach. Nevertheless, it is possible, despite the lack of representative monitoring data to infer nationwide threat potentials.

The essential factors contributing to the amount of soil erosion caused by water are precipitation, site incline, soil properties, degree of ground cover and the type of soil use. Soil use signifies the type of tillage which, in connection with the direction of tillage is much influenced by the way a field is structured. Nurse crops can be used to increase ground cover in permanent cultivation (e.g. vineyards) but also in annual crops in order to reduce the degree of erosive effects. Types of agricultural crops with particularly high potential for soil loss include potatoes, maize, sugarbeet and winter wheat as well as numerous special crops and vineyards on steep slopes. The specific variable which is likely to have the greatest direct influence on erosion risks – more than any other interactions of climate change and water-related soil erosion – is the amount of change in precipitation intensity. In respect of all the other contributing factors such as ground cover, there are clearly major uncertainties in assessing the impacts of climate change.

In the case of North Rhine-Westphalia it was possible to use temporally highly disaggregated precipitation data to ascertain the development of precipitation-related erosivity. From the mid-1970s onwards the time series shows a significant trend towards increasing rainfall erosivity, thus indicating the risk of increased loss of soil. It has so far not been possible to update the relevant data. The Federal Government and several Länder are currently working on this issue with the objective to be able to provide a much enhanced indicator in the next Monitoring Report.

There is a diverse range of measures conceivable for preventing erosion, in particular in arable fields. The options range from site-adapted crop rotation which ensures continuous ground cover for the entire year, to nurse crops and the use of mulches, to adapting the direction of tillage as well as permanently ploughless, conservation-oriented soil tillage, in order to maintain a natural soil structure and to achieve particularly thorough ground cover by means of protective plant remnants.

The existing data and results demonstrate that climate change has major impacts on soil erosion. For a reliable evaluation of climate-related changes to soil erosion by means of representative measuring data, it is necessary to develop an even closer network with the purpose of carrying out continuous standardised measurements with a strong focus on particularly endangered, climate-vulnerable natural areas. Important technical approaches can be derived from current activities concerned with developing the conception and implementation of an 'association dedicated to climate change-related soil monitoring'.

Increasing precipitation intensities increase the risks of soil loss. (Photograph: © murasal / stock.adobe.com)

Interfaces

BO-I-1: Soil moisture levels in farmland soil
BO-R-2: Permanent grassland

Objectives

Protection of the ecological efficacy of soils by means of reducing or preventing soil erosion and soil compaction and by maintaining organic matter content (DAS, ch. 3.2.4)

As far as possible avoiding soil losses by ensuring site-adapted use, especially by taking into account slope gradient, water and wind conditions as well as ground cover (BBodSchG, § 17 (2) 4)

Continuous reduction of soil erosion by 2020 (NBS, ch. B 2.5)

Humus strengthens soil resilience

Soils are affected by climate change in a number of ways. Only healthy, vital and resilient soils can withstand the risks of desiccation and erosion caused by wind and water, enabling them to continue their multifarious positive functions crucial for maintaining a landscape's water and mineral regimes.

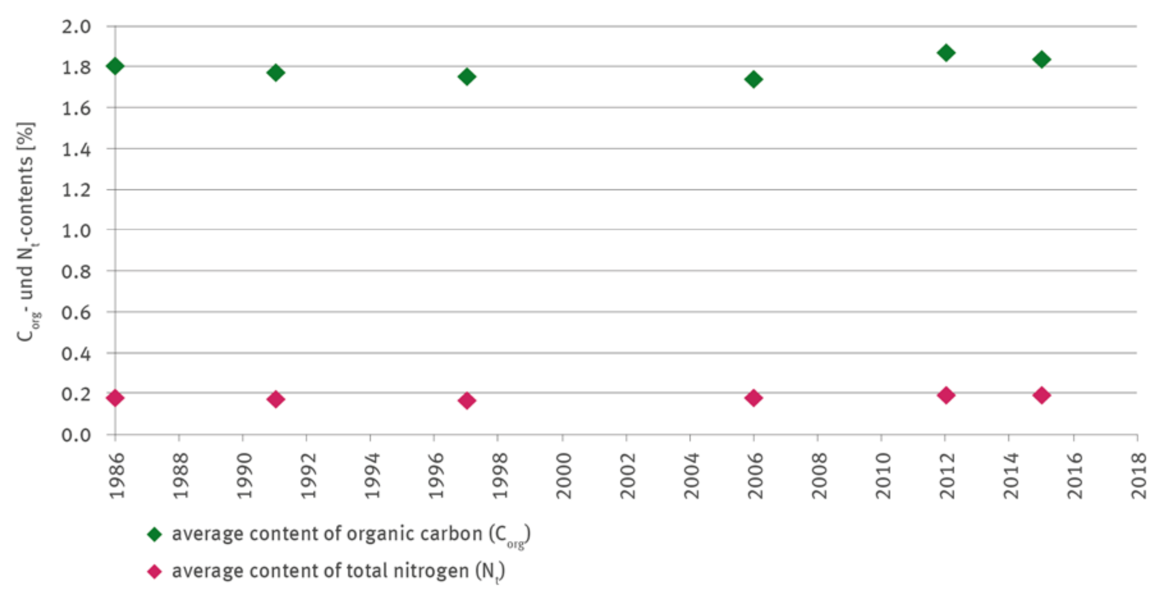
Humus plays a major role in the resilience of soils, as it influences nearly all soil properties and functions in complex ways. Humus is the entirety of organic matter in the soil, composed of all dead vegetable and animal remains as well as their organic conversion products. Humus is an important storage medium for nutrients and water. It ensures favourable soil structure thus benefiting the air and water regime of soils. Moreover, humus reduces summer-related dessication and furthers the activity of soil organisms as well as the development of stable soil structures. The latter provides effective protection from soil compaction and soil erosion.

Maintaining site-adapted humus contents and, where necessary, also augmenting the amount of humus in the soil, therefore are important adaptation measures in safeguarding the health of soils. In that context, it is important to remember that climate change has a direct bearing on the humus contained in soils. Higher temperatures can accelerate mineralisation processes in the soil and consequently also the decomposition of organic matter. At the same time, it is possible for climate change to have humus-enhancing effects, e.g. increased temperatures enable plants to produce more biomass thus also increasing the amount of material available in the soil for conversion to organic matter. These relationships appear even more complex when also taking into account the prevailing precipitation conditions, because both humus decomposition and humus formation require water in adequate quantities, i.e. not too much and not too little.

In view of these complex relationships of climate change and humus formation or decomposition, it is currently not possible to make any reliable statements on changes regarding contents and reserves of organic matter. Besides, changes in soil use such as ploughing up grassland for

BO-R-1: Humus content of arable land – case study

On average, the humic soil contents in permanent monitoring areas in Bavaria have not changed to any relevant extent since the mid-1980s. It must be said, however, that depending on site and use, developments can vary substantially.



Data source: Bayerische Landesanstalt für Landwirtschaft (analyses of soil monitoring sites in Bavaria) use as arable land, have much stronger impacts on humus content than any long-term climate change.

The contents of organic matter in soils are essentially dependent on site-typical circumstances (type of soil, groundwater levels etc) and it therefore cannot be augmented wholesale by adding organic materials. However, management tools such as adaptation of use can serve a useful purpose. On agricultural soils options include grassland regimes, application of farmyard manure, cultivation of catch crops or leaving harvest and root remnants on site for the maintenance and accumulation of humus. Many trends which are currently focused on intensifying agriculture actually counteract any efforts to stabilise or even augment the humus contents of soils. In forests and woodlands the composition of tree species and the amount of remnants from timber harvesting are crucial factors in the formation of humus.

Regular surveys of humus contents in soils are carried out by the Länder within the nationwide network of permanent monitoring areas (BDF). The Thünen Institute has established a homogeneous system of agricultural soil condition surveys (BZE-LW/Agricultural Soil Inventory) in more than 3,000 locations nationwide. A nationwide evaluation of 171 agricultural surveys found that there were statistically significant changes to humus contents in a total of 39 BDF locations. Essential humus changes were controlled on the basis of the humus starting level at each site[21].

The influence of longer-term climate change on the development of humus cannot be ruled out and requires further research. As shown by results from Bavaria, the mean contents of the most important humic components such as organic carbon (C_{org}) and total nitrogen (N_{tot}) in soil depths of 0 to 15 cm remained almost constant for the past few years. The reason being that changes in humic cotents, in particular humus increase, take place very slowly resulting in measuring inaccuracies. Depending on the type of use practised in the sites monitored, different developments have been observed: In Bavaria a significant decline in humus contents since the end of the 1960s was observed in the agricultural sites monitored where the biggest proportion of crop rotation consisted in maize and root crops, as against a lower proportion of cereal, rapeseed and fodder legumes[22].

Likewise, it is difficult to achieve an unambiguous evaluation of results, because an appropriate conclusion as to what amounts of humic content are optimal, depends on a site-specific assessment. Fundamental guidance on how to derive site-specific humic contents is available

Catch crops ensure continuous ground cover and further the development of humus.
(Photograph: © Burkhard / stock.adobe.com)

from BZE-LW[23]. This publication has made nationwide data on C_{org} in agricultural soils available and is to be reviewed in ten years time, in order to facilitate the evaluation nationwide of changes in humus reserves of mineral soils in relation to site and management type.

Interfaces

FW-R-5: Humus reserves in forest soils
BO-R-2: Permanent grassland

Objectives

Maintaining the site-typical humic contents of the soil, especially by means of adequate input of organic matter or by reducing the intensity of cultivation. (BBodSchG, § 17 (2) 7)

Site-adapted cultivation and safeguarding the sustainable fertility of soil and long-term usability of fields (BNatSchG, § 5 (2) 1)

Protecting the ecological efficacy of soils by means of [...] maintaining organic matter; intensification of soil protection in the light of the risks [...] of declining humic contents; implementation of site-adapted land use strategies in order to curb negative effects resulting from changes in soil and humus formation which in turn affects C sequestration (DAS, ch. 3.2.4)

Grassland conservation – important for soil protection

Permanent grassland is a type of agricultural use which, owing to permanent ground cover, provides comparatively good soil protection, along with humus enhancement and biodiversity, especially compared to arable use, because permanent grassland provides numerous favourable impacts as well as comparatively good soil protection from the projected adverse effects of climate change. Both the risks from desiccation and from soil loss caused by water and wind are much reduced in soil where grassland is present. In cases of heavy precipitation the precipitated water has a much better chance of penetrating a field with permanent grassland cover. Consequently, the maintenance or even expansion of permanent grassland, especially on sensitive sloping ground used for agricultural purposes or in floodplains, is a suitable measure for protecting soil even where it is affected by climate change.

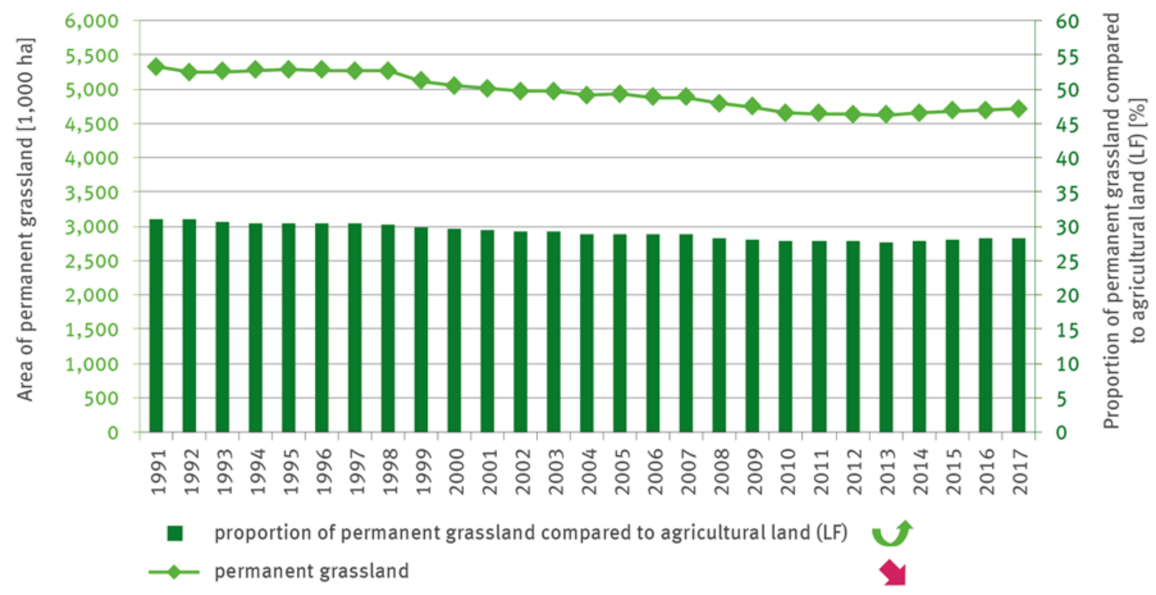
Likewise, the loss or ploughing of grassland is to be viewed critically for reasons of protection from climate change in general. Whenever grassland is ploughed up, a considerable part of carbon stored in the soil is released to the atmosphere in the form of greenhouse gases. This applies especially to grassland on organic soils which are particularly rich in high proportions of organic matter. This makes the maintenance of grassland highly relevant also in terms of climate protection. Furthermore, grassland plays a major role in species protection, the conservation of biodiversity and the protection of soils and water bodies.

The total of Germany's grassland areas decreased between 1991 and 2013 but has been increasing slightly since 2014. It can therefore be argued that the nationwide decline of grassland area was almost proportionate to the decline of agricultural land in Germany overall. Starting in 2014, the proportion of grassland in agricultural ground has been increasing again.

The data on the development of permanent grassland areas do not permit any specific statements on ecological weightings of the grassland areas lost. Ploughing took place generally at all grassland sites, i.e. even in locations with semi-arid and/or humid grassland areas of

BO-R-2: Permanent grassland

The conservation of permanent grassland is intended to protect soils under agricultural use from the adverse effects of climate change. Between 1991 and 2013 grassland areas were experiencing a continuous and significant declining trend. Since 2013 the areas and the proportion of land in agricultural use have been increasing very slowly. As far as statistical trend analysis is concerned, this development has not yet been mirrored in respect of grassland areas.



Data source: StBA (main land use survey; agricultural structure survey) great conservation and ecological value. Ploughing activities on wet soils or moorland soils is therefore especially precarious in terms of climate protection.

Ever since 2015 the precept of permanent grassland conservation has been in force as part of the 'Greening' objective, which was intended to achieve positive effects for maintaining biodiversity as well as the protection of water, climate and soil in agricultural landscapes. Accordingly, the conversion of permanent grassland into arable land should in principle be allowed only with official authorisation and, depending on the site incline and age of the permanent grassland, this should only be tolerated on condition that new permanent grassland be created elsewhere. In areas governed by designations under the Habitats Directive (FFH areas), an even stricter ban on ploughing and conversion is in force for permanent grassland. It must be said, however, that newly created grasslands do not have the same significance in terms of climate protection or biodiversity in view of the fact that they are typically species-poor[24].

Grassland use can protect soils comparatively well from many adverse impacts of climate change
(Photograph: © goldbany / stock.adobe.com)

Objectives

Promotion of site-adapted land use strategies (DAS, ch. 3.2.4)

Refraining from ploughing up grassland on slopes at risk from erosion, in floodplains, on sites with high groundwater levels and on moorland sites (BNatSchG, § 5 (2) 5)

Agriculture

Farmers have always had to respond to changing climate and weather conditions. There is a comparatively wide range of options available to them for adapting to climate change. As far as annual crops are concerned, it is usually possible to respond at short notice. The situation is more problematic, however, for farming operations involved in the cultivation of permanent crops or in livestock production as those types of farming require investment decisions for the long term.

In agriculture, a rather nuanced approach is advisable regarding the potential impacts of climate change. On one hand, there are adverse consequences to be expected for production, owing to periods of extremely dry and hot weather, heavy rain events or hailstorms. On the other, yield potentials would be increased by a moderate rise in temperatures and extended vegetation periods owing to adequate supplies of water. Besides, it is conceivable that conditions may develop which enable our farmers to cultivate crops which were previously impossible to grow in our latitudes. Impacts will vary considerably depending on prevailing crop preferences, physiogeographical circumstances and the specific climate change actually occurring regionally. Accordingly, any nationwide averages stated for Germany should be interpreted with caution.

Apart from plant production, climate change also affects the production of livestock. Losses to be expected will include areas like the production of milk, eggs and meat products owing to heat waves, drought-related shortages of basic forage and heat-related impairment of animal health. When animals are exposed to heat stress, this can reduce their fertility or the state of health of udders. It is important to remember that animals, not just humans, can be prone to infectious diseases transmitted by thermophilic pathogens. Both new and recurring pathogens can often be transmitted between animals and humans. There are close links between the health of humans, animals and the environment (One Health Concept). However, the necessary data have not yet become available on a nationwide basis.

Effects of climate change

Adaptations

New challenges from changed progress of seasonal weather patterns

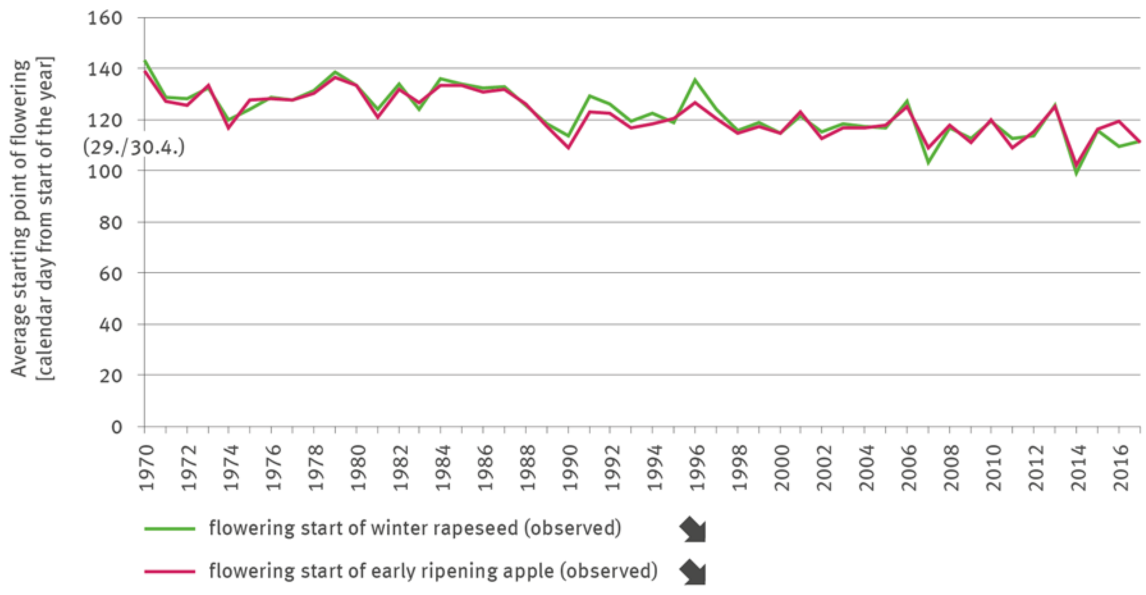
Hardly any other form of land use is as tied to natural seasonal rhythms as agricultural land use. Farmers always need to adapt the management of their specific crop to the annually changing weather conditions and weather patterns prevailing at any particular time. Weather conditions can impact on crop cultivation in both positive and negative ways. On one hand, greater accumulations of warmth in the presence of adequate availability of water further the growth of certain types of crop. On the other, excessively high temperatures or drought can entail losses in yield or quality, when for instance a cereal crop ripens too early.

Climate change impacts on seasonal weather patterns which in turn affect the seasonal development processes of agricultural crops. Spring is expected to bring rising temperatures, summers are likely to become drier and hotter and winters are expected to become milder and wetter. Such circumstances make it impossible to infer any simplified conclusions regarding height, quality or stability of yields, because the impacts of climate change can vary depending on agricultural cultivation and crop rotation. More than anything, there are regional differences to be taken into account.

Changes in natural seasonal rhythms and associated temporal shifts in the development of plants have been studied and documented for years by means of phenological observations. These nationwide studies involve the beginning of certain periodically recurring biological phenomena such as leaf and bud formation, flowering, maturity of fruit or leaf fall. The phenological observation network operated by DWD extends to wild plants, agricultural crops and management operations, thus providing indications regarding impacts on agricultural management, because changes in seasonal weather patterns confront farmers with new challenges. Farmers have to adapt their choice of crop and crop variety, crop rotation and scheduling of management operations to any new circumstances.

LW-I-1: Agrophenological phase shifts

Changes in seasonal weather patterns result in new challenges facing farmers in planning their agricultural management operations. Owing to higher accumulations of warmth in spring, appletrees and winter rapeseed flowering and earlier.



Data source: DWD (phenological observation network)

In Germany the beginning of spring is marked by the flowering of apple trees and winter rapeseed. Both flowering periods are independent of the influence of preceding agricultural operations such as the date of sowing. Apples belong to the category of permanent crops, while winter rapeseed is sown the previous year, no later than September. The flowering period is therefore in a direct link with climate factors, especially accumulations of warmth occurring in the first few months of the new year.

Depending on the weather pattern, the start of flowering in respect of apple trees and winter rapeseed tends to fluctuate from year to year, and in some cases the fluctuations are considerable. The differences from year to year can be as much as up to three weeks. However, looking at the past forty years and longer, both crop types show a significant trend towards earlier flowering. Compared to the 1970s winter rape and apples nowadays flower approx. 20 days earlier. As far as fruit-growing is concerned, the early onset of flowering can increase the risk of damage from late frost. In many locations the orchardists have already responded to this development by increasingly applying targeted anti-frost irrigation, i.e. spraying plants with very small water droplets. While the water freezes, crystallisation heat is released, which protects both leaves and blooms from frost damage.

However, in the case of winter rapeseed, early flowering can benefit both pest or pathogen control and crop rotation. This is why farmers increasingly prefer early-flowering varieties of winter rapeseed. However, phenological observation is unable to take a specific variety into account. This is why the effects of varietal changes are also reflected in the two flowering periods observed for phenological analysis. However, a comparison with the breeding process for apples where early flowering is not desirable, clearly shows that weather patterns exert considerable influence on early onset of flowering.

Early onset of apple blossom increases the risk of damage from late frosts. In orcharding situations it has become increasingly common to carry out anti-frost irrigation.
(Photograph: Lämpel / Wikimedia Commons, CC BY-SA 3.0)

Interfaces

LW-R-1: Adaptation of management rhythms
LW-R-6: Agricultural irrigation
BD-I-1: Phenological changes in wild plant species

Increased yield fluctuations entail higher production risks

Weather patterns are amongst the most crucial variables which determine agricultural production. An extended vegetation period and increased accumulations of high temperature can increase harvest yields. In addition, higher CO_2 concentrations in the atmosphere which are, after all, responsible for causing the greenhouse effect, can stimulate photosynthesis and plant growth. On the other hand, climate change associated with e.g. drought stress or extreme events such as storms, heavy rain, hailstorms and flooding also entails an increasing risk of yield losses.

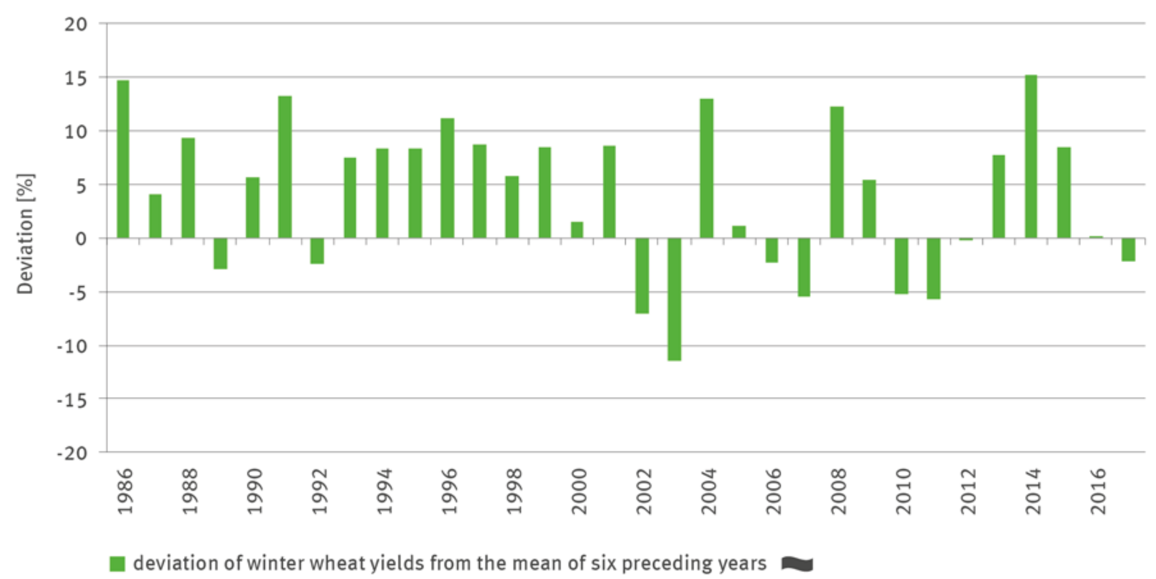
In the past fifty years, advances in plant breeding and technical progress have brought about increases in agricultural yields for important crop species in Germany. Breeding efforts have produced new varieties with improved properties in terms of amounts and stability of yields, quality, resource efficiency, stress tolerance and disease resistance. Likewise, there were improvements in terms of sowing, plant care and harvesting methods as well as fertilising and plant protection. It is true to say, however, that yields are dependent on several other factors besides.

As far as wheat is concerned, agricultural practice has been marked by yield stagnation in the past few years; this phenomenon is due to a complex set of causes which require closer examination. Apart from factors already mentioned, it is possible that cultivation on less fertile soils, so-called marginal sites, may be one of the causes; another factor may be crop rotation at closer intervals. It is important in agriculture to optimise operational management and use of resources. To what extent yield-enhancing measures are taken continues to depend largely on the achievable level of product pricing. The higher the price level, the greater the benefit from the use of yield-enhancing or yield-safeguarding materials such as mineral fertiliser and pesticides.

For the time being it is difficult to estimate to what extent climate change impacts on yield levels in Germany. Some participants in the debate argue that at least regionally the climate might impose limitations on a

LW-I-2: Yield fluctuations

Yields fluctuating from year to year can be attributed more directly to changes in weather patterns than long-term yield trends. Any increase in yield variability increases a farmer's production risk. Extreme years tend to result in substantial alternations between positive and negative deviations from yields of preceding years.



Data source: BMEL (harvest and farm reporting; special harvest and quality assessment) further increase in yields. Others argue that agriculture can cope with long-term climate change trends because especially in the cultivation of annual crops there are several options of responding to changed circumstances, e.g. by choosing appropriate crop species and varieties, adapting crop rotation and by appropriate planning of management tasks.

It is to be expected that increasing weather fluctuations from year to year will engender greater challenges which confront farmers with greater difficulties to adapt. Weather extremes such as long drought periods can lead to unpredictable drops in yield. In the drought year 2003 for instance, the average wheat yield nationwide was 12 to 13 % below the trend yield expected for that year. Likewise, the past two years saw agriculture confronted with awkward weather conditions resulting in yield drops. In northern Germany rainfall in autumn 2017 was excessively high making autumn sowings of winter cereals impossible in many locations; this led to the sowing of summer cereal crops which produce lower yields. High temperatures and low precipitation levels from April onwards resulted in an unusually early onset of harvest with poor yields. According to findings by the 'Besondere Ernte- und Qualitätsermittlung' (special survey of harvest and quality data' for 2018, compared to the three-year mean, yields for the German cereals harvest were down by 20 %[25]. In particular in northern and eastern Germany, yields for cereal crops were down by more than 30 %.

Interannual fluctuations in yields will reflect the impacts of climate change more clearly than long-term yield trends in view of the fact that the latter are a reflection of long-term adaptation plans not just in respect of climate change but also regarding market conditions. Fluctuations in yield were calculated by means of the deviation of annual yield from the average yield achieved in the six preceding years. The production risk faced by farmers increases as a function of increasing variability of yields. This is due to the fact that the calculation of factors such as operating resources and materials is based on the expectation of certain yield levels.

Looking at the example of winter wheat – currently the most important cultivated crop in Germany – in respect of the deviation of annual yield from the average yield achieved in the six preceding years, it becomes clear that the yields in this sector went through a lot of ups and downs. However, it is worth pointing out that the figures for this comparatively short time series must be interpreted with caution. These remarkable swings are clearly characterised by extreme years, which makes it currently impossible to refer to a generally valid trend. In the time series covering the period from 1986 to 2017, yield losses caused by the extreme spring drought of 2003 are particularly noticeable.

Depending on weather patterns such as, in this case, heat and drought, yields can vary substantially from year to year. (Photograph: Konstanze Schönthaler / Bosch & Partner GmbH)

It should also be borne in mind that there are, of course, distinct differences between Germany's regions. In particular in eastern Germany – where predominantly light sandy soils are farmed which react especially fast and vigorously to extreme precipitation levels – the interannual yield fluctuations were more pronounced than for instance in the central part of western Germany where soils in rather moist and cool upland regions produced more stable yields.

Interfaces

LW-I-3: Hailstorm damage in agriculture

Yield losses caused by extreme weather events

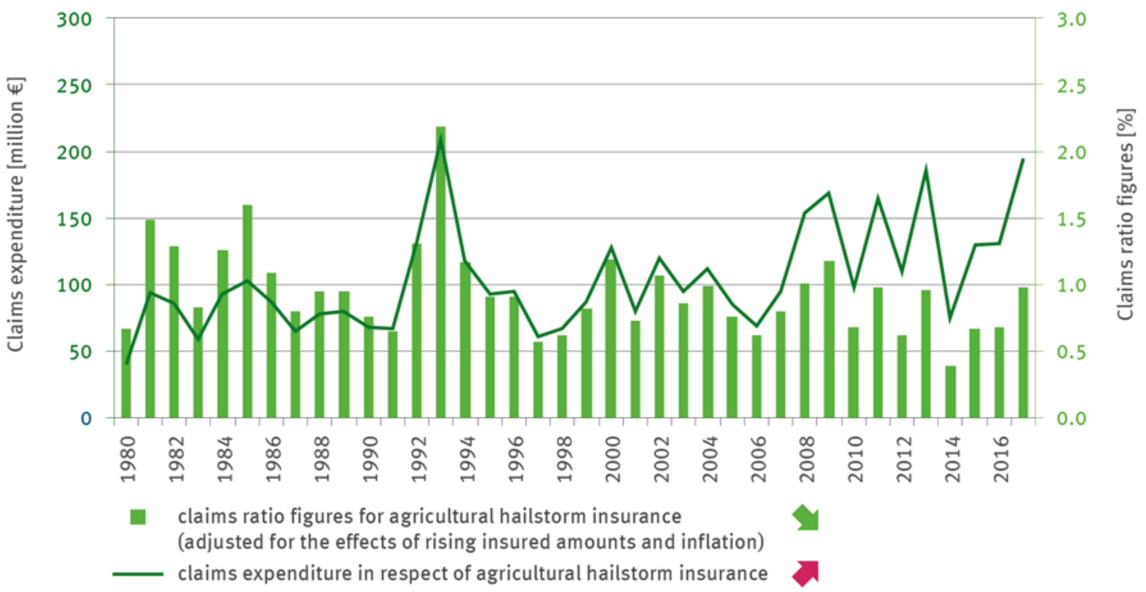
As a result of weather extremes Germany's plant production has again suffered some considerable yield losses in the course of recent years. As indicated by a study carried out by the GDV regarding insurance for agricultural multirisks (Landwirtschaftliche Mehrgefahrenversicherung) for Germany, annual harvest losses caused by weather-related risks in Germany amounted to some 510 million Euros per annum[26]. The bulk of yield losses was attributed to various levels of drought. Approximately a fifth of the damage was caused by hailstones as against a sixth caused by storm, heavy rain or flooding. Frosts too left a legacy of damage. If extreme events increase as a result of climate change, agriculture will have its fair share of harvest damage or harvest losses. The drought summer of 2018 has demonstrated that the average yield losses mentioned above can be much more severe. Protracted drought and heat caused harvest damage and yield losses amounting to 770 million Euros[27]. The affected farms were at least in part compensated for these losses by the state.

Although the exact relationships of climate changes, higher incidence of extreme weather events and the increase in damage to agriculture have not been clarified conclusively, they are the subject of close scrutiny by researchers.

So far, farmers have very limited chances of obtaining insurance for harvest losses caused by extreme weather events. Typically any statements regarding weather-related harvest losses are made in terms of approximated values. The exception to the rule is hail damage, because insurance for hail damage is relatively widespread in agriculture. More than two thirds of all farmland is insured for hail damage[28]. Regarding reports from hailstorm insurance companies in respect of insurance claims, it is therefore possible to make statements on at least part of the losses. Regarding any other damage borne by farmers themselves or for which, on a case-by-case-basis, they receive funding from aid programmes, there are no reliable data available.

LW-I-3: Hailstorm damage in agriculture

Extreme weather events such as drought, hailstorm, storm, heavy rain, flooding, frost and winter-related damage can cause yield losses in agriculture. Typically, the insurance policy covers only damage from hailstones. Increases in claims expenditure are essentially caused by increases in the amounts insured. Claims ratio figures make it possible to infer more direct conclusions regarding hailstorm events. These figures show a falling trend.



Data source: Institut für Agribusiness (technical figures hail)

The claims expenditure, i.e. the gross expenditure arising from insurance claims, has increased significantly since 1980. However, this is not exclusively due to increased incidents entailing claims. In fact, it is also a result of increases in insured amounts. In Germany, the market for agricultural hailstorm insurance is not considered saturated. Contrary to claims expenditure, claims ratio figures for agricultural hailstorm insurance are adjusted for the effects of rising insured amounts and inflation. In order to infer some more direct conclusions, it is therefore possible to use the claims ratio figures to identify the driving force underlying the claim, in this case hailstorm events. The trend indicated for the claims ratio is falling. 1993 was the year with the greatest incidence of hailstorms during the period examined. In 2002 major hailstorms, especially in south-west and eastern Germany, caused total losses in many locations, while in 2009 the north and south were affected most severely between late April and mid-August by a sequence of thunderstorms of extraordinary violence. The growing season of 2017 began with late frosts causing severe damage to fruit blossom, while later in the year additional losses in orcharding were caused by changeable summer weather with regional hailstorm events.

Although hailstorm insurance compensates farmers for tangible harvest losses, it does not cover any associated consequential losses incurred by a farming business as a whole. The insurance does not cover any losses in terms of market presence in a hailstorm year, or underused capacity of operational infrastructure or even increased expenditure arising from product harvesting and sorting efforts. This is another reason why many farmers do not regard concluding a hailstorm insurance contract as their only option. Especially in orcharding farmers increasingly use safety nets for product protection from hailstorms.

Hailstorm damage can result in substantial yield losses: field of maize damaged by storm and hailstones.
(Photograph: Zumthie / Wikimedia Commons, Public Domain)

Interfaces

LW-I-2: Yield fluctuations
BAU-I-5: Claims expenditure for property insurance

Increased pressure from harmful organisms – a distinct possibility

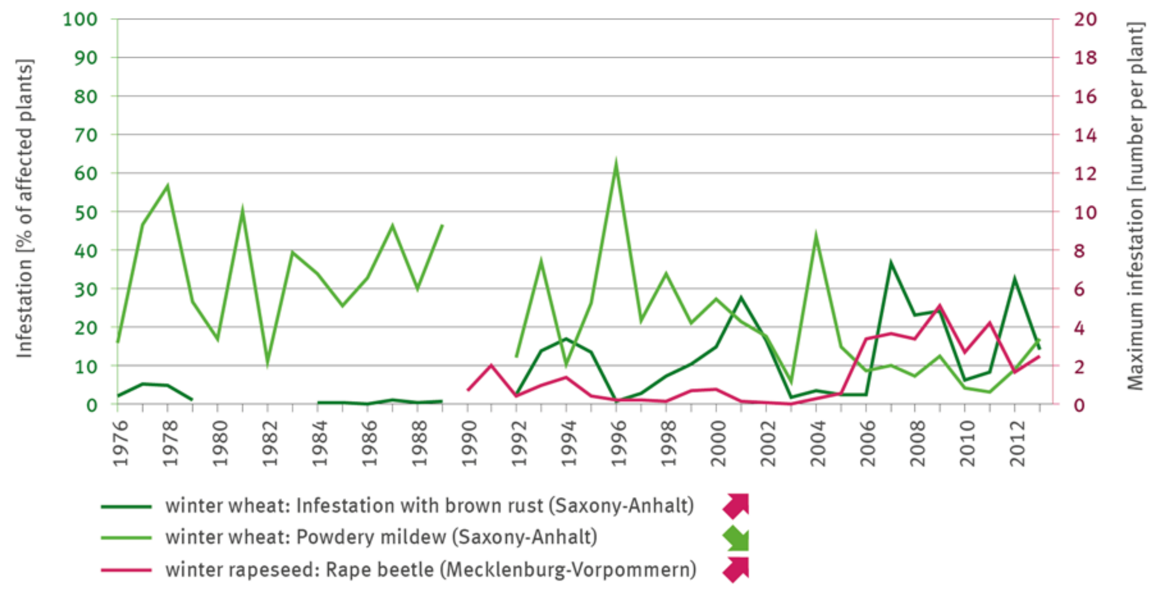
Climate change does not just change the conditions for agricultural crops but also for pests and plant diseases. Warmer weather and the extension of the vegetation period improve the opportunities for some pests to increase their range and to produce several generations per annum. However, other pests which depend on extended moist periods, might decline. In the next few years, it is therefore to be expected that climate change will bring about shifts in the species range of organisms harmful to plants. Damage caused by fungal diseases – apart from diseases triggered by thermophilic fungi such as mildew – will probably diminish in many areas. On the other hand, the importance of grass weeds and other weeds, animal pests and non-parasitic diseases might increase. Furthermore, insects basically always benefit from warmer temperatures. It is to be expected that new risks will arise from pests which have so far not occurred in our latitudes. Once introduced, these alien species will be able to establish themselves and spread owing to the changed climatic conditions in our regions.

However, observations so far do not permit any conclusions as to the increase or decrease of infestations with pests. It is not possible yet to make any detailed prognoses. It is undeniable, however, that numerous pests can respond very sensitively and spontaneously to changed weather conditions; this requires farmers to respond flexibly and with utmost speed in order to get problems with pest infestations under control.

So far there has not been any comprehensive research regarding any particularly close relationships between pests and their development under changing weather or climate conditions. To obtain clarity in this regard will depend entirely on systematic evaluations of infestation data for a wide range of different pests. According to the current state of scientific knowledge in respect of brown rust (Puccinia triticina) and powdery mildew (Erysiphe graminis) affecting wheat, barley and triticale – a hybridised form of wheat crossed with rye – and in respect of the rape beetle (Meligethes aeneus) – it is understood that climate change

LW-I-4: Infestation with harmful organisms – case study

In the case of brown rust, powdery mildew and rape beetle it is understood that climate change entailing warmer winters and dry, warmer springs, will further the spread of infestations. However, it is important to note that the development of pests takes place in very specific ways. On the basis of currently available data it is not possible to make any generalised statements on the impact of climate change on infestations. It will not be possible to update the time series before 2023.



Data source: Julius Kühn-Institut (analyses of infestation-data of the federal states) entailing warmer winters and dry, warmer springs will benefit the development of mass reproduction.

However, long-term data series are not yet available nationwide. Only some Federal Länder have processed data, and these were used in preparing the 2015 Monitoring Report. Updating the time series will not be possible before preparing the 2023 Monitoring Report.

Cases of brown rust occurring in Saxony-Anhalt and rape beetle in Mecklenburg-Vorpommern show signs of an increasing tendency. As far as powdery mildew is concerned, for which there are also data available from Saxony-Anhalt, there have been, since the 1970s, recurring years of high infestations. However, an examination of the time series as a whole reveals a significant decline. The data also show that the strength of infestations with a specific pest can vary considerably. There is no singular definitive weather pattern which furthers pest infestations.

For the time being, it is not possible to make any representative statements on the development of pest issues on the basis of data on brown rust, mildew or rape beetle provided by Saxony-Anhalt and Mecklenburg-Vorpommern. Obviously, there will be major differences in the infection risk and infestation between different pests and from region to region and year to year. In plant breeding there is an increasing focus on developing varieties with strong resistance to pests because, at least in some crop varieties, the strength or frequency of infestation is closely associated with the variety cultivated. It is worth mentioning that also the ways in which plant protection measures are carried out vary considerably. The Julius Kühn Institute which has responsibility for plant protection nationwide is in the process of conducting analyses on the climate and weather dependence of pest infestations. On the basis of the outcomes of this research it is expected that it will be possible to make comprehensive and representative statements on the development of pest infestations.

Apart from pollen, rape beetles also consume the pistil and ovary of rapeseed flowers; it is thus able to cause considerable damage at flowering time.
(Photograph: © agrarmotive / stock.adobe.com)

Interfaces

LW-R-5: Use of pesticides

Objectives

Reducing the introduction of new pests, efficient control of new harmful organisms, setting priorities for pest control on the basis of risk potential (including fast risk assessment and associated decision-making), efficient monitoring systems for certain harmful organisms (National Action Plan on the sustainable application of pesticides, 2013, ch. 5.2.4)

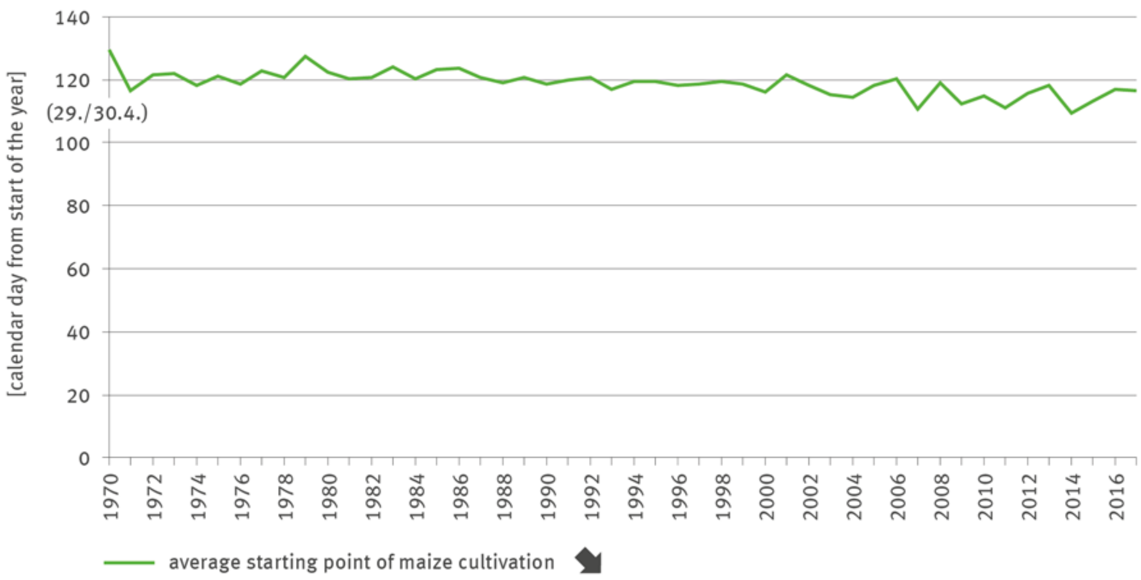
Adaptation of management planning

Owing to changes in seasonal weather patterns associated with climate change, farmers are forced to adapt their management planning accordingly. The most favourable times for tilling, sowing and harvesting as well as the application of fertiliser and pesticides have to be redetermined specifically for every year. Both direct and indirect effects of weather patterns have to be taken into account in scheduling various management operations. As far as the direct effect of weather is concerned, it is for example important to determine the most favourable time for tilling, and this timing is heavily dependent on soil moisture. Another example is the scheduling of sowing in spring, because specific crops such as maize must not be sown until the soil has reached a certain temperature. With regard to indirect effects of changed weather patterns it is understood that they play a role in the choice of crops and varieties or crop rotation made by farmers in response to changing climatic circumstances.

Such adaptation practices are basically nothing new in agriculture, as these challenges have always had to be addressed in carrying out management operations which had to respond to the seasons and phenological development phases of crop species. Nevertheless, it is conceivable that the incidence of unpredictable weather patterns is on the increase. In order to guard against the consequences of extreme weather events, to avoid erosion, and to safeguard the replenishment of water and nutrients in dry periods, farmers have to maintain high infiltration rates as well as storage capacity for water and nutrients and good aggregate structure in the soil. It is vital to maintain the organic matter in the soil and, where necessary, to increase its contents as required for a specific location. Stabilising measures on individual farms can include cultivation of catch crops, nurse crops, various species combinations, incorporation of harvest remnants, cultivation of perennial crops, organic fertilisation and adaptation of soil tillage. At a higher organisation level, the following elements are considered essential for adapting agriculture to climate change: Feed and farm manure cooperations, the integration and utilisation of perennial fodder plants in crop rotations, the conservation of grassland, the stability of mixed livestock-cum-arable farms as well as ecological farming and

LW-R-1: Adaptation of management rhythms

With regard to individual management operations for crop cultivation, farmers respond by scheduling these tasks according to changing weather patterns. Maize cultivation was brought forward by approximately five days in the course of the past forty years. The trend is significant.



Data source: DWD (phenological observation network)

landscaping (e.g. agroforestry systems, contour management, beetle banks).

Apart from data on temporal changes in the development of plants, the GWS 's nationwide phenological observation network also collates data on changes in management operations carried out in respect of agricultural crops. Depending on the management operation concerned, the effects on scheduling vary. Apart from weather patterns, there are usually several other factors to be considered. Of greatest relevance is the selection of varieties and crop rotation. Sowing can only commence after the previous crop cultivated as part of the crop rotation has been removed. Organisational requirements in individual farming businesses may also play a crucial role. Depending on the cultivated area and the extent of a farm's own machinery or the contractor's machinery, management operations may have to be rescheduled. In other words, the rescheduling of management operations in agriculture is not exclusively dependent on weather patterns. Nevertheless, relevant observations may provide useful pointers for the adaptation of management plans.

The cultivation of maize crops usually takes place in the course of April and May. In spring any effects from management operations will be comparatively minor, and the influence of weather patterns play a more important role at that time, rather than at a time when management operations are scheduled for summer and autumn. In those cases, weather effects can for instance influence the frost decomposition of catch crops. In cases where this cannot be safeguarded, additional work may be necessary in the preparation of seedbeds for the maize main crop.

In the past forty years maize cultivation was always started earlier. Of course, there are distinct differences from year to year, but the trend shows a significant trend towards increasingly earlier cultivation. For example in the 1970s and 1980s, cultivation was carried out preferably between late April and early May. After 2000 cultivation took place on average approximately one week earlier, in some years even in mid-April.

Farmers respond to changed climate conditions by adapting their management plans.
(Photograph: © Dusan Kostic / stock.adobe.com)

Interfaces

LW-I-1: Agrophenological phase shifts
BO-R-1: Humus content of arable land

Prospects for new crop species

A warmer climate and milder weather patterns open up new options for agriculture in the choice of crop species . The cultivation of thermophilic crop species in Germany might benefit from expansion provided there is sufficient market demand and the prospect of cultivation appeals to farmers from a commercial point of view. Thermophilic crop species include grain maize, sorghum, soybeans, sunflowers and durum wheat.

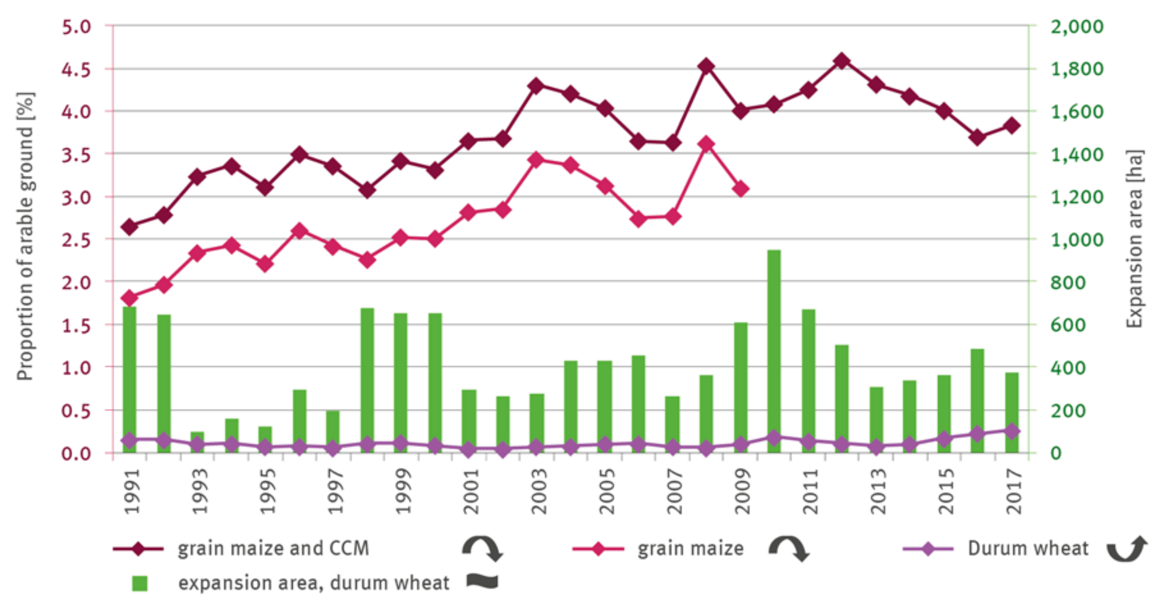
The cultivation of soybeans has already expanded over the past few years. In 2018 soybeans were cultivated on approximately 24,000 hectares. As part of the Federal Government's protein plant strategy (EPS) public funding was made available from 2013 until 2018 for a network with the purpose of expanding and enhaning the cultivation and processing of soybeans. Thanks to the existence of attractive distribution channels and high producer prices, especially in the food industry (e.g. tofu), the interest in soybean cultivation and seeds in both traditional and ecological farming is on the increase. In addition, eco-farming is dependent on GMO-free soybean seeds; it is therefore to be expected that also the production of soybean seeds will attract increasing interest.

While the sorghum type of millet which originates from the Sahel region copes well with drought, it does need a lot of warmth. So far temperatures in Germany have been too low for cultivating this crop species. Millet is of particular interest in terms of energetic use. If climatic requirements for the cultivation of millet improve, this crop species might become an interesting addition or even alternative to the range of bioenergetically useful crop species. There are long-term data available for making cultivation areas suitable for growing grain maize and durum wheat. These data would lend themselves for modelling the development of thermophilic crop species. The cultivation of soybeans, however, has not been surveyed separately as a main species in soil use until 2016. Owing to its minor importance, the cultivation of millet has been covered statistically only in terms of its sum total.

Regarding grain maize the extent of cultivation areas has increased significantly in the 1990s. For its ripening grain

LW-R-2: Cultivation and propagation of thermophilic arable crops

Grain maize and durum wheat are thermophilic arable crops. Subject to warmer climate conditions, their cultivation in Germany might be expanded. In the course of the past twenty years grain maize cultivation has already gained in importance. Durum wheat cultivation still plays a minor role.



Data source: StBA (main land use survey; livestock survey), BSA (Official Gazette) maize depends on comparatively high amounts of warmth. Consequently, the expansion of cultivation area for this crop species is focussed on climate patterns suitable for this crop species. Grain maize is used mainly as animal feed rather than for the production of bio-energy. Consequently, the prospects of livestock breeding have to be taken into account, because fodder requirements will shrink as livestock (especially pig) numbers decrease. On the other hand, the expansion of energy crop cultivation has no bearing on this development. As soon as it has been harvested, grain maize has to be dried in order to lower its water content to approximately 14.5 %. Hence the costs of drying are the crucial profitability factor. The more favourable the weather pattern and the drier the grain maize as it comes in from the field, the greater the commercial gain from its cultivation. There is a certain amount of fuzziness in interpreting the relationships of expanding the cultivation area for grain maize and climate patterns. This is due to the fact that grain maize can be processed to make a moist silage feed known as a corn-cob mix (CCM). In the production of CCM both the grains and the cob (or ear) of the plant are utilised. In this type of use favourable drying conditions are commercially less important than in the process of letting grain maize ripen naturally. From 2010 onwards statistics no longer differentiate between naturally ripened grain maize and CCM. Having said that, the total extent of the area used for grain maize cultivation – before the statistic amalgamation of both types of cultivation – was three to four times greater than that used for CCM. It is therefore possible to use the combined grain maize / CCM data as a basis for deriving statements.

Durum wheat, too, is a thermophilic crop species and relatively drought-tolerant. Within Europe durum wheat is grown especially in Spain, France and Italy. In Germany it has been cultivated for many years as a niche crop. The largest expanses of cultivation are nowadays in Saxony-Anhalt and Thuringia. As far as cultivation is concerned, durum is a challenging and risky crop as its usability strongly depends on its freedom from fungi and diseases. Durum is predominantly used and distributed as semolina for pasta production. Therefore flaws in the harvested product – which manifest clearly as black spots – exclude the product from sale. Prevailing weather patterns – especially at harvest time – also play a very important role, and in many regions they have so far been too unpredictable to ensure successful cultivation. If weather patterns change, especially if more summer droughts become established, the conditions for successful cultivation might improve in this country. So far, however, the importance of durum cultivation, with a share of approximately only 0.25 % of the total cultivated area is rather low. It is not possible to provide an unambiguous interpretation of the slight increase which has been observed since the beginning of this millennium. In future, further indications of an increased interest in growing durum might be taken from an increased expansion of durum cultivation areas in Germany. If there is an increase in the extent of cultivation areas, this would indicate that farmers expect increased demand for seeds both domestically and from abroad. For the time being, however, no such trend is apparent.

In future, thermophilic millet might become of interest for bioenergetic use.
(Photograph: Isidre blanc / Wikimedia Commons, CC BY-SA 4.0)

In order to be able to make a connection between the development of cultivation area for thermophilic crop species and climate change, longer-term data series would be required, because farmers' cultivation decisions can lead to distinct annual swings in terms of cultivated areas. First and foremost, market conditions (attainable prices, regional sales opportunities) play a major role in these matters.

Interfaces

LW-R-3: Adaptation of the variety spectrum

Objectives

Breeding research for expanding the range of crop species in order to ensure optimal yields for 'new' types of crop hitherto neglected (e.g. millet or grain legumes) under future site conditions and to mitigate risks such as weather extremes, infections with pathogens and infestations with pests (in line with the sustainability concept adopted by BMELV 2008, p. 10)

Different climate – different varieties

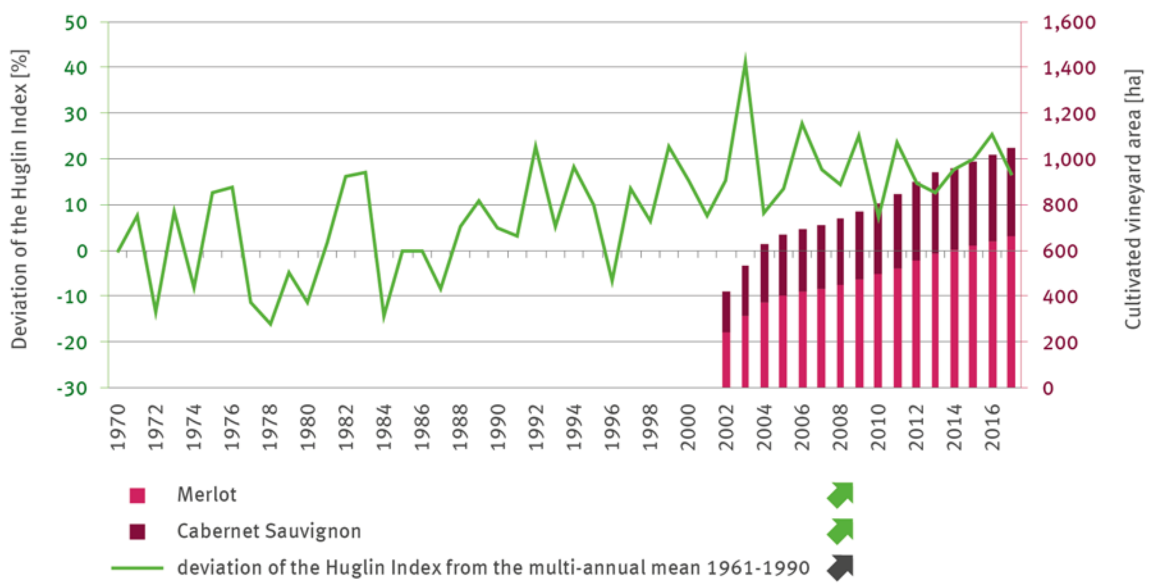
Similar to the opportunities for adaptation by means of cultivating thermophilic crop species, the choice of varieties is a means for farmers to respond to changes in circumstances by retaining the same crop species but considering a change in crop variety. In such decisions preference is given to varieties which promise high-quality crops, secure yields and good chances for sale and marketing when faced with the expected change in circumstances. Naturally, the choice of variety will always be the outcome of factors weighed up by farmers in their decision-making process. In all those deliberations, the weather pattern is only ever one of several factors. Occasionally, the choice of variety can be a spontaneous decision, informed primarily by a farmer's experience gained in the most recent cultivation period or by market chances which might become apparent at the time of decision-making.

In deciding on annual crop varieties farmers can be relatively flexible. However, with regard to perennial crops they have to make a long-term commitment when deciding on a specific variety. In viticulture, for instance, the crop variety requires careful deliberation, because vines have a long lifespan of up to twenty or thirty years. This requires vintners to make longer-term production decisions when planting a new vineyard. Besides, wine happens to be an agricultural product which potentially offers extremely high added value and major commercial importance at the same time requiring comparatively little cultivation space. Consequently, a great deal of attention is paid to the choice of variety.

For assessing the cultivation potential of specific grape varieties in different wine-growing regions, the so-called Huglin Index is used. It totals the days with temperatures of more than 10 °C for the period of 1st April to 30th September and indicates whether the amounts of warmth required by a grape variety for successful cultivation over an extended period can be achieved in a particular region. In the course of the past approximately forty years the Huglin Index has risen significantly for the whole of Germany. This has resulted in some, so far predominantly highly thermophilic red grape varieties – hitherto limited to southern regions – becoming suitable for the

LW-R-3: Adaptation of the variety spectrum

Increasing amounts of warmth signify that even particularly thermophilic red grape varieties become suitable for cultivation in German cultivation areas. Although the cultivation area used for growing the internationally popular red grape varieties Merlot and Cabernet Sauvignon is still limited, there are indications that it is in the process of expanding significantly.



Data source: DWD (German climate atlas – agriculture), StBA (basic survey of vineyards and vineyard survey) cultivation of vines in German areas of cultivation. Such varieties include Merlot, Cabernet Sauvignon and Syrah. These grape varieties are highly acclaimed internationally which makes some vintners very keen to cultivate them subject to suitable climatic conditions. The areas where Merlot and Cabernet Sauvignon are cultivated, as recorded by wine statistics since 2002, are still comparatively small. However, the increase in vineyard space dedicated to growing these varieties indicate mounting interest. It is to be expected that climate change will in future be reflected in the choice of grape varieties in Germany.

Breeders organise the development of their varieties in line with the new requirements. The applications for approval of varieties received every year by the Bundessortenamt (German office for the approval of varieties) provide clues indicating which variety properties are being developed by breeders. Nevertheless, it typically takes between eight and ten years to breed a new variety, i.e. the figures do not always reflect any changes in demand for a variety in real time. The use of modern methodology in plant breeding research might result in a more rapid and more efficient provision of varieties adapted to changed climate conditions such as drought or increased CO_2 concentrations. The use of early ripening varieties of grain maize increases the probability that higher dry matter contents can be achieved in harvesting thus reducing the drying costs involved. As a result, early ripening varieties might become more attractive. It must be said, however, that the late ripening varieties still offer higher yield potentials. Current breeding efforts therefore focus on developing early ripening maize varieties with greater yield potential.

Interfaces

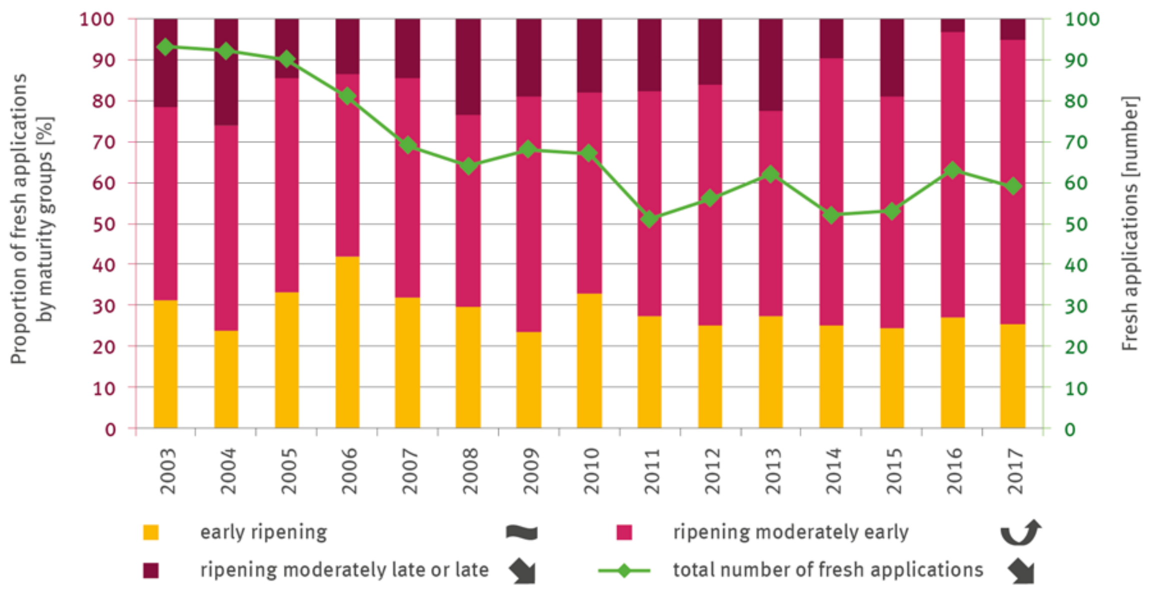
LW-R-2: Cultivation and propagation of thermophilic arable crops

Objectives

Furthering innovations in plant breeding with a view to adaptation to climate change, the nutrient regime of cultivated plants and properties relating to resistance and quality (DAS, ch. 3.2.6)

LW-R-4: Maize varieties by maturity groups

So far, there is no evidence for a discernible trend towards an increase in applications for approval of early ripening maize varieties submitted to the Bundessortenamt. Currently, this development seems to be masked by other effects.



Data source: BSA (grain maize – applications for approval)

Targeted application of pesticides

It is not yet possible to make any tangible forecasts regarding the impacts of climate and weather patterns on the pest infestation or infection with pathogens of agricultural crops. It is undeniable, however, that pests can respond very sensitively and spontaneously to changed weather conditions; this requires farmers and horticulturists to respond flexibly and with utmost speed in order to get problems with pest infestations under control.

It is therefore ever more important for farmers to keep a close eye on their own stocks in order to ensure integrated plant protection. This involves taking precautionary measures in order to buffer any extreme weather events or latent infestations by cultivating healthy and resilient plants. Furthermore, it is necessary to monitor crops and to ensure resistance management when using chemical pesticides by giving priority to non-chemical measures.

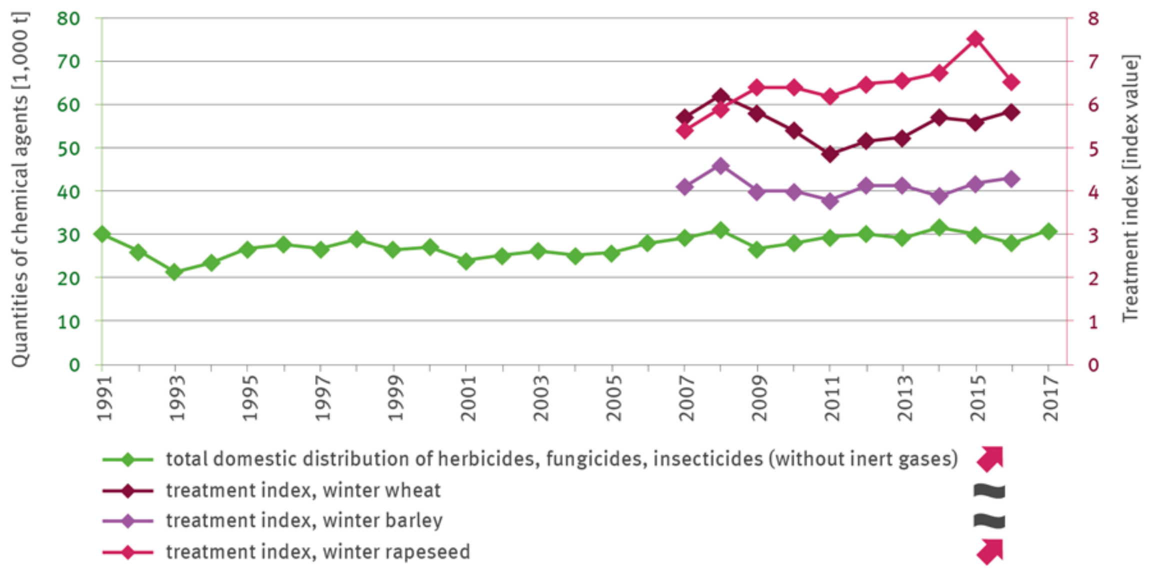
The National Action Plan on Sustainable Use of Plant Protection Products (NAP) adopted by the Federal Government and the German Länder aims to further limit the potential risks posed by the application of pesticides and to limit the application of chemical pesticides to what is absolutely necessary. Climate change can result in changing the first occurrence and development as well as the infection or infestation conditions of various pests. The appropriate response proposed is the targeted monitoring of crops and the observation and, where necessary, adaptation of reference values as required for effective control.

In practice this means that production systems will have to be adapted and that increased investments will be required in up-to-date and enhanced systems for forecasting and assistance in decision-making.

When interpreting long-term data series on the distribution and the intensity of pesticides, it should be borne in mind that, apart from weather-related causes, developments are influenced by a considerable number of other factors. For example, increasing specialisation of a farming business can entail an increase in problems associated with plant protection. It is also important to remember that decisions to minimise tillage in the interest of soil

LW-R-5: Use of pesticides

Climate change will entail major uncertainties in terms of plant protection. These uncertainties should not result in increased distribution of pesticides or intensified plant protection. Regarding the total of domestic distribution, a rising trend was observed for the overall period covered.



Data source: Bundesamt für Verbraucherschutz und Lebensmittelsicherheit (reports according to § 19 Plant Protection Act), Julius Kühn-Institut, plant protection services of the federal states (network reference farms plant protection)

protection and humus production can result in increased weed growth competing with crop plants.

In other words, management decisions can bring about an increased use of herbicides if their use is the last resort left in the arsenal of plant protection. Another point to be taken into account in interpreting the data on distributed amounts of pesticides and intensities of plant protection, is the fact that modern highly effective pesticides may make it possible to use smaller quantities of these agents if they are known to provide, at least in part, stronger eco-toxicological effects. Nevertheless, from an ecotoxicological angle, it is true to say that these agents, albeit to lesser extents, are saddled with the same risk potential as older types of agents which were used in larger amounts, thus making it possible that the overall risk potential increases even if the amount distributed remains the same.

The chart shows the domestic distribution of pesticides. The illustration provides only a rough guideline for the amounts distributed in Germany, partly because pesticides are also traded beyond Germany's borders. This trade is not covered in the chart. In the course of the past twenty years, the distributed amounts have settled around a certain level. If the spectrum of pests or pathogens changes as a result of climate change, for instance because weeds and weed grasses as well as insects benefit particularly from warmer weather, it is conceivable that this may also be reflected in the proportions of areas targeted by pesticides (herbicides, fungicides, insecticides) for the total domestic distribution covered in this chart. It is of interest to note that no such shifts have been identified for the past twenty years.

The treatment index makes it possible to make statements on the intensity of pesticides. It offsets the number of applications made per annum by the amounts used per spraying operation in relation to the highest permitted application quantity for the respective crop and indication. Any increase or decrease in the application intensity of pesticides is expressed in terms of rising or falling treatment indices. Despite any challenges associated with climate change, this should not result in an increased intensity of plant protection.

If the infestation with pests becomes more unpredictable, careful and regular crop checks will become increasingly important. (Photograph: Bits and Splits / stock.adobe.com)

Interfaces

LW-I-4: Infestation with harmful organisms

Objectives

Reducing the dependence on the application of chemical pesticides including the introduction of further development of alternative plant protection procedures, breeding of resistant and resilient crops and expansion of cultivated areas for ecological farming (National Action Plan on Sustainable Use of Plant Protection Products 2013, e.g. ch. 5.1 and 6.1.2; the UBA's 5-point programme for sustainable plant protection, ch. III)

Further development and systematic implementation of integrated plant protection with the objective to limit the use of pesticides to what is absolutely essential (National Action Plan on Sustainable Use of Plant Protection Products 2013, ch. 4.9 and 5.1)

Reduction of and compensation for risks which might be caused by the application of chemical pesticides (5-point programme for sustainable plant protection, ch. III)

Irrigation becomes more lucrative

A basic requirement for high and stable agricultural yields is an adequate supply of water. Especially in the production of potatoes and vegetables or special crops, rainwater alone will usually not suffice. In such cases, superior quality and high production yields can only be achieved with additional irrigation of the fields in question.

Two adverse effects of two distinct climate trends can already be observed today in respect of adequate water supply for agricultural crops during the main growth period, which is of crucial importance for ensuring good yields: On one hand, (early) summer precipitation declines, while on the other, summer precipition can, with greater frequency, occur as heavy-rain events, thus impairing the availability of rainwater for plants. Farmers have the option to respond to this situation by growing more varieties with tolerance of drought stress, or by adapting their tillage operations in a way to increase soil moisture or by means of increased and more efficient watering or irrigation of agricultural crops.

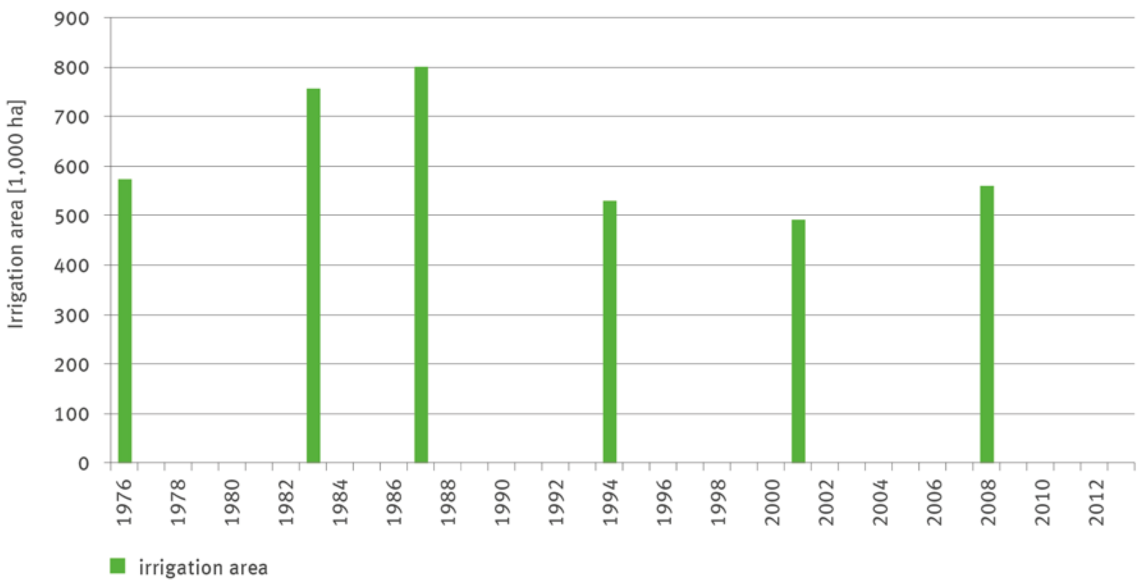
This is why an expansion of irrigation, especially of sensitive agricultural crops or crop rotations, is to be expected as one of the possible responses by farmers. In other words, climate change shifts the focus more strongly to irrigation; at the same time as increases in the efficiency of water use in agriculture become more relevant.

In Germany, a total of 451,800 hectares of agricultural land was irrigated in 2015. More than half of this took place in north-eastern Lower Saxony. In other Länder of Germany, there are also regions where intensive irrigation is practised; however, the irrigated areas are less extensive (Statistisches Bundesamt, data collected in 2015). Irrigation water is used in particular in fruit growing, partly as frost protection, as early onset of flowering entails the risk of damage from late frosts.

To date there have been no annual surveys of cultivation areas equipped with irrigation technology and enjoying water abstraction rights; trend statements are therefore not available at present. Data collated by

LW-R-6: Agricultural irrigation

Under climate change conditions, the need for irrigation is likely to increase and extend to additional crops To date there have been no regularly collected data available on agricultural irrigation. Any information obtained from the Bundesfachverband Feldberegnung (Federal professional association for matters of field irrigation) in the past has not been updated.



Data source: Bundesfachverband Feldberegnung (irregular surveys among the German federal states on the state of irrigation) the Statistische Bundesamt on farm businesses and irrigated cultivation areas, nevertheless show a distinct increase from 2009 until 2015. During this period, the actually irrigated area increased from 372,750 hectares by 21 % to 451,800 hectares. In 79 % of businesses sprinklers are used for irrigation, 32 % of farmers use (also) drip irrigation. Nationwide 77 % of water for irrigation purposes is abstracted from groundwater and spring water whereas approximately 11 % is derived from surface water and from public or private supply networks respectively (Statistisches Bundesamt, data collected in 2015[29]).

The interest in irrigation has been mounting nationwide since 2002. Funding for industry-wide institutions in respect of irrigation issues has been continued by the European Agricultural Fund for Rural Development (EAFRD), i.e. the EU, as well as by the Federal Government and the German Länder since 2014 which is being continued for the current IASCP funding period which began in 2018. Funding is granted on condition that the equipment installed be water-saving.

From an ecological point of view, irrigation cannot be judged to be of equal value in all regions or situations. Adverse effects of irrigation can manifest in terms of lowering the groundwater level and changing the soil's mineral balance. For the time being the proportion of agricultural abstraction of water for irrigation which amounts to 1.25 % of the sum total of water abstraction is very low in Germany (Statistisches Bundesamt, data collected in 2016)[30]. Nevertheless, sustained impacts on the water regime in regional irrigation 'hotspots' or conflicts of use cannot be ruled out. In north-eastern Lower Saxony, the limitations placed on businesses by means of water allocations – in accordance with permission required under water law – might be a limiting factor for any further expansion of irrigation. During the 2018 drought, it is estimated that some of these water allocations were indeed exceeded. This shows why it is essential to take measures for increasing the efficiency of water use. Opportunities include the improvement of humus content, furthering deep root penetration, optimal tillage, creative crop rotation, choice of suitable species and varieties, adapting planting densities, irrigation control and adapting irrigation technology.

If summer precipitation declines any further at the same time as falling increasingly as heavy rain, irrigation may indeed become of commercial interest.
(Photograph: Martina Nolte / Wikimedia Commons, CC BY-SA 3.0)

Interfaces

BO-I-1: Soil moisture levels in farmland soil
LW-I-1: Agrophenological phase shifts

Objectives

Furthering the infrastructure for agricultural irrigation via IASCP by more efficient use of water, e.g. reducing water loss in the irrigation of agricultural land (DAS, ch. 3.2.3)

Further development of water-saving tillage systems and irrigation technology, extending irrigation opportunities (BMELV's sustainability concept, p. 10)

Giving proper consideration to qualitative aspects of irrigation water (based on DIN 19650, DIN 19684-10) and assessment of water management aspects in respect of the abstraction of water for irrigation purposes (DWA-M 590)

Woodland and forestry

Germany's woodland areas amount to approximately 11.4 million hectares which equates to roughly a third of the entire land surface. Owing to their multiple economic, social and ecological functions, woodland ecosystems are of particular importance. The Federal Forest Act therefore provides that woodland is to be conserved, and its functions are to be maintained and, where necessary, enhanced and its proper management is to be safeguarded.

Climate change and the associated greater frequency and intensification of extreme weather patterns such as heat and drought and possibly also storms combine to confront forestry with one of its greatest challenges. The impacts on the nation's forests have to be taken very seriously as climate-related changes are progressing at unprecedented speed. These processes pose particular problems with regard to forests, as trees are long-lived and fixed in place, which means that over their entire lifespan, forest stands are exposed to a great variety of different environmental and growth conditions. If forests cannot adapt to environmental changes, this will result, not just in weakened trees, but in disrupting the entire forest ecosystem. Drought and storm damage as well as extensive pest infestations can lead to the loss of the forests' protective function accompanied by increased soil erosion. The decomposition processes of decaying biomass entail increased green house gas emissions. Other potential consequences may be declining timber quality and reduced yields. Besides, an oversupply of timber that comes to market after major damaging events often involves price erosion. Forestry management which hitherto has dealt with long rotation cycles which require long-term planning will have to be able to respond very quickly. It means that future changes in terms of growth conditions will have to be taken into account without knowing precisely where and to what extent the actual changes will take place.

The National Forest Inventory (BWI) is revised every 10 years. The outcomes for the most recent decade surveyed, as incorporated in the 2019 Monitoring Report therefore date back to 2012. The years, 2018 and 2019 were marked by a combination of extreme drought, an above-average incidence of forest fires, bark-beetle infestations and storms, resulting in serious damage to forests and woodlands. As stated by the Federal Länder, the drought year 2018 produced approximately 32.4 million cubic metres of damaged timber. In 2018, fires alone caused the loss of stands over an area of 2,349 hectares. Specialists reckon that the figures for 2019 will reflect an even higher amount of damaged timber. Most seriously affected are spruce stands. There are indications, however, that deciduous trees such as European beech will have suffered serious damage. It will not be possible to illustrate these current developments until preparation of the 2023 Monitoring Report.

Effects of climate change

Adaptations

Adaptability of natural tree species

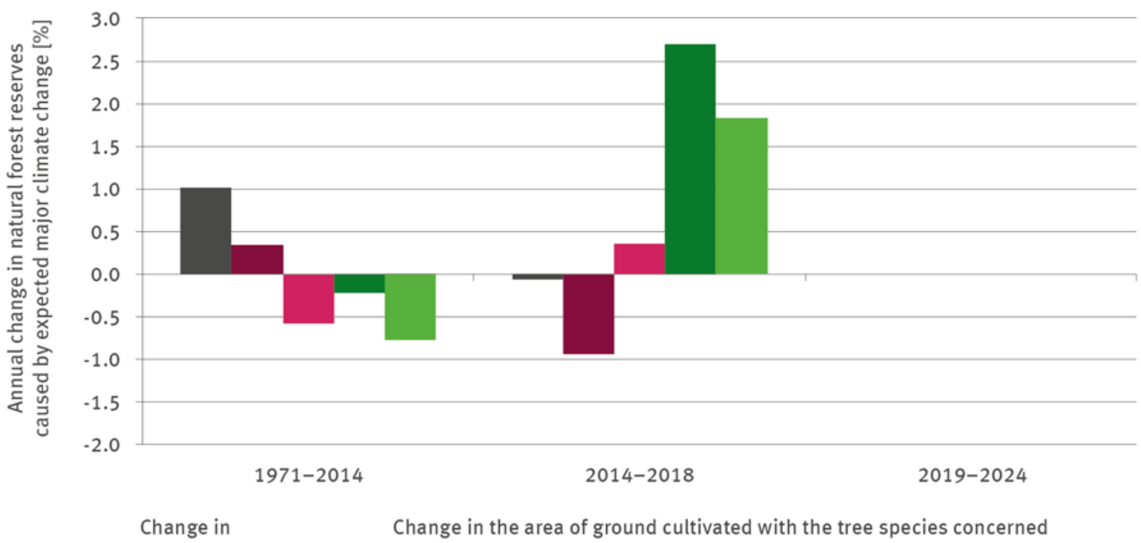
Woodland and forest ecosystems have great longevity. Accordingly, forestry management has to deal with extended rotation cycles. Planning must be for the long term and has to take future changes in growth conditions into account. Tree species which hitherto coped well with the climatic conditions prevailing at their location may, in coming decades, become more vulnerable to damage and incremental loss. In commercial forests the species composition is informed by forestry principles of utilisation and cultivation. This is an area marked by interactions of natural succession and anthropomorphic intervention.

In natural forest reserves woodlands evolve free from direct human intervention. In late 2017 Germany had 742 natural forest reserves covering a total of 35,500 hectares. In most of these reserves, the autochthonous tree species predominate. Whether the limits of their adaptability are exceeded as a result of climate-related changes is an issue that is being examined by means of ongoing observation of natural woodland dynamics. The outcomes of these observations will make it easier for woodland and forest managers to make decisions on the extent to which warmth- and drought-tolerant tree species in stands used for forestry purposes should be incorporated in order to safeguard the continued future use of timber.

Regional projections of future climate change make it possible to differentiate between natural forest reserves on one hand where future changes in water supply are expected to be rather negligible and on the other, forests where the water regime will presumably be affected quite badly thus threatening stands to be exposed to drought stress. By categorising the prevailing tree species in groups characterised by specific adaptability properties and by monitoring their long-term development, it is possible to infer statements on the development of adaptation processes in forest ecosystems. Adaptability is regarded as comparatively high in respect of sessile and pedunculate oak, ash, sycamore, Norway maple and so-called pioneer species such as silver birch and downy birch, sallow, aspen and rowan. However, it is to be expected that European beech will be rather vulnerable to drought stress. Besides, it should be remembered that

FW-I-1: Tree species composition in designated forest nature reserves – case study

In natural forest reserves where more distinct climate-related changes with higher temperatures and drier conditions as well as more frequent and more pronounced weather extremes are expected, the share of beech trees has declined.



Data source: Nordwestdeutschen Forstliche Versuchsanstalt / Projektgruppe Naturwälder (federal state data from research and monitoring in natural forest reserves) also other factors such as pest infestation, wind throw or competition for light, water and nutrients will influence the development of individual categories of tree species.

In the natural forest reserves of Länder such as Baden-Württemberg, Bavaria, Brandenburg, Hesse, Lower Saxony, North-Rhine Westphalia, Rhineland-Palatinate, Saxony-Anhalt and Schleswig-Holstein there have been indications of shifts in tree species compositions up to 2014, which cannot be attributed to climate-related changes. In most cases, stands were characterised by increases in stand density which was taken as an indication that the vitality of trees has not been visibly affected. While beech trees were able to increase their share, the proportion of oak species and the ash / maple group had declined. This development can be explained on one hand by the competitiveness of beech trees, and on the other, by disease-related die-back affecting oak and ash trees. The group of pioneer tree species showed only negligible change. Overall, events did not indicate that developments were strongly influenced by climate change.

As far as the second observation period from 2014 to 2017 is concerned, the direction of development was reversed in those natural forest reserves where more distinct climate-related changes with higher temperatures and drier conditions as well as more frequent and more pronounced weather extremes are expected. The stand density increased only negligibly while the share of beech trees declined, compared to increases in the proportion of all other groups of tree species. It is true that the rather short observation period requires caution in respect of interpreting outcomes; however, the outcomes do confirm the expected developments under climate change. This interpretation is further supported by the fact that in natural forest reserves where rather negligible changes in water supply are expected, the development which occurred during the first observation period is still ongoing. In this category the stand density and proportion of beech trees continue to increase. In other words, for the first time it is possible to discern differences in the development of the two groups.

Natural forest reserves free from any effects of management intervention demonstrate which tree species in a particular location prove to be the more successful competitors. (Photograph: Peter Meyer / NWFVA)

Objectives

Examination of the climate adaptation potential of stands free from tending or utilisation operations in existing woodlands where no utilisation takes place. On this basis, pointers are given that are intended to assist forestry decisions. (Waldstrategie 2020, p. 11)

Conservation and evolution of natural and near-natural woodland communities (NBS, ch. B 1.2.1)

Spruce trees under increasing pressure

The targeted extension of spruce plantations in German forests began more than 200 years ago. In those days many forests were badly fragmented, because they had been opened up for the purpose of forest pasture and intensive use of timber. Owing to their undemanding nature, sturdiness, and easy propagation, spruce trees suggested themselves as the ideal tree species for rapid reforestation of large areas. The useful and versatile timber was considered suitable to overcome an impending timber shortage. It is true to say, however, that spruce trees, owing to their mostly shallow root system are vulnerable to storms and droughts. As a result of this massive extension of spruce cultivation, these trees were also planted on sites which do not meet the species' requirements for rather cool and moist climatic conditions. In view of prevailing climate change scenarios the conditions at those sites can only get warmer and drier.

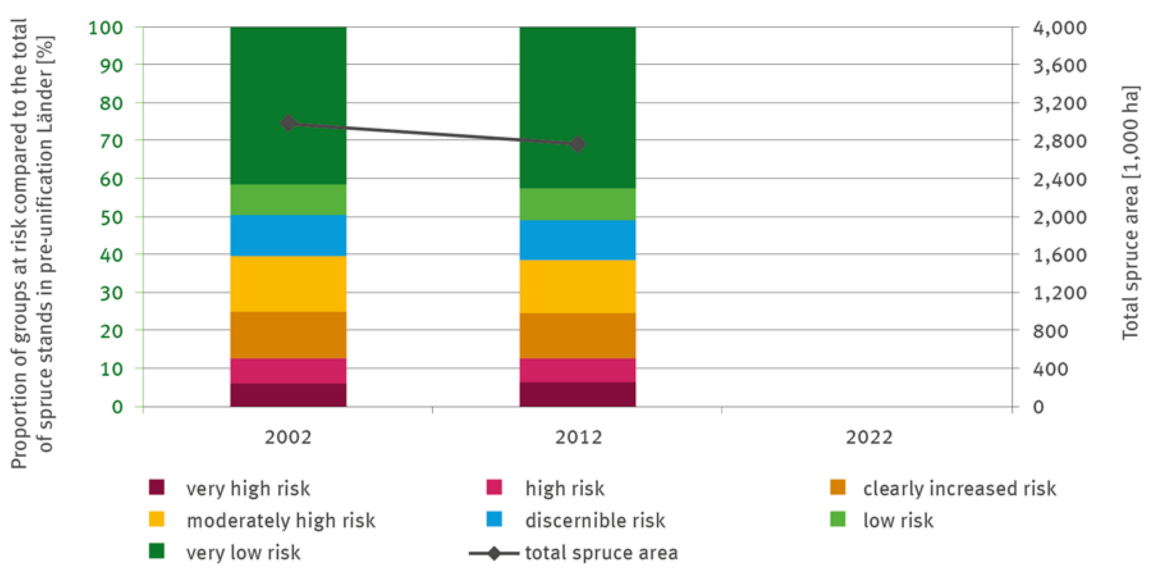
There were early indications that pure stands of spruce trees were fraught with high cultivation risks. From the late 19th century onwards, there were already repeated incidents of pest infestation or storm events which destroyed localised stands. However, the true extent of vulnerability of this species did not come to light until vast areas of spruce plantations were affected by damaging events in the course of the past two decades. Severe hurricanes such as Vivian or Wiebke, Lothar and Cyril resulted in large volumes of damaged timber.

Even a moderate increase in temperature by less than 2 °C will heighten the spruce cultivation risk considerably as many more cultivation areas will exceed the temperature and drought thresholds for spruce trees. Problems such as above-average pest infestations and poor growth potential, currently occurring only in marginal zones of spruce cultivation areas, will in future extend to areas which have so far been regarded as productive and controllable cultivation areas.

The National Forest Inventory carries out a regular spot-check survey of forest conditions and production potentials. When the second inventory took place in 2002, the survey was for the first time extended to the whole of Germany. The third inventory took place in 2012. When

FW-I-2: Endangered spruce stands

As climatic circumstances change, spruce trees will be challenged by increasingly unfavourable growth conditions. The risk situation did not yet change drastically in Germany during the period between the two National Forest Inventories of 2002 and 2012. Spruce tree cultivation on high-risk sites has not declined to any relevant extent. Overall, the expanse of spruce forest area has declined.



Data source: Thünen-Institut für Waldökosysteme, Bayerische Landesanstalt für Wald und Forstwirtschaft (modeling based on the National Forest Inventory) superimposing the spruce cultivation area captured in the second and third National Forest Inventory on the climatic risk areas for spruce trees as defined for the 1981-2010 Standard Climate Reference Period, it becomes clear that there have been hardly any changes during that period. In 2002 12.7 % of all spruce trees stood in locations where they were exposed to a high or very high risk, also in terms of their climate threshold, i.e. where the climatic conditions were already then quite unfavourable in view of low precipitation totals and comparatively high annual average temperature levels. In 2012 this proportion was still 12.5 %. On the other hand, the share of spruce trees (with at least 90 % of spruce trees per stand) in areas with low or very low risk has increased by 1.2 % between 2002 and 2012. These rather negligible changes suggest the inference that the situation regarding risks of drought damage for the period of 2002 to 2012 has not changed to any relevant extent. The outcomes of the next National Forest Inventory which will incorporate any impacts from recent very dry and warm years, will become available in 2022.

Overall, the spruce cultivation area was by 215,000 hectares smaller in 2012 compared to 2002. Consequently, the proportion of spruce cultivation area compared to the entire forest area in Germany has decreased from 28.4 % to 25.4 %. This development is largely due to spruce wind-blow and to the objective of converting pure spruce forest stands to deciduous and mixed forests in order to increase the amount of forests appropriate to their location. Previously, any specific adaptation of drought-sensitive spruce stands had been given secondary consideration in forestry management decisions.

In principle, the determination of cultivation risks or potentials of important species is central to forestry planning. If the risks of failure can be assessed at the point of cultivation, forestry managers can, notwithstanding any uncertainties and knowledge gaps, adapt their operational decisions on the choice of tree species accordingly.

The drought years of 2018 and 2019 have affected spruce trees quite badly. (Photograph: © K I Photography / stock.adobe.com)

Interfaces

FW-I-5: Extent of timber infested by spruce bark beetle
FW-R-3: Conversion of endangered spruce stands

Objectives

Driving forward the conversion of pure (single-species) stands to mixed stands consisting of site-appropriate trees which are low-risk (DAS, ch. 3.2.7)

Maintaining the overall forest area in Germany and increasing the stability and diversity of forests. Cultivation of site-appropriate tree species with high resilience, adaptability and growth performance (Waldstrategie 2020, p. 23)

Continuous reduction of the proportion of non-native tree species (NBS, ch. B 1.2.1)

Changes in incremental growth

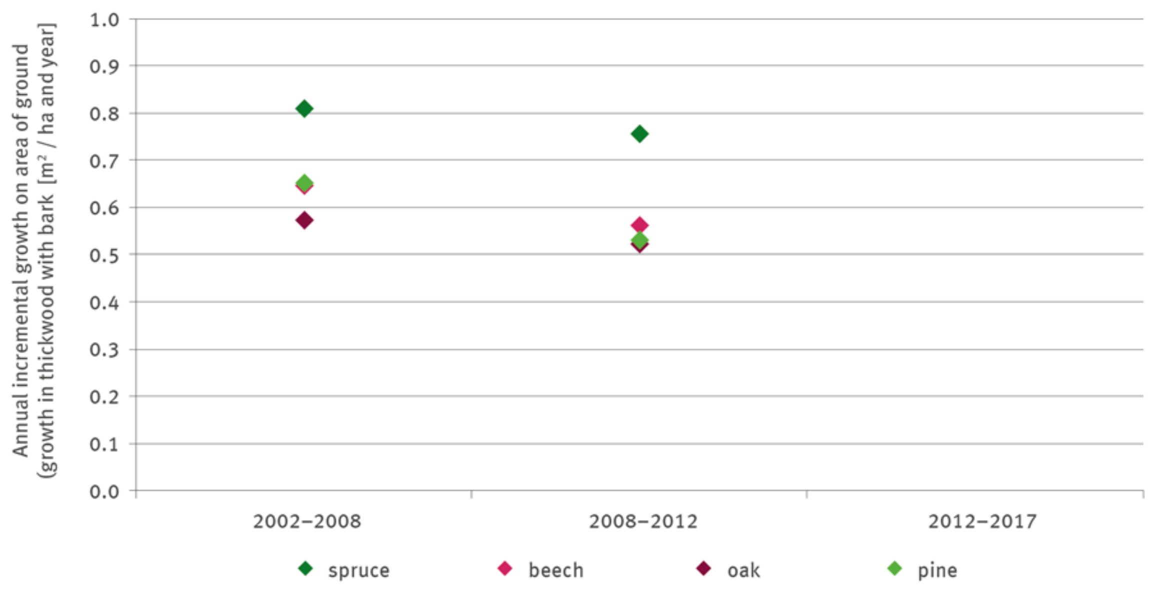
How quickly trees grow and how much timber volume per time unit develops, is essentially dependent on the nutrient and water supply at their location and on the prevailing temperatures. In mountainous topography or in cold hollows which have so far had limited warmth, temperature increases can indeed have positive impacts on incremental growth in localised stands. In areas such as the Upper Rhine plateau where growth is already limited now in many places owing to heat or drought, further increases in temperature and increasing drought caused by climate change will, however, have adverse impacts on timber growth. In general it is expected that changes in the weather associated with climate change will have different impacts on timber growth in respect of specific locations and stand compositions.

Apart from weather-related effects, there is also a lot of discussion regarding the fertilising effect of increased carbon dioxide concentrations in the atmosphere. This increase can, in principle, benefit productivity provided there is no restriction on other important growth factors. Another major influence is the age structure of forest stands as the growth performance of trees depends on their age. In young trees less than 20 years old volume growth is low. In subsequent years volume growth will increase considerably while in old trees it will decline according to the species concerned. Any analysis of growth data will therefore have to take the age factor into account.

The interaction of all influencing factors combined is complex and it is hard to predict in terms of impacts on future growth. It is abundantly clear, however, even now that there will be winners and losers from the effects of climate change depending on the specific site conditions of a forest. In principle, productive timber growth, apart from the quality of the timber, is a relevant variable in forestry, as it ultimately determines the level of achievable timber yields. If growth increments in commercial forests decline continuously to a considerable extent – e.g. owing to unfavourable weather conditions – targeted forestry management actions will be required in order to maintain the productivity function of the forest or forests concerned. Besides, timber increment is also important

FW-I-3: Incremental growth in timber

The incremental growth in the period of 2008-2012 was lower for all main tree species than in the preceding period of 2002-2008. This suggests that individual drought years have so far not been crucial for incremental growth figures. In fact, the particularly warm and dry years of 2003 and 2006 occurred in the first period which still produced higher incremental growth figures.



Data source: Thünen-Institut für Waldökosysteme (analysis based on the National Forest Inventory) insofar as it is a prerequisite for a forest's ability to function as a carbon sink. The more timber accrues in a forest, the more carbon dioxide can be extracted from the atmosphere for storage as carbon in the timber. It as assumed that every cubic metre of timber stores approximately 250 kg of carbon. This means that forests with a positive carbon regime make a valuable contribution to protection from climate change.

The outcomes of National Forest Inventories available so far are starting points for the establishment a long-term time series pertaining to timber increments. From 2002 onwards, there are nationwide inventory data available. The data provide opportunities to draw inferences regarding the effects of extreme weather situations in a specific observation period. For example, it was not possible to find evidence, especially for spruce forests, in the former Länder for the period from 2002 until 2012 in the same volumes as the high average timber increments which were found in those areas until the end of the 20th century. It is assumed that, especially during the hot and dry years of 2003 and 2006, productivity losses will have occurred. However, it must be said that also in the subsequent period of 2008–2012 from which drought years were absent, the nationwide mean of timber increments for the four main tree species declined further, with pine trees most badly affected, followed by beech trees.

The outcomes of an interim inventory carried out for the purpose of reporting on greenhouse gas emissions (CI 2017) were not yet available at the point of preparing the 2019 Monitoring Report. It was therefore not yet possible at that time to describe the timber increments for the period 2012-2017. A longer-term time series will make it possible in future to illustrate the long-term impacts of climate change on timber increments.

Depending on weather conditions, timber yields can vary considerably from year to year.
(Photograph: Andreas Bolte / Thünen-Institut)

Interfaces

LW-I-2: Yield fluctuations

Objectives

Safeguarding the production of timber from sustainable forestry; meeting the increasing domestic demand for timber even after 2020 from predominantly domestic production (Waldstrategie 2020, p. 7)

Forestry becomes riskier

The long rotation cycles involved in forestry require very careful and long-term planning of forest management; and only if planned actions can be implemented will it be possible to achieve the desired cultivation objectives. Climate change can impact in two ways on the ability to plan the utilisation of commercial forests in line with forestry principles. On one hand, changed weather patterns can weaken trees thus making them more vulnerable to damage, especially infestation with insects. On the other, it is assumed that the frequency and intensity of extreme events such as storms will increase as a result of climate change.

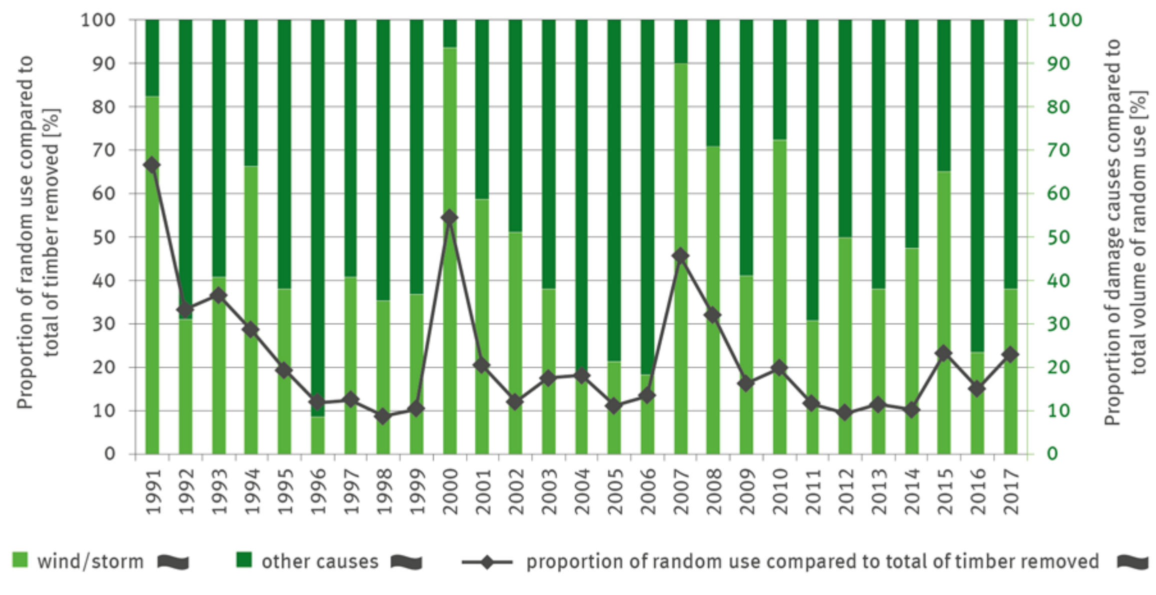
Both types of development can lead to increased incidence of wind-blown and wind-broken timber and to forced usage after pest infestations. This type of timber jeopardises the chance of safeguarding the ongoing production as it offers breeding habitat for bark beetles. In addition it is worth noting that any random use of timber represents a burden on the entire forest ecosystem which in turn is detrimental to the medium- and long-term productivity of a forest. It makes ongoing cultivation more difficult and represents a safety hazard for forestry employees and forest visitors.

This is why wind-blown and wind-broken timber has to be removed from commercial stands. Especially after major damage events such random use of timber tends to tie up considerable capacity required for other forestry operations. This diverted capacity is then unavailable for implementing targeted cultivation measures which are, after all, of great importance in achieving the required adaptation to climate change. As a rule it takes several years until the consequences of calamities have been dealt with enabling foresters to return to planning and managing 'normal' utilisation and cultivation actions.

For the forest owner – no matter whether it is the state, the local community or a private forest owner – major volumes of wind-blown, wind-broken and infested timber are associated with considerable revenue shortfalls. In fact, the restoration costs in damaged stands are distinctly higher and the timber qualities often inferior. At the same time, timber prices decline distinctly, especially in

FW-I-4: Damaged timber – extent of random use

Random use owing to wind-blown, wind-broken and infested timber is detrimental to forestry in many ways. A trend towards more random use of timber has not emerged so far. However, strong winter storms which occurred especially in 1990, 1999, 2007 and 2010 resulted in considerable volumes of damaged timber.



Data source: BMEL (compilation based on federal state information), BMEL and StBA (timber logging statistics) the aftermath of major damage events. Besides, timber will have to be stored longer and this causes additional costs. In fact, this is why in late 2018, a new eligibility status for funding – entitled 'Promotion of measures to deal with the consequences of extreme weather events in the forest' – was agreed as part of IASCP and endowed with additional funding from Federal Government sources amounting to 10 million Euros for 2019.

Even though there is no statistically sound evidence for a trend developing over the past barely twenty years towards increases in the extent of random use of timber, forestry circles have gained the impression that phases without any relevant influences of forced usage are becoming ever shorter.

The extremely high proportion of random use as part of the total removal of timber is caused mainly by wind-blown and wind-broken timber, i.e. it is brought about by storms. For example, in late winter of 1990 hurricanes Vivian and Wiebke resulted in extensive restoration work required in the following year of 1991, and this extended to major parts of Germany. In December 1999 Lothar devastated extensive parts of south-west Germany. In January 2007 cyclone Cyril destroyed forests particularly in North-Rhine Westphalia with a focus on Sauerland. In late March 2015 hurricane Niklas wrought havoc in Bavaria but left behind smaller amounts of damaged timber than comparable hurricanes. In early October 2017 the autumnal storm Xavier caused damage in deciduous woodlands in Brandenburg while trees were still fully covered in foliage. It is expected that the 2018 statistics will show an increase in storm-related volumes of damaged timber resulting from hurricanes Friederike and Burglind which struck the country in January. In years without supraregionally important storm events the bulk of random use is due to damage by insects. In this context, the drought year of 2018 is expected to reveal a major increase in damage.

In evaluating data on wind-blown, wind-broken and infested timber it is important to remember that, as a rule, these data do not provide a comprehensive overview of the actual damage caused to timber. Not all Federal Länder provide data on private and corporate forests in addition to data on state-owned forests. Besides, the focus of data collection has so far been on winter storms. Apart from impacts caused by climate change, there can also be other trends exerting strong influences on the time series. As far as the age structure of German forests is concerned, stands tend to contain the older range of the spectrum. It is important to note that older trees are more vulnerable to wind-blow than younger ones, and the greater the timber reserve, the greater the volume of damaged timber. The latter can also mean that depending on where the calamity is located, the damage caused can vary in terms of volumes. For example, storms in regions with fairly open stands of pine forest which are widespread on sandy soils in Brandenburg or Mecklenburg-Vorpommern, will cause smaller volumes of damaged timber than storms in the Black Forest with its high volumes of timber.

While in full foliage, beech trees on wet soil in Brandenburg also fell victim to the autumnal storm Xavier in early October 2017. (Photograph: Tanja Sanders / Thünen-Institut)

Interfaces

FW-I-5: Extent of timber infested by spruce bark beetle

Objectives

Aiming for particularly stable mixed stands with increased resistance to widespread misadventures caused e.g. by storms and bark beetle infestations (DAS, ch. 3.2.7)

Cultivation of site-appropriate tree species with high resilience and growth performance (Waldstrategie 2020, p. 23)

Bark beetle – a major problem for spruce trees

Many trees suffer from diminished vitality caused – as projected – by climate-related changes, especially during summer droughts. Thermophilic insects and pathogens, however, can benefit from such conditions. As far as coniferous trees are concerned, increasing damage – caused by bark beetles such as spruce bark (or typographer) beetle and six-dentated bark beetle, which breed in the bark of spruce trees – is thought to be associated with changed weather patterns. In the course of the past ten years this type of damage reached supraregional importance in Germany.

Even if climate change is not the only cause of increased pest infestation, it is assumed – at least with regard to the spruce bark beetle – that higher temperatures cause this species to swarm earlier in the year thus enabling an additional generation to develop.

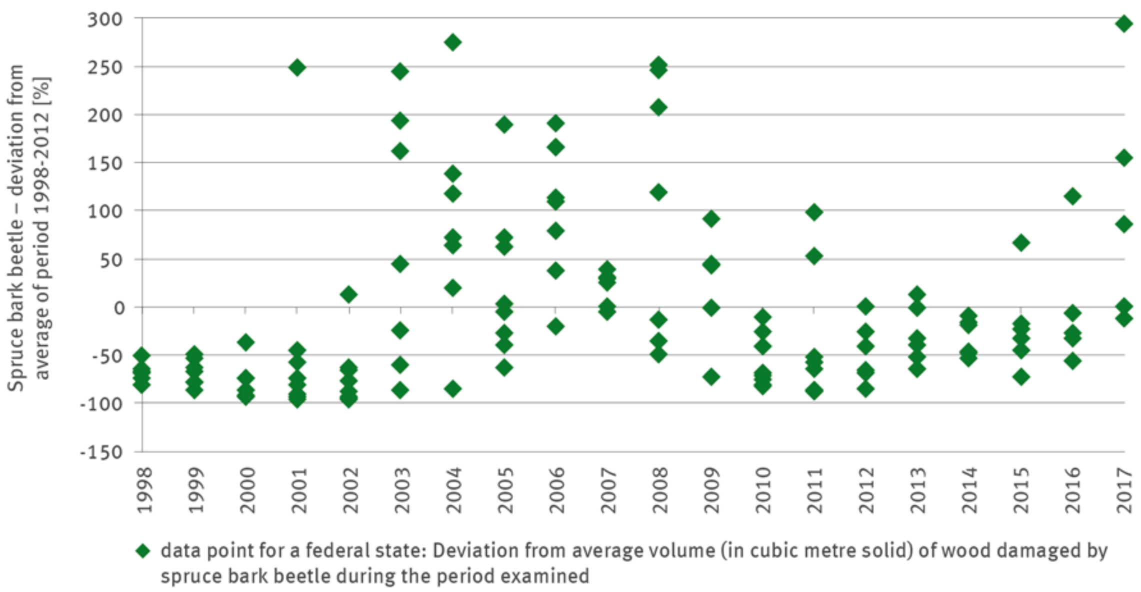
Infested timber has to be removed from commercial stands in order to prevent this type of beetle from further extending its range unhindered. Beetle-infested timber is basically still usable but has to be removed quickly from affected stands. If this infested timber is left standing, eventually losing its bark, its usefulness becomes limited, i.e. only as firewood.

Data on the volume of timber damaged by pest infestation are not available in a harmonised form nationwide. However, the data series on the volume of timber damaged by spruce bark beetle collated by eight Federal Länder make it possible to estimate the development.

These data clearly show that beetle infestation caused as a result of the heat and drought year 2003 increased rapidly in nearly all the Federal Länder examined. The after-effects continued for some subsequent years, reinforced by another very warm and dry summer in 2006. In 2007 the rather rainy month of May and a cold September, the bark beetle population was not able to reproduce quite as successfully. This did not occur until 2010 when the volume of damaged timber again reached the level experienced in the heat summer of 2003. However, since the warm summer of 2015, volumes of damaged timber have been increasing

FW-I-5: Extent of timber infested by spruce bark beetle – case study

The spruce bark beetle benefits from dry and hot weather and prefers to infest trees that are already damaged or weakened in some way. Infestation data from eight Federal Länder demonstrate that hot and dry years and also storm events entail a volume of damaged timber that is distinctly higher than the long-term mean.



Data source: Journal AFZ-DerWald (overview of the federal states on forest protection) again. It is also possible to discern the consequences of extreme storm years which typically entail increased beetle infestations of damaged or thrown trees. Such years account for the above-average volume of damaged timber in one of the Federal Länder in 2001 (after storm Lothar had passed through in December 1999) and in several Länder in 2008 (the aftermath of storm Cyril). In view of the succession of winter storms in 2018 (Friederike, Burglind) and the extremely hot and dry summers of 2018 and 2019 it is to be expected that the volume of damaged timber will increase considerably. According to records provided by all Federal Länder approximately 32.4 million cubic metres of damaged timber accrued in 2018, and even bigger volumes are expected to have been recorded for 2019.

The spruce bark beetle is representative of other pests which enjoy improved reproduction thanks to changes in the weather pattern. Apart from bark beetles, coniferous trees are increasingly damaged also by silver-fir adelges and by fungi as a result of climate change. As far as deciduous trees are concerned, pests include the common European cockchafer, the oak processionary moth, gipsy moth, the oak-boring beetle, the leaf-mining moth on horse chestnuts, the small beech bark beetle and the beech jewel beetle on beech trees. The increasing incidence of these species is thought to be associated with warm and dry summer weather.

The rapid removal of beetle-infested timber from affected stands is one of forestry's major challenges. However, only rapidly harvested timber remains usable.
(Photograph: Andreas Bolte /Thünen-Institut)

Interfaces

FW-I-4: Damaged timber – extent of random use

Objectives

Aiming for particularly stable mixed stands with increased resistance to widespread misadventures caused e.g. by storms and bark beetle infestations (DAS, ch. 3.2.7)

Cultivation of site-appropriate tree species with high resilience and growth performance (Waldstrategie 2020, p. 23)

Higher risk of forest fires

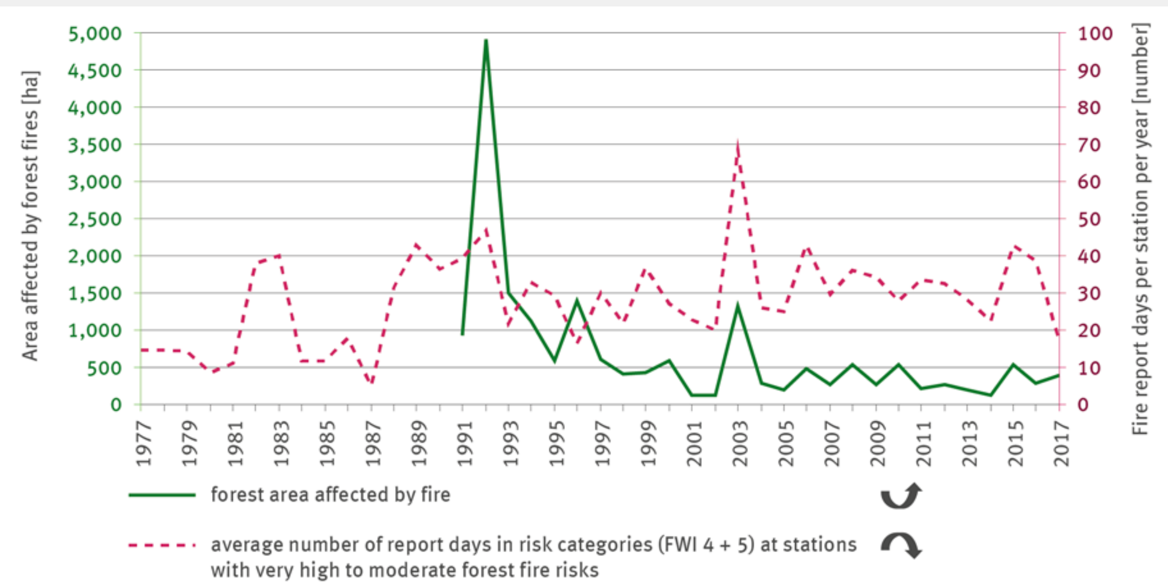
Compared to damage in terms of windblown, wind-broken or pest-infested timber, damage caused by forest fires has so far played a secondary role in most regions of Germany. Brandenburg and in regions such as Mecklenburg-Vorpommern, Saxony, Saxony-Anhalt and Lower Saxony are characterised by a more continental climate. These regions are among the traditional areas of pine cultivation. In summer they are often subject to extended dry periods thus putting them at greater risk of forest fires which is therefore a very serious risk factor in those regions.

Forest fires can be caused by a number of different factors. Major triggers are above all negligent actions and arson. Whether the first ignition leads to a forest fire depends essentially on the amount of dry, flammable material available on site and therefore on weather and stand structure. Whether the fire is able to spread depends on wind speeds, fire monitoring and fire fighting capacities. Apart from the weather, all the other causal factors usually change gradually. However, when there are abrupt changes as e.g. in 2003 which witnessed frequent and some extensive forest fires, these can usually be attributed to extreme weather conditions with intense drought in the spring, summer and autumn months as well as extreme heat.

According to Federal statistics, the number of forest fires and the size of forests affected in Germany declined significantly between 1991 and 2017. The fact that the size of the burn area has declined to a greater extent than the number of fires indicates that there have been improvements in recognising incipient forest fires at an early stage and in containing them successfully. It is true to say that, with financial assistance from the EU, the Federal Länder have in recent years indeed invested considerably in forest fire prevention and in improving the infrastructure required for early recognition of and fighting of forest fires. For example, in the eastern Länder which are particularly at risk from forest fires and in the east of Lower Saxony, which is also at risk of forest fires, the old fire watch towers were replaced by digital and remote controlled optical sensors which facilitate the immediate communication of alerts to forest fire alert

FW-I-6: Forest fire risk and forest fires

Between 1991 and 2017 the areas affected by forest fires declined significantly. Weather-related forest fire risks have remained mostly the same during that period whereas in some areas they have been increasing. The situation in the dry and hot years of 2018 and 2019 is not reflected in the illustration.



Data source: Bundesanstalt für Landwirtschaft und Ernährung (forest fire statistics Germany), DWD (regionalised Canadian FWI) centres. Furthermore, traditional precautionary measures such as the installation of wound strips and water abstraction points were driven forward, and improvements were made regarding public information. While the latter is of importance in respect of negligent actions, it also furthers the willingness of forest visitors to alert the fire brigade as soon as they spot a fire (usually by using their own mobile) thus facilitating rapid interventions.

In connection with climate change there are ongoing discussions about the increased risk of forest fires in view of the fact that the critical months are becoming warmer and drier. The weather-related forest fire risk is expressed by means of an index value. The higher the value on the 5-level scale, the higher the risk of forest fires. Over recent years, the time series for the number of days on which high index values were reported at levels 4 and 5 is showing values that are rising significantly.

In the 1990s forest fire prevention and fire fighting in the eastern Federal Länder underwent reorganisation which led to advanced and well functioning structures. As a result, there was a distinct decline in records of damage from forest fires during the time period under observation. In the dry years of 2003, 2006, 2015 and 2016 it is possible to see that there was a higher risk of forest fires as well as a more extensive area affected by forest fires. Records for the moist year of 2017, with a nationwide area of 395 hectares affected by forest fires, clearly show a below-average incidence compared to the multiannual mean. In contrast, 2018 was an extremely dry year. In Brandenburg alone, 491 forest fires devastated approximately 1,664 hectares of forest; nationwide stands in an area of 2,349 hectares were lost. Firefighting efforts were hampered to some extent by any ordnance remaining in the ground from past wartimes. In the light of this knowledge, concepts are required for precautionary and proactive forest fire protection including the targeted removal of any ordnance so that firefighting can be carried out unhindered.

As weather conditions become hotter and drier, the challenges posed by forest fire prevention and firefighting are likely to increase rather than diminish. The continuous improvement of systems has therefore become a permanent task.

Climate change may increase forest fire risks. This is most likely to increase the challenges faced in forest fire prevention and firefighting. (Photograph: © Butch / stock.adobe.com)

Interfaces

BS-I-1: Person hours required for dealing with damage from weather-related incidents

Objectives

Precautionary measures against forest fires (as per the individual Länder's legislation pertaining to forests)

Climate-related crown defoliation?

For many years, the condition of crowns was considered a suitable indicator for illustrating the impacts of pollutants on the vitality of forest trees. Nowadays it is known that the causes are more numerous, interacting in complex ways. Developments on the weather front have meanwhile come into much sharper focus to the same degree as the links between the temporal progress of needle and leaf loss and summer weather patterns have become obvious.

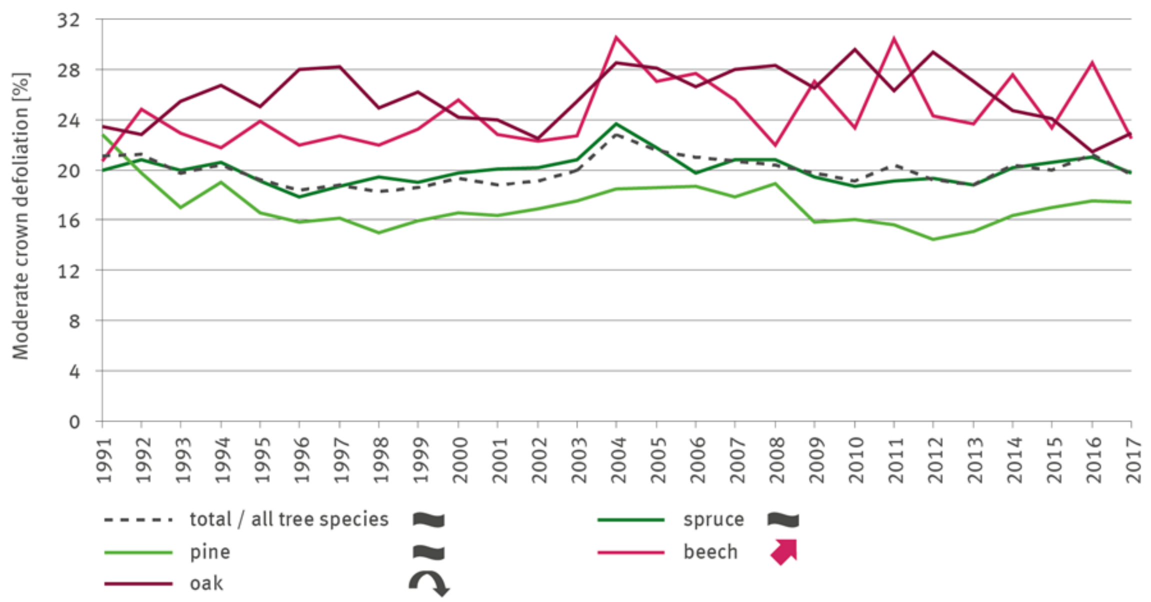
In all statistics on the development of forest condition, the hot year 2003 figures prominently owing to records of increased losses of leaves and needles affecting the main tree species. The drought-tolerant pine tree, in comparison with previous years, was the only tree species that showed no significant changes in the subsequent year of 2004. Leaf and needle losses can be the direct consequence of drought and heat but they can also be caused indirectly by increased pest infestation. In view of the relationships described above, it seems apt to discuss the influence of climate change on the condition of forest tree crowns.

However, trees losing their leaves or needles does not necessarily mean that they are damaged. In the case of deciduous trees, the spontaneous shedding of leaf mass under unfavourable conditions is frequently an appropriate adaptation response. This response helps trees to take precautions against losing too much water. The situation becomes only critical when an accumulation of drought-stress years causes crown defoliation to become a permanent feature in the affected trees. This kind of development is bound to lead to productivity losses or even to trees dying. As far as coniferous trees are concerned, the situation is slightly different, because they respond less spontaneously with needle loss owing to their greater investment into making permanent leaves. In these cases it seems more reasonable to assume that crown defoliation suggests some kind of damage affecting the trees.

The interpretation of needle and leaf defoliation becomes even more complicated when in addition potential interactions with fruiting processes are taken into account. These processes can also have considerable influence on crown condition. In so-called mast years with

FW-I-7: Forest condition

Up until 2017 there had been no indications that the condition of forests was deteriorating continuously owing to climate-related changes. However, the impacts of particularly hot and dry years such as 2003 find expression – with the exception of pine trees – in distinct needle and leaf losses observed in all main tree species. As far as deciduous trees are concerned, greater fluctuations in crown defoliation have been observed.



Data source: BMEL (forest condition survey) particularly heavy fruiting, trees reduce their investment into leaf and needle mass. That is when a tree's crown appears more transparent.

So far, there is only scant information available on fruiting regularities to inform discussions about links with climate change. For example, in former times beech and oak trees would have mast years approximately every six or seven years, whereas these days the frequency is every two or three years. However, any tangible links with climate change remain to be proven.

Up until 2017 there had been no indications that the condition of forests was deteriorating continuously owing to climate-related changes. There is evidence, however, that unfavourable weather patterns, especially hot and dry summers, can lead to needle and leaf losses. In 2018 it was noted in some locations that even pine trees suffered heavy drought-related damage. If the frequency of such extreme conditions increases in future, and restructuring the forest to create drought and heat-tolerant stands does not progress fast enough, this might indeed lead to increased forest damage.

Even drought-tolerant pine trees suffer from excessive drought such as these European black pines near Würzburg. (Photograph: Tanja Sanders / Thünen-Institut)

Interfaces

FW-I-5: Extent of timber infested by spruce bark beetle

Objectives

To increase the stability and diversity of forests (Waldstrategie 2020, p. 23)

Mixed forests – diversity spreads the risk

Forest experts are united in the expectation that from the second half of the 21st century onwards, climate change will exert particularly strong influence on forests. However, the potential climate change scenarios differ a lot from each other. This means that forestry will have to deal with substantial uncertainties in planning. Nonetheless, it is possible to incorporate various probabilities of future climate change in the planning process. The tree species mix is an important starting point to make stands more stable and increase their vitality thus safeguarding the important functions of forests for the future. However, to control the tree species mix requires very far-sighted strategies in terms of forest restructuring.

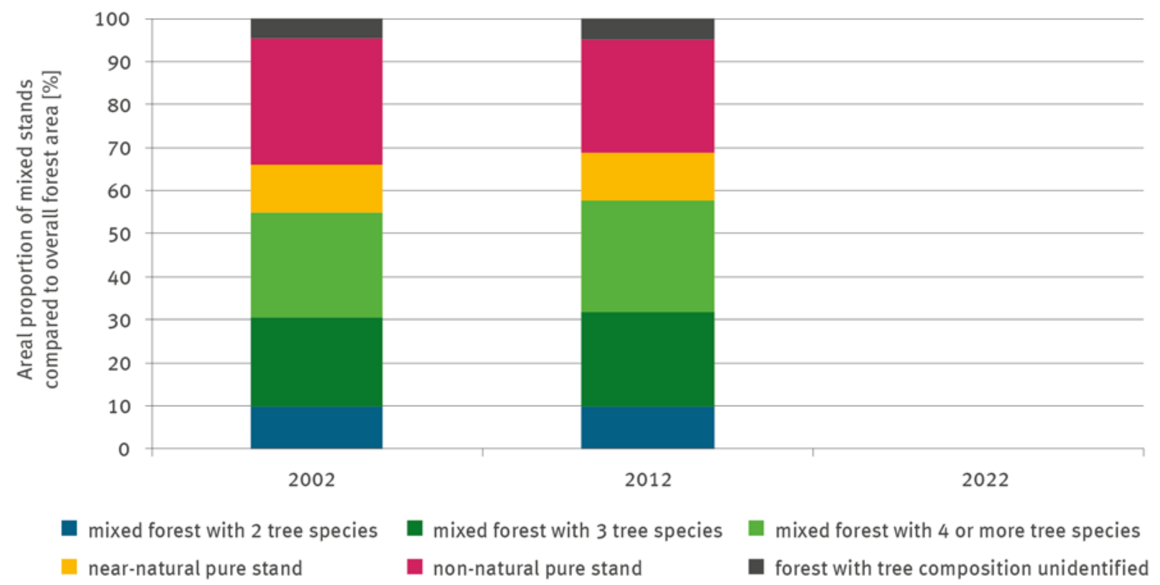
Foresters have adopted the targeted promotion of mixed forests as a risk-spreading strategy according to the following motto: The more diverse the tree species that make up a forest community and the more diverse the forest structures, the lower the risk that in case of a gradual or sudden change in site conditions, the entire forest would be affected by damage or even collapse.

There will always be some species which can handle the new conditions thus providing the foundation for a re-development of the stand concerned. Besides, tree species diversity is often linked with a high degree of structural and habitat diversity. This often includes the provision of diverse habitats for organisms which counteract pests thus subsequently reducing the distribution of pests and opportunities for infestation compared to homogeneous pure stands. This is why mixed stands are often less vulnerable to attacks by pests. This applies in particular to new harmful organisms some of which are specialised to prey on a either single or just a few tree species. From the point of view of production, diversification in the composition of tree stands can also be a suitable response to the uncertainty of future timber prices.

For reasons described above, uniform and species-poor stands are the particular focus of foresters in respect of forest restructuring efforts. This issue is considered as in greatest need of action.

FW-R-1: Mixed stands

In view of uncertain forecasts regarding future climate developments, the promotion of species and structural diversity in forests is a suitable strategy for spreading the risk. In 2002 mixed forests consisting of two or more tree species covered almost 54.9 %, compared to already 57.8 % of the forest area by 2012. Leaving the proportion of near-natural pure stands aside, the proportion of mixed stands could be increased in approximately a quarter of the entire forest area.



Data source: Thünen-Institut für Waldökosysteme (analyses based on the National Forest Inventory)

In principle, the objective is to convert these stands to diverse structures with predominantly native tree species thus spreading the risk as desired. At the same time, however, the specific site requirements, yield aspects and other forest functions have to be addressed. On some sites pure structures consisting of single-species trees such as beech will develop, while on others mixed stands of varied composition will develop. In principle it is true that there are natural limits to the proportion of mixed stands; however, German forests have a long way to go until the optimal mix is achieved.

The proportion of mixed stands is increasing in Germany's forests, and as far as adaptation requirements are concerned, developments are heading in the right direction. The 2002 National Forest Inventory showed that just about 55 % of forest area contained mixed stands compared to 45 % pure stands. There are no stand statistics available for the remaining almost 5 %. The outcomes of the subsequent inventory in 2012 show that the proportion of mixed stand areas increased to almost 58 %. The proportion of areas with near-natural pure stands remained stable at 11 % until 2012. Pure stands which were not near-natural consisting mainly of spruce and pine trees and which are the focus of forest restructuring, declined by 3 % during the period in question.

For an evaluation of outcomes it is irrelevant whether the increase in mixed stands is ultimately a result of targeted forest conversion measures or whether these changes occurred spontaneously, i.e. as part of natural succession processes. The outcomes of the next National Forest Inventory will become available in 2022.

Climate projections are uncertain; by mixing tree species, foresters and forest owners are on the safe side.
(Photograph: © RuZi / stock.adobe.com)

Interfaces

FW-R-2: Financial support for forest conversion
FW-R-4: Conservation of forest-genetic resources
FW-R-3: Conversion of endangered spruce stands

Objectives

Forest owners should drive forward the conversion of forests containing pure stands to mixed forests of site-appropriate trees which are low-risk (DAS, ch. 3.2.7)

Establishing diverse, stable and profitable mixed stands (Waldstrategie 2020, p. 23)

Maintaining the overall forest area in Germany and increasing the stability, diversity and near-natural character of forests. The cultivation of site-appropriate and predominantly native tree species makes an important contribution towards achieving this objective. (Waldstrategie 2020, p. 23)

Adaptation of forests to the challenges of climate change, e.g. by cultivating mixed forests of the greatest possible diversity (NBS, ch. B 1.2.1)

Continuous reduction of the proportion of non-native tree species (NBS, ch. B 1.2.1)

Conservation and evolution of natural and near-natural woodland communities (NBS, ch. B 1.2.1)

Proactive restructuring of forests – giving nature a helping hand

Natural regeneration is usually a favourable and the most natural form of forest regeneration. This process involves focusing forestry operations on the removal of individual mature trees from a stand. This creates gaps of sufficient size to provide enough light for seedlings to grow which emanate from neighbouring trees. The traditional near-natural method of restructuring forests used to consist exclusively in letting natural regeneration take its course.

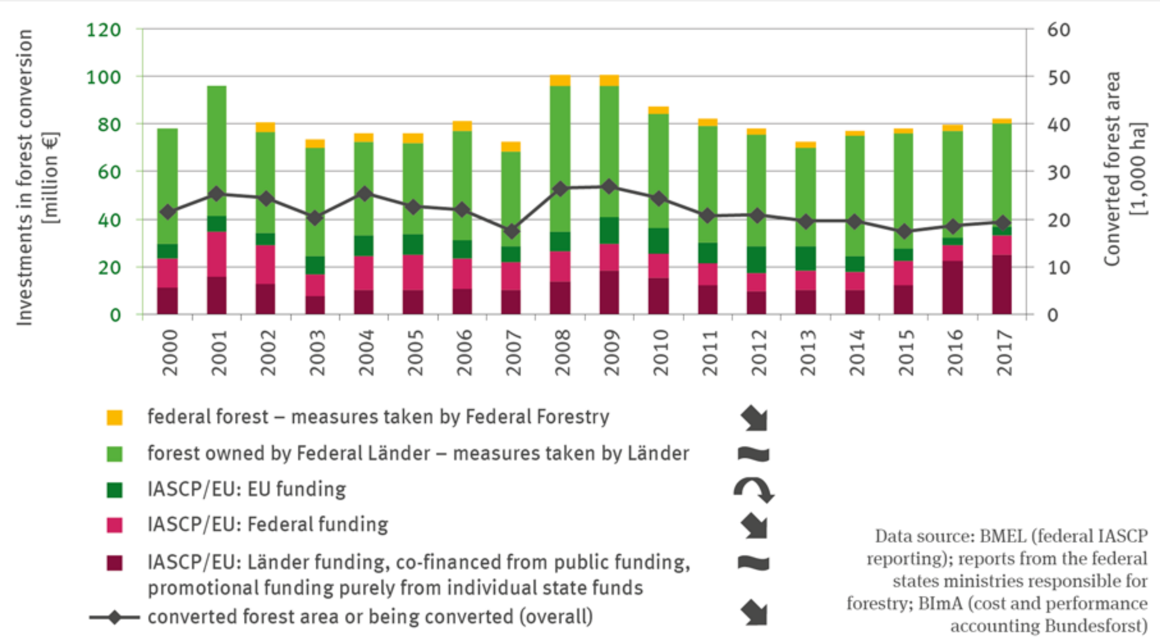
However, the adaptation of forests to changed climate conditions often requires a targeted restructuring of existing stands. Natural regeneration does not always lead to a change in tree species, especially when there are no suitable seed-bearing tree species nearby. The occasional exception are trees that emanate from natural wind dispersal of seeds, for example pine, birch or poplar trees, which can drift into a stand even from considerable distances, and also from being dropped or buried by jays and squirrels.

Where the objective is to convert non-native conifer stands to mixed forests or to incorporate specific thermophilic species or trees with thermophilic provenance into stands, it is imperative to adopt methods of artificial regeneration. This involves incorporating the desired tree species into stands either by sowing or planting, and in cases where browsing by game is a problem, by taking appropriate protective measures to get them established. In this approach, it is also possible to carry out targeted supplementation of otherwise spontaneous natural regeneration.

Forest restructuring is an objective that has meanwhile been embedded in numerous forestry strategies and programmes nationwide and at Länder level. Appropriate funding is being provided at EU level and by Federal and Länder governments for forest restructuring, both in private and corporate forests as well as state-owned forests. Funding mechanisms vary considerably among the Federal Länder.

FW-R-2: Financial support for forest conversion

The restructuring of forests owned by the Federal government as well as corporate and private forests is promoted by means of funding from EU, Federal and Länder sources, as well as from individual budget sources. The average area of forest conversion which took place in recent years up to 2017 amounts to approximately 22,000 hectares annually. These restructuring operations attracted an average amount of approximately 82 million Euros per annum.



Data source: BMEL (federal IASCP reporting); reports from the federal states ministries responsible for forestry; BImA (cost and performance accounting Bundesforst)

As far as private and corporate forests are concerned, the predominant proportion of funding activities are sourced from funding provided by the IASCP and EAFRD programmes. Individual Länder vary in how they combine their various funding allocations from the EU, Federal government and their own government. A few of the Länder provide additional support from their own budgets for forest restructuring measures as per guidelines on forest or woodland promotion or specific programmes. In this manner, between 25 and 41 million Euros were invested in restructuring private and corporate forests in the period from 2000 to 2017.

As far as forests are concerned that are owned by individual Länder, forest restructuring is pursued almost exclusively as part of 'normal' forestry management which receives funding from budgetary sources. Proactive restructuring measures that are taken into account in calculating indicators usually serve the objective to establish native tree species and to increase the mix of tree species. This includes, apart from forest regeneration measures, actions to supplement natural regeneration in young stands as well as advance planting and underplanting. The purpose of advance planting is to achieve a growth advantage for the desired target species in a stand. This involves planting and sowing new target tree species among the main stand where growth is usually still hesitant and single-layered. The objective is to incorporate these new target tree species into the new main stand after the existing stand has been harvested. In the period from 2000 to 2017, the Länder have invested between 38 and 61 million Euros annually in forest restructuring.

The proportion of forests owned at Federal level amount to just 4 % of the overall forest area in Germany. Essentially, this is forest on (former) military exercise sites and along Federal waterways and motorways which come under the remit of BmIA (Bundesanstalt für Immobilienaufgaben/Institute for Federal Real Estate), with its Department Bundesforst. The same express objective applies to forest owned by the Federal government, namely to convert non-native stand into stable mixed stands which are more natural. For the period examined, the mean value of Federal forestry investment into forest restructuring measures amounts to some 3.2 million Euros annually.

Compared to the nationwide proportion of Länder-owned forest amounting to 29 % of the overall forest area, the proportion of funding – allocated to the restructuring of Länder-owned forests as part of nationwide investment – is disproportionately high. Averaged out over recent years this amounts to almost 56 %. By comparison, the proportion of funding invested in the restructuring of private and corporate forests which cover approximately 67 % of the overall forest area, amounting to on average 39 %, is clearly lower[31]. One of the reasons for this is that, especially with regard to private forests, many forest owners carry out forest conversion measures for which they do not request funding and therefore, there is no information available in respect of their extent.

In non-native forests it is sometimes necessary to incorporate targeted tree species in order to make stands adaptable. (Photograph: © highwaystarz / stock.adobe.com)

Interfaces

FW-R-1: Mixed stands
FW-R-3: Conversion of endangered spruce stands

Objectives

Forest owners should drive forward the conversion of forests with pure stands to mixed forests of site-appropriate trees which are low-risk. (DAS, ch. 3.2.7)

Cultivation of native and mostly autochthonous tree species with high resilience and growth performance (Waldstrategie 2020, p. 23)

Adaptation of forests to the challenges of climate change, e.g. by cultivating mixed forests of the greatest possible diversity (NBS, ch. B 1.2.1)

Continuous reduction of the proportion of non-native tree species (NBS, ch. B 1.2.1)

Conservation and evolution of natural and near-natural woodland communities (NBS, ch. B 1.2.1)

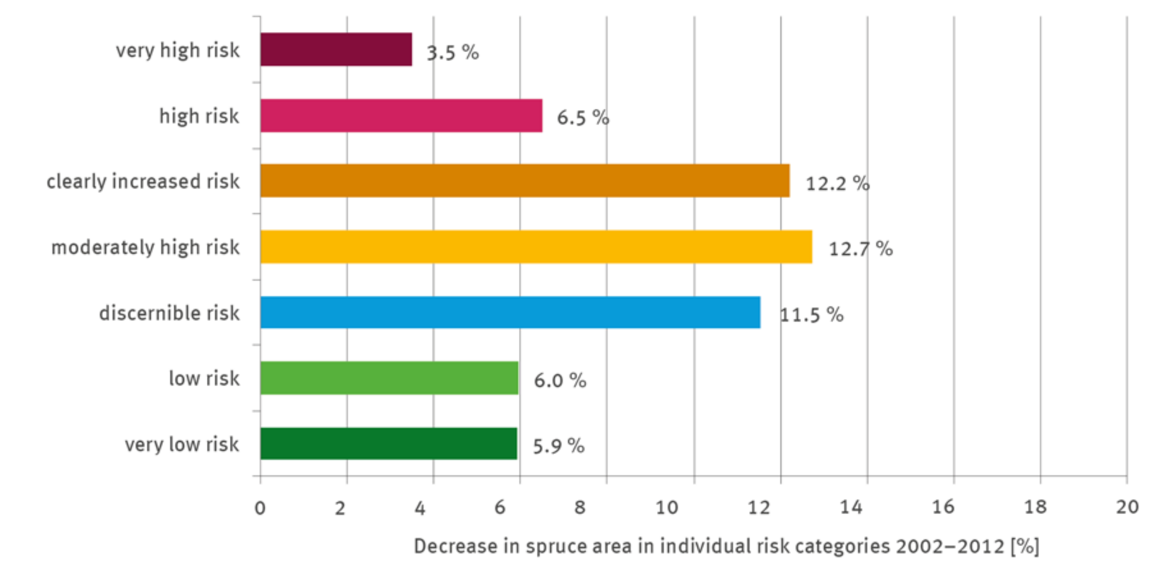
Targeted conversion of endangered spruce stands

The focus of forest conversion is on pure coniferous stands, in particular, when they are located in areas where they are out of place even now, or where they will in future, be out of place owing to climate change. In central and southern Germany and at higher altitudes, pure spruce stands were planted frequently. There are problems with unsuitable spruce stands from both forestry and ecological angles, especially on warm/dry sites. Forest conversion should therefore concentrate, as its first priority, on those locations which are categorised as critical and where, in view of the projected climate change outcomes, the situation is likely to become even more critical.

A differentiated analysis of the evolution of spruce forest areas between 2002 and 2012 shows that during that period, no systematic actions were taken on a nationwide basis which targeted forest conversion in high-risk areas of spruce cultivation. Compared to the moderate climatic situation prevailing in the period from 1961 to 1990, at the end of which targeted forest conversion was started, it is possible to see that in 2002 approximately 6.6% of the spruce forest area would come under the category of high or very high spruce cultivation risk. This risk category now includes areas with an annual average temperature of more than 8°C and an average total annual precipitation level of less than 800mm. In view of the objective of sustainable forest management, spruce trees should be tolerated in those stands only as a mixed forest species in moderate to low proportions. In fact, in German forests spruce trees were still the main tree species in 2002 on approximately 196,700 hectares of those comparatively warm/dry areas, i.e. the species covered more than 90% of the total cultivation area. By 2012 this area was reduced only slightly to approximately 186,100 hectares while amounting to 6.7% of the total spruce cultivation area. The causes for this decline might have been either targeted forest conversion measures or destruction of stands by calamities such as infestation with bark beetles. The modest decline in those ten years might be due on one hand to the possibility that many stands in these risk categories had not reached maturity and that for commercial reasons a targeted forest conversion had been postponed. On the other hand, it is conceivable that

FW-R-3: Conversion of endangered spruce stands

The forest conversion of pure spruce stands is progressing. However, between 2002 and 2012, conversion measures were not focused systematically on areas with particularly warm/dry climate conditions where the cultivation risk is now distinctly high or very high.



Data source: Thünen-Institut für Waldökosysteme, Bayerische Landesanstalt für Wald und Forstwirtschaft (modeling based on the National Forest Inventory) the trunk diameter of the trees used for underplanting – in line with forest conversion measures – was still too small to register in terms of the inventory.

Looking at this issue from a nationwide angle, it is not evident from the period of 2002 to 2012, that for areas with distinctly high to very high spruce cultivation risk, any particularly strenuous efforts were made to replace spruce trees by site-adapted and less vulnerable species. By comparison it is interesting to note that the highest absolute reduction of spruce forest area took place in almost 108,100 hectares of areas in very low risk categories, where site conditions would have been conducive to the continued cultivation of spruce trees as the main tree species. It must be said, however, that this risk category is by far the largest in terms of surface area. It is reasonable to assume that storm risks not covered by this risk indicator may have played an important role in conversion decisions.

In discussions on climate-optimised forest conversion, the focus for forestry management is on site-appropriate spruce stands. It is conceivable that by the time the next inventory takes place, the regeneration of other tree species used for underplanting spruce stands will have grown to a sufficient height for figuring in the main stand thus reflecting a different situation in 2022.

In forest conversion priority must be given to pure spruce stands which come under the high-risk category.
(Photograph: © AVTG / stock.adobe.com)

The risk categories illustrated are as follows:

- very low risk = spruce tree viable as main tree species
- low risk = viable as main tree species subject to adequate mix with other tree species
- discernible risk = viable as mixed forest component in high proportions
- moderately high risk = viable as mixed forest component in medium proportions
- clearly increased risk = viable as mixed forest component in modest proportions
- high risk = viable as mixed forest component in low proportions
- very high risk = viable as mixed forest component in very low proportions

Interfaces

FW-I-2: Endangered spruce stands
FW-R-1: Mixed stands

Objectives

Forest owners should advance the conversion of forests with pure stands to mixed forests of site-appropriate trees which are categorised as low-risk. [...] When selecting tree species [...] care must be taken that they are site-appropriate and able to adapt to future developments. (DAS, ch. 3.2.7)

Cultivation of native and mostly autochthonous tree species with high resilience and growth performance (Waldstrategie 2020, p. 23)

Genetic diversity – key to adaptation

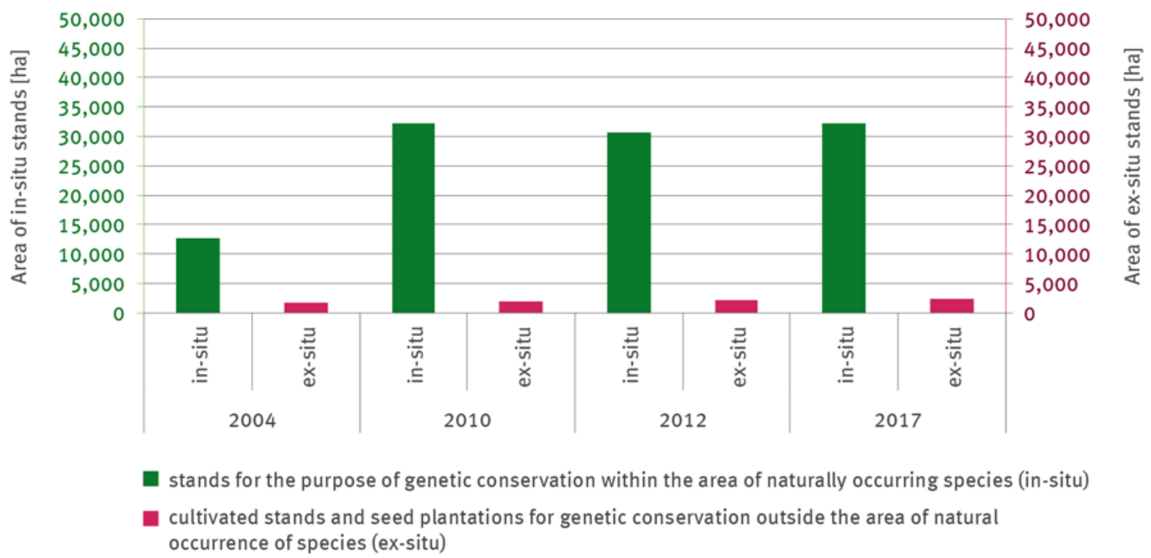
As part of the wider progress of climate change extreme weather events and their consequences increase the pressure on the selection of appropriate tree species for forest stands. It is only the genetically adapted individuals, i.e. individual trees, which can survive, grow and reproduce within greater populations. In view of the multitude of interactions and the dynamics of individual factors it is not possible to predict to which individuals or populations this will apply. This dilemma can only be resolved by maintaining a sufficiently large number and diversity of potentially adaptable individuals. The reason for this is the fact that genetic diversity is the basis for adaptability and species richness, both at the level of individuals and populations. This is why the monitoring and maintenance of genetic diversity and the genetic system has been the focus of measures to conserve genetic resources for almost 100 years[32]. Of particular importance is the ongoing determination and recording of genetic suitability of various indigenous tree species occurring in various parts of Germany.

The measures to conserve genetic resources for forestry purpose can be differentiated as in-situ and ex-situ. The in-situ measures are part of dynamic conservation. Their purpose is to conserve the relevant genetic resources as so-called 'gene conservation object' at the site where they occur. Natural regeneration safeguards and transmits its genetic information to the next tree generation. Particularly endangered species or varieties are kept in specially established archives and where necessary in ex-situ seed plantations. The ex-situ measures are static measures with the objective to safeguard the current character of genetic diversity. This includes taking measures for the long-term storage under controlled conditions of seed material, pollen, plants or plant components as carriers of genetic information. Such conservation strategies are characterised by requiring differing amounts of surface area, investment costs, utilisation and monitoring. This is why expensive ex-situ conservation is less frequently used than in-situ conservation.

In Germany the individual Länder have the remit for gene conservation measures. It is the Länders' individual concepts which create the framework for the conservation of genetic resources for forestry measures. Nationwide

FW-R-4: Conservation of forest-genetic resources

It was possible to expand the in-situ and ex-situ conservation resources in recent years. They ensure that the genetic diversity is retained for frequent and rare tree species. This has created the basic requirements for conserving the adaptability of forests.



Data source: Bundesanstalt für Landwirtschaft und Ernährung (gene conservation objects: GENRES (information system on genetic resources) – FGRDEU (national inventory of forest genetic resources)) the genetic information on the indication of all genetic conservation objects is collated in a National Inventory of Forest Genetic Resources (FGRDEU). The data are updated and supplemented every few years.

A straight-forward interpretation of changes in number und surface area of genetic conservation objects in Germany is not possible. This is because genetic adaptability to changing climatic conditions is influenced by numerous factors and cannot be estimated other than with utmost difficulty. The number of genetic conservation objects per tree species and the size of conservation areas can only convey a rough idea. In principle, the interpretation of these data require detailed silvicultural knowledge and the application of specific indicators (e.g. conservability, ecological conservation index). For example stating the 'in-situ conservation area' for rare and secondary tree species would exaggerate the conservation status of small population numbers or low numbers of individuals. On the other hand, the number of overall genetic conservation objects does not give any clues regarding the size of the population. Besides, genetic inventories which would meet the principles of silvicultural monitoring are still in their infancy. It is therefore unreasonable to apply a one-dimensional principle such as 'the more genetic conservation objects, the better' because for every tree species there is a meaningful extent of genetic conservation stock beyond which any increase in surface area or amount of stored genetic conservation objects would not result in improving the safeguarding conditions.

Overall, the conservation of forest-genetic resources has made distinct progress. This is reflected e.g. in the nationwide uniform approval of designation criteria for genetic conservation objects, the increasing application of genetic markers for the characterisation of forest-genetic resources and the establishment of nationwide monitoring programmes (currently for copper beech and spruce trees) in terms of population genetics and evolutionary issues. These developments provide an additional basis for assessing the genetic adaptability of trees under climate change conditions.

In Germany the areas used for in-situ and ex-situ genetic conservation objects have increased in recent years. Just between 2010 and 2012 there was a minor reduction in the extent of in-situ stands. As far as the more frequently occurring forest tree species are concerned – for which the Forest Reproductive Material Act (Forstvermehrungsgutgesetz/FoVG) governs the production , the trading, and the import and export of forest reproductive material – the surface area of in-situ stands increased from 12,681 to 32,681 hectares between 2004 and 2017. Rare and endangered tree species are not governed by the FoVG. For pubescent oak, wild service tree, true service tree, crab apple, wild pear, yew, field maple, green alder, grey alder and bird cherry, data were collected in a systematic and homogeneous manner. The factors examined were topography, population size, vitality status and age structure of the occurrences. By 2017 the in-situ stands reported were found to have expanded to approximately 4,560 hectares. The surface area of cultivated stands and seed plantations established for the purpose of (ex-situ) genetic conservation was found to have expanded too, i.e. from 1,777 hectares in 2004 to 2,470 hectares in 2017.

Genetic conservation is also extended to tree species which nowadays are less frequently found in forests.
(Photograph: Amt für Waldgenetik, Teisendorf)

Interfaces

FW-R-1: Mixed stands

Objectives

Conserving the diversity and an adapted gene pool of tree and shrub species (Forstliche Genressourcen in Deutschland, p. 29)

Conserving the genetic diversity of forest plants (Waldstrategie 2020, p. 23)

Humus – friend in need

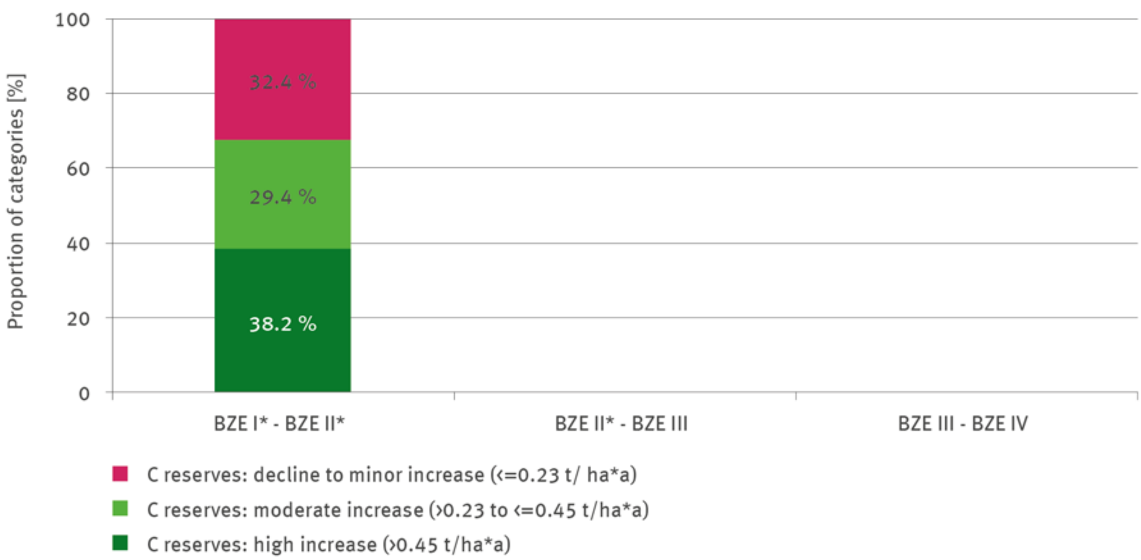
Apart from controlling the composition of tree species, forestry professionals have additional ways of furthering the adaptability of forests to changing climatic conditions. Humus conservation therefore is an important key to the creation of favourable growing conditions and greater stability. This is because humus or rather organic carbon, its vital component, creates a favourable soil structure thus making it hugely important for the supply of nutrients and water to forest trees. Especially on nutrient-poor and rather dry sites, the conditions for forest trees can be enhanced by ample supply of humus.

However, the interactions between climate-related changes and the content or reserve of humus go far beyond the scenario outlined above. Apart from its favourable influence on the adaptability of forests, sufficient humus reserves are also worth striving for in view of protection from the impacts of climate change in view of the fact that soil is one of the most important carbon sinks. Any amount of carbon sequestred in the soil is not contributing to climate change as carbon dioxide in the atmosphere. Humus conservation therefore is both an adaptation measure and a method to counteract climate change. Another interaction that enters discussions is the influence of weather patterns on the activity of micro-organisms in the soil, and in that context the formation and decomposition of humus.

In virgin forests, the organic matter which is available for the formation of humus is particularly plentiful, as all trees are decomposed when they die, thus ultimately adding to the formation of humus. In commercial forests, the situation is different and this is because the greater part of carbon is removed from the forest by harvesting. The actual extent depends largely on the proportion of trees remaining in a stand after harvesting. The more leaves, needles or branches remain on the felling site in the forest, the more organic matter is available for replenishing the humus reserves. In that context, it also matters how well the harvesting remnants are distributed in the areas where felling has taken place. As the demand for energy from timber rises, increasing incentives emerge to make use also of inferior material including crown material. In contrast with agriculture, the opportunities

FW-R-5: Humus reserves in forest soils

High contents of organic carbon in forest soils further the water storage capacity and improve the supply of nutrients. They also improve the trees' chances of surviving hot periods with poor precipitation levels. Between 1987 and 2008 there were more areas on which humus reserves in mineral soils had increased than areas where they had decreased.



* BZE I: 1987-1993; BZE II: 2006-2008

Data source: Thünen-Institut für Waldökosysteme (analyses on the basis of the soil inventory (BZE) in forests) of compensation for the removal of carbon and nutrients from the forest are quite limited. It is therefore ultimately crucial to achieve the best possible adaptation of use intensity to site requirements. This is the only way to ensure that sufficient humus is formed.

As part of forest soil condition surveys (BZE) research is carried out nationwide to assess carbon reserves in the upper 30 cm of mineral soil and the humus cover in the forest. Data collected so far permit a comparison of the situation in the period between 1987 and 1993 with the period between 2006 and 2008. Overall there were more areas where the carbon reserves in mineral soil had increased since the first survey; the increase was particularly distinct in northern parts of Germany. In southern Germany there was no indication of major changes. However, it is questionable whether the changes observed can be attributed to the targeted promotion of humus formation because any trend may be masked by forest restructuring measures, changes in the deposition of pollutants as well as by liming procedures.

There were no appreciable changes in carbon reserves found in the humus cover on most sites between the two survey periods. It must be said, however, that it is not possible at the moment to interpret the survey results without a degree of ambiguity. The organic carbon in the humus cover is subject to comparatively rapid formation and decomposition processes thus exposing it to particularly strong external impacts. Furthermore the humus levels fluctuated quite strongly from site to site which makes the interpretation of rates of change difficult. This is why the indicator does not illustrate changes to carbon reserves in the humus cover.

For the purpose of assessing the changes to carbon reserves in the upper 30 cm of mineral soil, the first two surveys differentiated between the class boundaries for a decrease or slight increase; a moderate increase; and a high increase in such a way that the forest area assessed was divided up evenly among these three classes. When the soil condition survey (BZE) is next updated; the documentation will illustrate changes by reflecting shifts in the area proportions allocated to the three classes.

High humus reserves in forest soils reduce the vulnerability of forests to drought.
(Photograph: Petra Dühnelt / Thünen-Institut)

Interfaces

BO-R-1: Humus content of arable land

Objectives

Forests are to retain their function as CO2 sinks. (Waldstrategie 2020, p. 11)

Existing carbon reserves should be conserved and augmented and the formation of new carbon reserves should be encouraged. (European Forest Strategy, item 13)

Protecting the ecological efficacy of soils by means of […] conserving organic matter, and implementing site-adapted land use strategies in order to reduce detrimental effects caused by changes in the formation of soil and humus (DAS, ch. 3.2.4)

Forestry information on adaptation

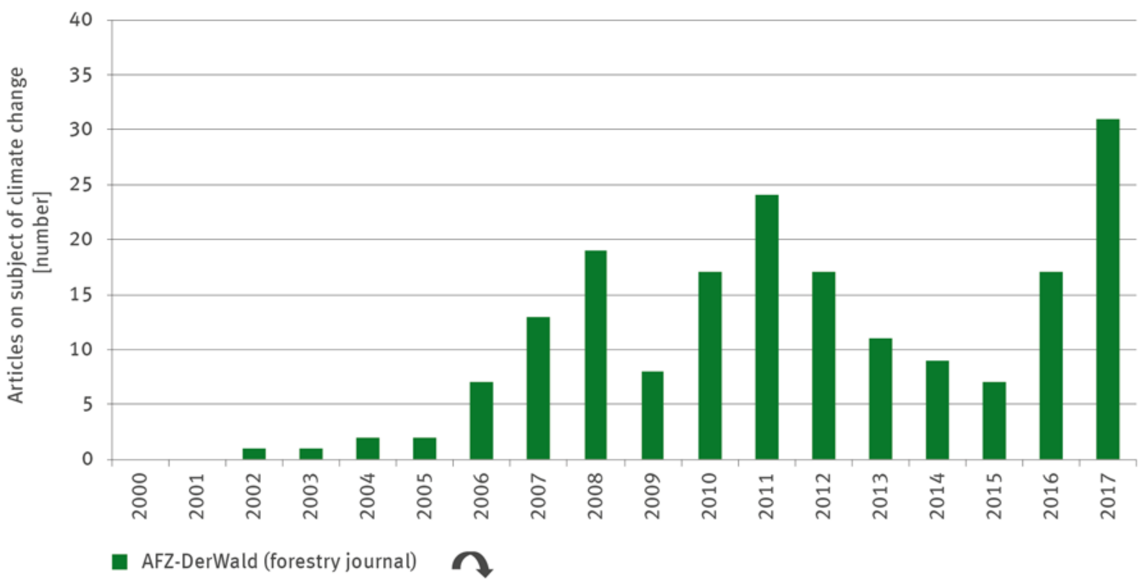
In view of climate change forestry will be confronted with immense challenges in the next few decades. Numerous practical development and management issues will arise in connection with the adaptation of forests including the choice of tree species, the technical implementation of forest conversion and the adoption of suitable measures for a targeted approach to tending forests. Action is required not only in state and corporation forests but also in private forests as the latter comprises approximately 48 % of Germany's entire forest area[33].

Private forest owners often have small forests averaging a surface area of less than 10 hectares. These owners have their focus mostly on matters not pertaining to forestry thus managing their forests very much on the basis of their own individual and rather disparate objectives. In most cases, the commercial incentive to engage with silvicultural concepts and to acquire the appropriate knowledge is rather scant. Such unfavourable conditions for tending and developing forests, in view of demographic changes and structural changes in rural areas, are likely to get worse[34].

Any forestry advice given to private forest owners therefore plays an important role in these circumstances. Such advice must be able to create the prerequisites for the management of private forests to make its own useful contribution to the adaptation of forests. In this light it is essential to be aware that it is not possible to transfer the cultivation procedures created for and applied in extensive, self-contained and intensively managed state-owned forest complexes in exactly the same way to private forest management, because the baseline conditions are often very different. For example, spruce-dominated stands are often particularly unstable owing to a lack of appropriate thinning. In view of the small size of forest area and the unfavourable development of stands, protective measures against browsing by game, such as fencing are usually too labour-intensive and too expensive. Besides, many forest owners find it hard to part with their traditional spruce cultivation or they simply lack the knowledge or time to consider any options of site-adapted forest cultivation.

FW-R-6: Forestry information on adaptation

It is therefore impossible for private forest owners to access any collective information ,'bundled' on a nationwide basis regarding the form, extent or depth of summarised forestry advice. The increasing number of articles published in the practice-oriented journal 'AFZ DerWald' on climate change conveys a rough idea of the intensity of relevant discussions among forestry professionals.



Data source: Thünen-Institut für Waldökosysteme (analyses of the journal AFZ-DerWald)

Silvicultural advice is provided by numerous different organisations. The individual Länder have e.g. state forest administration authorities, state forest management offices and forestry associations as well as forest owner associations with the remit to impart such advice. Generally speaking the entire field of forestry consultation is as diverse as it is confusing. It is therefore impossible for private forest owners to access any collective information, 'bundled' on a nationwide basis regarding the form, extent or intensity of forestry advice.

An important organ for the dissemination of relevant information is magazines or journals which are read in particular by forestry practitioners. One of these forestry journals is the 'AFZ Der-Wald' which has concise articles in German and is therefore most effective in terms of reaching the public. Articles published in this journal on the subject of climate change and relevant adaptation are read by a very wide readership who engage with forestry management issues.

In the years between 2000 and 2011 the number of articles dedicated to grappling in a critical manner with the subject of climate change has definitely increased. After a temporary decline in the years up to 2015, this number has increased again in the years up until 2017. As a rule, it is not possible to differentiate strictly between subjects dealing with protection from climate change and subjects dealing with adaptation. The data make it possible to infer that issues concerned with climate change have entered increasingly into practice-oriented discussion by circles of forestry professionals. At the same time, it is not reasonable to infer to what extent such discussions and recommendations are followed up by an actual tangible implementation into practice.

Private forest owners require appropriate professional advice in order to be able to make a useful contribution to forest conversion to prepare for climate change.
(Photograph: © Robert Crum / stock.adobe.com)

Objectives

Information deficits should be eradicated at both Federal and Länder level in order to persuade 1.8 million forest owners of the necessity to carry out adaptation measures. (DAS, ch. 3.2.7)

In view of the increase in social, climate-political, ecological and commercial demands made on forest management, the relevant consultation services for small private forests should be enhanced and adopted as a public duty in the sense of safeguarding future livelihoods and in the interest of the public good. (Waldstrategie 2020, p. 14)

Biodiversity

The distribution of animal and plant species, of their communities or of ecosystems is largely dependent on the earth's climatic conditions. Any changes e.g. in temperature, precipitation or the frequency of extreme events have long-term impacts on seasonal development, behaviour and reproduction, competitiveness and feeding relationships. According to projections, many of the climatically favourable habitats of species occurring in Germany will shift either north or to higher altitudes in mountain ranges or along humidity gradients. Climate change can put species at risk, when their distribution ranges shrink or when the species affected are unable to colonise new habitats owing to restrictions on their distribution. This risk can also occur when the development rhythms of specific species are no longer synchronised. According to present consensus, climate change – next to change of land use – is considered one of the most important factors influencing biodiversity.

Apart from direct impacts, climate change also has indirect impacts on biodiversity. Triggers are adaptations to land use including agriculture and forestry or measures to protect the human population and infrastructure such as changes in water management. Another trigger can be the implementation of climate protection measures such as the expansion of renewable energies or the insulation of buildings; this can influence the occurrence of species and the quality of their habitats. However, in most cases, it is difficult to prove to what extent these developments affect biodiversity, as there are usually numerous other factors which play a role.

In order to improve the protection of biodiversity under changing climatic conditions, it is essential, above all, to create prerequisites for the conservation of sufficiently large populations and their genetic diversity thus ensuring that the habitats of species are interconnected well and that other adverse effects on species or habitats are diminished as far as possible.

Effects of climate change

Adaptations

Temporal development of wild plant species undergoes seasonal shifts

In our climes, the seasonal development of plants is primarily influenced by climate- and weather-related temperature patterns. A warm winter, for example, leads to very early flowering of trees such as hazel or common alder. For this development, it is longer-term weather patterns preceding flowering rather than individual warm or cold days which are crucial. If temperatures remain high e.g. during several consecutive weeks in winter, a sum total of warmth accumulates thus accelerating a plant's development.

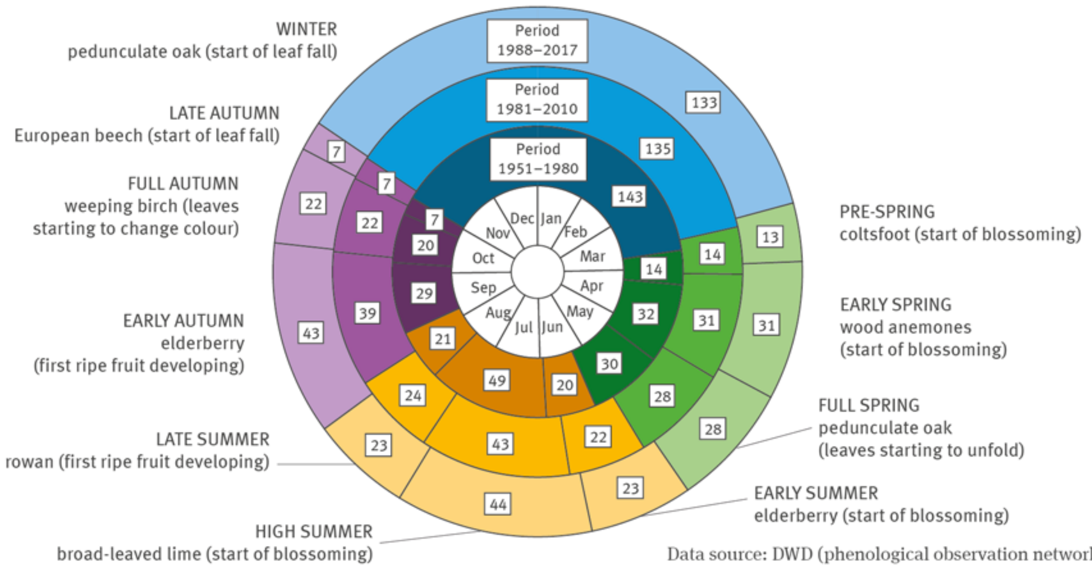
Changes in natural seasonal rhythms and associated temporal shifts in the development of plants have been studied and documented for years by means of so-called phenological observations. These nationwide studies involve the beginning of certain periodically recurring biological phenomena such as leaf and bud formation, flowering, maturity of fruit or leaf fall. The phenological observation network operated by D includes the observation of a broad spectrum of wild plants whose specific development phases mark the beginning of phenological seasons. Wild plants are particularly suitable for the observation of phenological shifts, as their responses are free from the influence of human manipulation in breeding processes or from agricultural actions.

The interpretation of shifts in seasonal cycles can only produce reliable results if this is done on the basis of extended sequences. This is why phenological data as well as climate-related data are averaged over periods of 30 years. Using the so-called phenological clock to compare the mean starting points of phenological seasons for the reference period 1951 to 1980 and the comparative period 1981 to 2010 with the starting points of the period from 1988 to 2017, the following pattern emerges: Regarding the phenological seasons from pre-spring via early summer until early autumn, the two periods after 1981 started earlier than in the reference period 1951 to 1980 whereas the seasons of autumn, late autumn and winter started later. This means that especially the early autumn

BD-I-1: Phenological changes in wild plant species

On average, the beginning of phenological spring, summer and autumn has advanced in the course of the past 67 years. While winter has become distinctly shorter, early spring has become distinctly longer. These changes reflect the adaptability of plants to the changed climate. On the other hand, they can also have consequential effects on biodiversity potentially leading to a situation which ultimately puts animal and plant species at risk.

Comparison of average start and average duration (number of days) of ten phenological seasons during the reference periods 1951-1980 and 1988-2017



Data source: DWD (phenological observation network)

in the mean of the years 1988 to 2017 was approximately 14 days longer than in the reference period 1951 to 1980 whereas the winter season was approximately ten days shorter compared to the winter seasons between 1951 and 1980. This comparison also demonstrates that the summer mean of the three periods in question remained unchanged amounting to approximately 90 days whereas the beginning and end of summer in the period 1988 to 2017 was on average approximately twelve days earlier than in the reference period 1951 to 1980. An analysis of the starting dates of phenological seasons in the period 1988 to 2017 compared to the reference period 1951 to 1980 reveals statistically significant, and in most cases highly significant differences between the two periods for all seasons.

On one hand, shifts of phenological seasons reflect the adaptability of plants and animals to changed climatic conditions. On the other, changes in development cycles caused by climate change also indicate consequential impacts on biodiversity. Phenological shifts can, in some cases, decouple the synchronicity of development between organisms. This affects established interactions for example between plants and their pollinators or interactions in predator-prey relationships. This effect impacts on the structure and functions of ecosystems and can put animal species and plant species at risk. For example, in the Netherlands it was proven that in pied flycatcher populations the number of individuals declined owing to the temporal decoupling of the time when nestlings are reared from the time when there was an optimal supply of their food source.[35] Pied flycatchers are long-distance migrants which spend winters in Africa; hence they are unable to respond adequately to the changed cycles in the development of their food organisms.

In Germany, there have been no wide-ranging studies or systematic observations of the consequences of such changes in relationships between plants and animals caused by phenological shifts. This is why at this point in time it is only possible to say that further shifts in phenological phases are to be expected.

The same applies to temporal extensions observed in respect of phenological vegetation periods. Those periods are equivalent to the sum of the days of phenological spring, summer and autumn. While the mean vegetation period in the years 1951 to 1980 amounted to just 222 days, it was extended on average by 8 days to 230 days in the period 1981 to 2010, and in the period 1988 to 2017 by an average of 10 days to 232 days. It is important to note that the duration varies considerably from year to year. For example, an extension of the vegetation period can result in higher productivity of ecosystems which, in turn, can affect the relationships between various species. So far, there have been no systematic studies in Germany of the effects of an extended vegetation period on biodiversity.

Nowadays, coltsfoot flowers earlier in the year than even in the middle of the previous century.
(Photograph: © kraichgaufoto / stock.adobe.com)

Interfaces

LW-I-1: Agrophenological phase shift
LW-R-1: Adaptation of management rhythms
WW-I-6: Start of the spring algal bloom in standing waters

Objectives

Buffering and minimising the impacts of climate change on biodiversity in Germany (e.g. shifts in vegetation zones, changes in bird migration behaviour, threats to psychrophilic species) (NBS, ch. B 3.2)

The influence of climate change on bird species is increasing

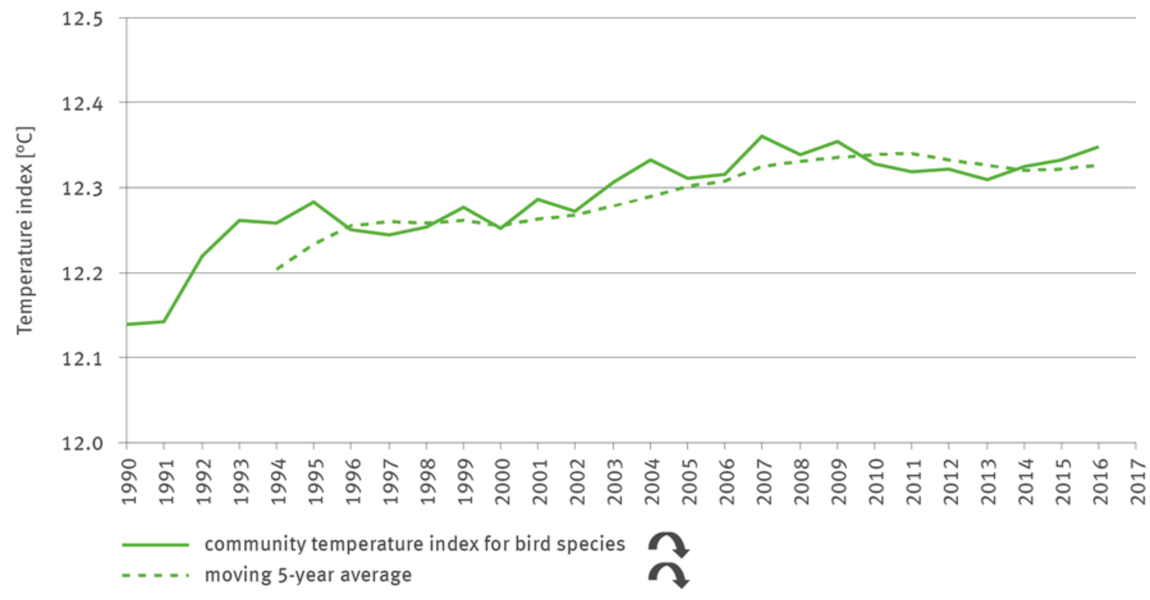
Birds are comparatively sensitive to changes in their environment. This means that the composition of bird communities can change strongly as a function of environmental impacts. As a rule, such changes are the result of various impact factors combined. As a rule, there is no single cause for a change in species communities and the decline or loss of individual species. There is however evidence from scientific research which indicates that, in addition to changes in land use, climate-related changes can play a crucial role.

Breeding birds require species-specific temperatures at breeding time. These are lower, for instance, in respect of whinchat, thrush nightingale and icterine warbler than for stonechat, nightingale and melodious warbler. If, as a result of climate change, temperatures during the breeding season increase in terms of the long-term mean, onditions will become more favourable for thermophilic species which will then become more frequent compared to other bird species. Vice versa psychrophilic species will decline compared to other bird species.

In the period between 1990 and 2016, such a development has been observed in 88 bird species breeding in Germany. As indicated by the temperature index for frequently occurring breeding bird species, the relative frequencies of the breeding birds observed have shifted in this period in favour of thermophilic species or, putting it another way, shifted to the detriment of psychrophilic species. From 1994 onwards the sliding 5-year average of the temperature index first shows an increase taking place until approximately 2010, but afterwards the development remained more or less the same. However, the development from 2010 onwards can be attributed to effects of weather patterns which had an impact regardless of the long-term climatic trend. In the years 2009/10 to 2012/13 there were several consecutive hard winters with adverse impacts on the numbers of many breeding birds. As part of ecological

BD-I-2: Community temperature index for bird species

Climate change entails changes in species communities. In respect of 88 breeding bird species occurring in Germany the relative frequencies have shifted between 1990 and 2016 in favour of thermophilic species or, putting it another way, shifted to the detriment of psychrophilic species. At present it is not sufficiently clear what further impacts this will have on biodiversity. The trend reversal indicated suggests the cause to have been a number of severe winters between 2009 and 2013 which had an effect independent of the long-term climatic trend.



Data source: Dachverband Deutscher Avifaunisten e.V.

change processes, the occurrence of extraordinarily cold winters is of major importance even at a time of progressive climatic warming.

For the purpose of calculating the temperature index, a species-specific temperature requirement value is allocated to each of the 88 bird species occurring in their European distribution area, based on the average temperature for the reference period 1961 to 1990. These species-specific temperature requirement values – weighted according to the relative frequency of the species in any particular year – are included in calculating the index. The greater the rise in the temperature index of frequently occurring breeding bird species, the stronger the shift in the relative frequencies among thermophilic species and consequently, the stronger the influence of temperature rise on the group of birds under observation. The index values shown refer to Germany nationwide. This proves that it is not possible to make any statements on a changed composition of regional breeding bird communities.

Other groups of species such as butterflies or vascular plants can also be used as indicators for long-term temperature changes related to climate change. In this context species shifts become most obvious in ecologically marginal regions such as mountain ranges. For instance, Europe-wide studies of vegetation in the peak areas of mountain ranges above the treeline show that the composition of species communities of vascular plants in those areas is changing. This is where thermophilic species from areas at lower altitude form colonies. Likewise, in rivers, lakes and seas, changes are taking place regarding the composition of species communities.

Apart from shifts in the frequency of species within existing species communities, climate change also leads to the immigration and distribution of species which have not occurred in our climes before. These developments take place in respect of both, plants and animals. Examples for this are the melodious warbler which emanates from south-western Europe and became a German breeding bird in 1980 extending its range ever since, or the praying mantis which came from the Mediterranean to Germany in the 1990s and is gradually spreading ever more northwards.

The icterine warbler is one of the species affected by climate change. In Germany its numbers have suffered a serious decline since 1990.
(Photograph: © Ron Knight / Wikimedia Commons, CC BY 2.0)

Interfaces

FW-I-1: Tree species composition in designated forest nature reserves
FI-I-1: Distribution of thermophilic marine species
FI-I-2: Occurrence of thermophilic species in inland waters

Objectives

Buffering and minimising the impacts of climate change on biodiversity in Germany (e.g. shifts in vegetation zones, changes in bird migration behaviour, threats to psychrophilic species) (NBS, ch. B 3.2)

Increase in naturally flooded areas benefits biodiversity in alluvial meadows

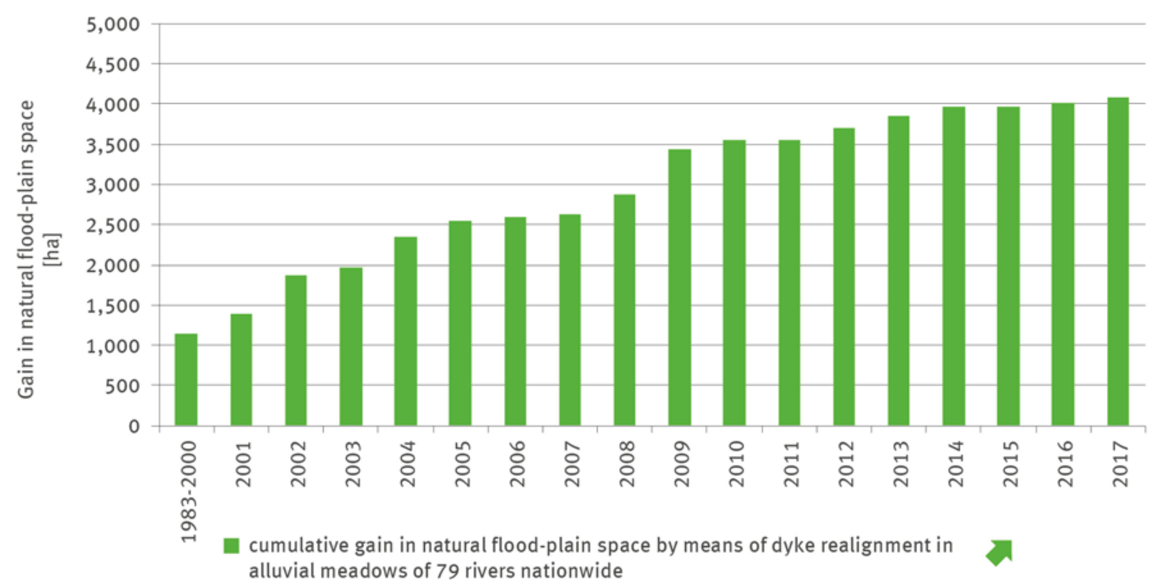
Apart from direct impacts on biodiversity as described above, climate change and the associated climate protection and adaptation measures also cause indirect impacts, above all in terms of changed land use. As estimated by experts these indirect impacts from climate change influence the development of biodiversity even more strongly than direct impacts from changing climatic conditions. Owing to the complex interaction of various factors of influence it would be hardly possible, for the time being, to attempt an exact quantification of indirect impacts of climate protection and adaptation measures in respect of species and habitats.

The changes in land use which can be attributed to climate change also include adaptation measures in respect of the development of water bodies, water courses and alluvial meadows. Apart from heightening dykes, the installation of holding ponds or other technically-based measures, the durable restoration of natural flood plains is considered an effective component of comprehensive floodwater risk management.

Where rivers can spread into such flood-plains in case of floodwater events, run-off is slowed down and the floodwater wave attenuated. Such newly gained flood-plains were in many cases under intensive agricultural use. Where areas are exposed to natural floodwater dynamics, they can be re-colonised by many species of plants and animals typical of alluvial meadow habitats. This includes numerous rare and endangered species which are adapted to the special conditions of heavily alternating water levels, such as beaver, otter, kingfisher, sand-martin, marsh harrier, various species of duck – especially those sensitive to disturbance – as well as numerous species of dragonfly and amphibians. Besides, habitats that can flood naturally such as alluvial meadows, serve as important links in biotope networks and within the system of protected areas designated under Natura 2000.

BD-I-3: Restoration of natural flood-plains

The relocation, renaturation or slotting of dykes carried out since 1983 has produced an increase in natural flood-plains. By their connection to water courses or water bodies and by restoring the dynamics of natural flooding, new and – in terms of nature conservation – valuable habitats have been created for numerous rare and endangered animal and plant species. Likewise, alluvial forests have been created which are just as important in terms of nature conservation.



Data source: Möhring et al. 2012, BfN (own research)

The renaturation of dykes for the purpose of restoring natural retention areas in alluvial river meadows shows that measures for adaptation to climate change taken within the framework of nature-compatible flood-water protection can also have beneficial impacts on biodiversity.

By means of renaturation, relocation or slotting of dykes in respect of 79 rivers nationwide, an area of 4,080 hectares of former alluvial meadows was, in the period from 1983 to 2017, reconnected with the natural flooding dynamics of water courses. As a result they are, during floodwater events, flooded without any human intervention or control. The installation of controlled flood-water polders or some other type of controlled flooding of alluvial meadows have not been taken into consideration. The annual net gain depends on the size of completed projects in the year concerned which makes this figure highly variable. Only comparatively small areas were gained in the period from 2014 to 2017.

It has to be said that, as a rule, measures for the purpose of regaining natural flood-plains were not taken exclusively or primarily for the adaptation to climate change. Nevertheless, the past 15 years have demonstrated increased awareness that climate change entails changes in the run-off dynamics of river catchment areas, which require the restoration of natural retention areas in order to prevent flood-water damage, e.g. to residential areas, transport infrastructure or agricultural land.

In 2009 a nationwide inventory of alluvial meadows was made which showed that of formerly approx. 1.5 million hectares of alluvial meadowland on riversides, only approx. 480,000 hectares remain available as retention areas for floodwater.[36] Compared to those figures, the regaining of naturally flooded alluvial meadow areas in the period from 1983 to 2017 is a relatively small area.

The restoration of natural flood-plains is in the interest of flood-water protection while also benefiting biodiversity. (Photograph: © Pavel Klimenko / stock.adobe.com)

Interfaces

WW-I-3: Floodwater
WW-R-3: Riparian vegetation on the banks of small and medium-sized watercourses
RO-R-3: Priority and restricted areas for (preventive) flood control
RO-R-6: Settlement use in flood-risk areas

Objectives

Extending retention areas on riversides by at least 10 % by 2020 (NBS, ch. B 1.2.4)

Former flood-plains suitable as retention areas should be restored as far as possible unless counter-indicated by overriding interests of the common good (WHG, § 77 (2))

Promoting measures with moderating effects on extreme events, e.g. for improving the hydromorphology (including the reconnection of oxbow lakes, but also the relocation of dykes) (DAS, ch. 2.3)

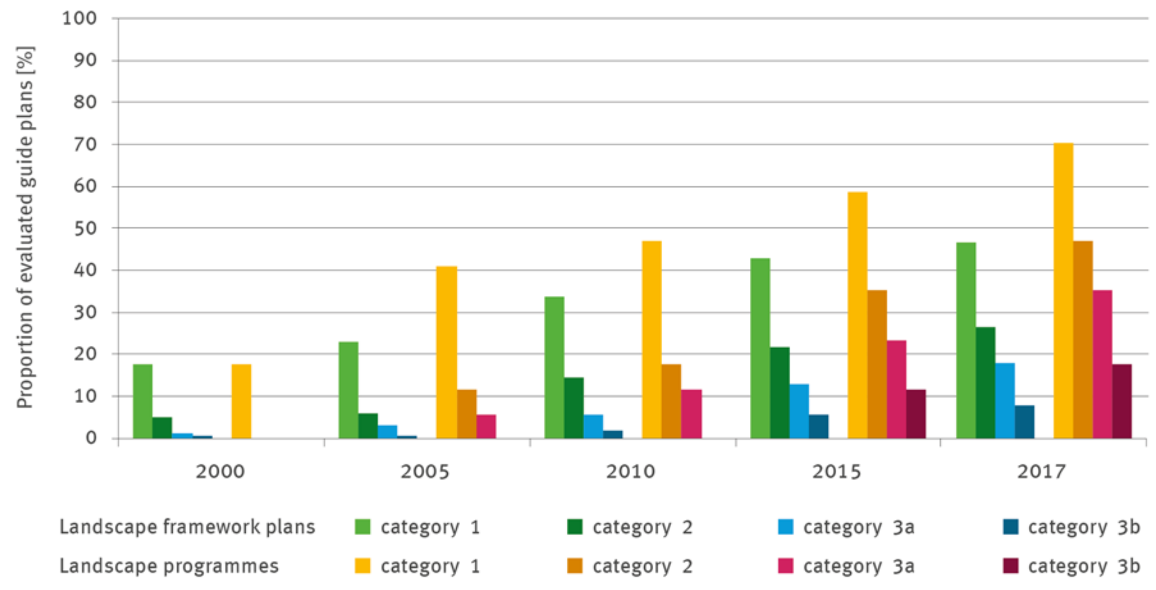
Climate change impacts gaining importance in landscape planning

Land use plays an essential part in biodiversity, which makes it one of the central starting points for the conservation of animals and plants and for the development of suitable habitats. Climate change therefore presents, in many respects, new challenges regarding a nature-compatible and future-oriented approach to controlling land use, as in all probability the competition for land is going to increase. The enhancement of various forms of renewable energy for the purpose of climate protection – especially the use of biomass for energy production – is leading regionally to the intensification of land use in terms of agriculture and forestry.

In order to safeguard biodiversity it is necessary when making decisions related to nature conservation, to take both direct and indirect impacts of climate change into account, to identify the essential objectives both in terms of concepts and planning and to prepare the requisite measures. Comprehensive planning of land use therefore plays an essential role in nature conservation. Programmes related to landscape planning incorporate important co-ordinating functions at the level of federal Länder, setting priorities in decisions on requirements and measures in respect of nature conservation that are of relevance to the federal state in question. Apart from programme-based objectives and guidelines for nature conservation policies of a federal state, they also contain spatially tangible illustrations e.g. on a specific state's biotope network or on its areas of particular value in terms of nature conservation. Landscape framework plans are generated for planning regions, administrative districts or government districts. They illustrate the requirements of landscape programmes in a tangible form, contain proposals on the designation of priority areas and make statements that are specific to particular regions.

BD-R-1: Consideration of climate change in landscape programmes and landscape framework plans

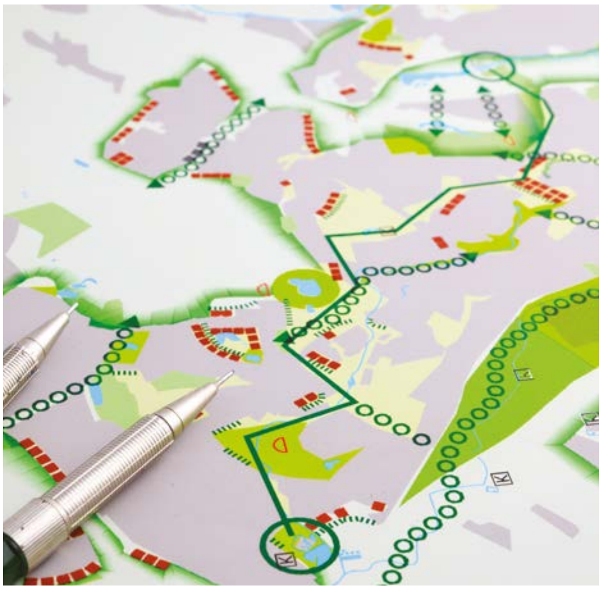
Landscape programmes and landscape framework plans provide a platform for tangible objectives and principles of nature conservation and landscape conservation at the level of individual states and regions. Climate change impacts and the resulting challenges for the protection of biotopes and species are increasingly incorporated in planning. However, the majority of plans still show a lack of tangible statements including objectives or measures relating to climate change.



Data source: BfN (own analysis)

Unfortunately, regulations contained in individual Länder's nature conservation legislation regarding the generation and updating of landscape programmes and landscape framework plans are not homogeneous. For example, the city states of Berlin, Bremen and Hamburg as well as the states of Saarland and since 2010 also Hesse have abolished the generation of landscape framework plans.[3737] In some cases, the current legal position also means that outdated landscape programmes do not have to be updated any more. Besides, the updating cycle for landscape framework plans also varies from state to state. However, as before, there is still a rule in force according to which landscape programmes and landscape framework plans represent the central planning level which serves as a platform in which it is possible to embed any requirements on spatial planning resulting from climate change as well as requirements in respect of nature conservation.

As shown by an evaluation of 16 landscape programmes operated by Länder and the available landscape framework plans – there were 162 in 2017 – the impacts of climate change and the resulting requirements in terms of planning are not yet taken into consideration widely. However, as far as plans are concerned which were analysed in respect of the period from 2000 and 2017, a distinct increase is noticeable in references to climate change. For example, climate change and themes relating to climate protection and adaptation to climate change in connection with nature conservation issues are mentioned in slightly more than two thirds (71 %) of landscape programmes. The process of evaluation included statements made in the plans relating to land with storage or sink functions for carbon. By contrast, a clear majority of plans has so far omitted to include descriptions of tangible impacts of climate change on biodiversity. According to the 2017 status, only approx. 17 % of landscape framework plans provide a rationale for individual nature conservation objectives and measures which are at least in part associated with climate change. The analyses undertaken do not permit any detailed statements regarding the specific technical depth or consideration of climate change in the plans analysed. Nevertheless, it is obvious that landscape plans at the level of Länder and regions, with a view to the challenges of climate change, have so far included only scant statements on tangible objectives and measures. The current initiatives taken by individual Länder suggest, however, that the opportunities of control through planning will be utilised more thoroughly in future programmes and updating of plans.



Landscape planning provides opportunities to prepare adaptation measures for the protection and development of biodiversity. (Photograph: © darknightsky / stock.adobe.com)

Consideration categories regarding climate change in landscape programmes and landscape framework plans

1 Areas of land relevant to climate change (with storage or sink function for carbon) are mentioned in connection with nature conservation issues.
2 Impacts of climate change on biodiversity are described.
3a Individual nature conservation objectives and measures are based on reasons of climate change.
3b Individual nature conservation objectives and measures are based exclusively or mostly on reasons of climate change.

Interfaces

RO-R-1: Priority and restricted areas reserved for wildlife and landscape conservation

Objectives

Anticipatory consideration in landscape planning of the dynamics and changes in nature and landscape owing to climate change (DAS, ch. 3.2.5)

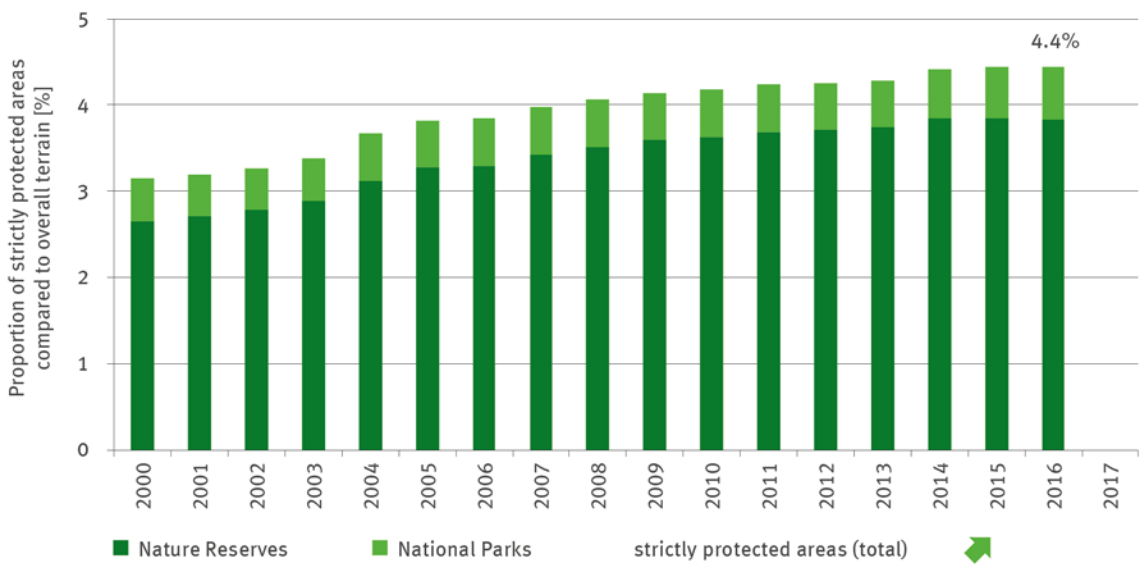
Protected areas – refuges for animals and plants exposed to climate change

Animals and plants in the wild, as well as their habitats are exposed to varied influences in German landscapes characterised by anthropogenic use. Apart from the adverse effects of progressive intensification of land use, climate change in many cases creates additional stresses. Given these circumstances, the creation of refuges for the protection of valuable areas of nature conservation is gaining increasing importance for the continued existence of native and in many cases endangered animal and plant populations. Apart from the size and quality of protected areas, the spatial distribution and networking of these areas play an important role in these times of climate change.

There are strict protection regimes in force in nature reserves and national parks in order to enable the conservation and development of rare and endangered species and biotopes. In national parks it is their large scale which plays a very special role. The majority of the expanse of a national park is supposed to be dedicated to enable natural processes to take place with as little disturbance as possible. The indicator reflects the overall terrain of strictly protected areas in Germany. The outcome of this calculation is based on the percentage of land in nature reserves and national parks as a proportion of Germany's overall terrain. Natura 2000 areas as well as core and buffer zones of biosphere reserves are included, provided they have been designated accordingly. In terms of statistics, the overall terrain of these strictly protected areas has increased from 1,129,225 hectares in 2000 to 1,591,580 hectares in 2016. With reference to the overall terrain of Germany, this represents an increase from 3.2 % in 2000 to 4.4 % of the terrain by 2016. The increase in the total terrain of strictly protected areas had been achieved partly by the implementation in the past of the Natura 2000 network. It is expected that in Germany the amount of new designations of strictly protected areas as Natura 2000 areas for the purpose of their legal protection will probably be rather negligible in future. This is mainly because most of the Natura 2000 areas have already been placed under legal protection, and the Länder tend to choose,

BD-R-2: Protected areas

Nature reserves and national parks are strictly protected areas which provide refuges in which adverse impacts on animals and plants can be avoided or moderated. In these circumstances, protected areas create favourable prerequisites for the conservation of species and habitats particularly at risk from climate change. The statistically significant increase in strictly protected areas must be regarded as positive.



Core and Buffer Zones of Biosphere Reserves listed as National Parks provided they are designated Nature Reserves or National Parks

Data source: BfN

apart from nature reserves or national parks, other forms of protection.

While the terrain of nature reserves increased steadily between 2000 and 2014, the terrain of national parks increased only between 2003 and 2004, as a result of the foundation of the Eifel National Park in North-Rhine Westphalia, the Kellerwald Edersee in Hesse; as well as the creation of the Black Forest National Park in Baden-Württemberg in 2014 and Hunsrück-Hochwald in Rhineland-Palatinate and Saarland in 2015.

The increase in the cumulative terrain of strictly protected areas must be regarded as positive, especially in view of the new challenges arising from climate change and its impacts on species and biotopes. The formal designation of a protected area, however, is only a first step on the journey towards the adaptation of the protected area network to the challenges associated with climate change. Habitats particularly at risk from climate change such as wetlands or mountain ranges are part of the group of highly valuable nature conservation areas. This is why the aspirations to protect those areas harmonise well with the objectives of adapting to climate change.

The protection of suitable areas at adequate scales has to go hand-in-hand with effective management of these areas to comply with the declared objectives of nature conservation. The regulations governing individual protected areas can vary a lot and the number of all protected areas in Germany is considerable. To date, it has therefore been impossible to make any comprehensive statements on the quality of the areas concerned and their management. Besides, it is not clear either to what extent some aspects of adaptation to climate change are being taken into account already in the management of protected areas. Presumably, there are even now dynamic developments taking place with regard to climate change which will make it necessary in future to adapt the objectives pursued as well as the management carried out in protected areas.

It is also intended that nature reserves and national parks safeguard parts of the transnational biotope network as well as extending it, as required by the German Federal Act on Natural Conservation. Adequate connectivity in the biotope network will enable genetic exchanges among populations. This is indeed an indispensable prerequisite for the conservation and development of species. This is why, in view of climate change, the biotope network is becoming ever more important, in order to improve the migration and distribution opportunities among various occurrences of animal and plant species over a wide area. Both the expansion of the overall terrain of protected areas and the biotope network make essential contributions to the nationwide endeavour to reconnect habitats, thus contributing to the objective of adapting to climate change. All the same, indicators do not help with inferring any statements on whether the specific challenges arising from climate change are given sufficient consideration in current planning and implementation efforts regarding the biotope network.

Strictly protected refuges gain in importance where stress factors associated with climate change are on the increase. (Photograph: © Soeren Wilde / stock.adobe.com)

Objectives

Analysing the options for the adaptation of the existing nature conservation network to future challenges arising from climate change (DAS, ch. 3.2.5)

Taking into account the requirements arising from climate change in generating or updating plans for conservation and development as well as management plans for protected areas (DAS, ch. 3.2.5)

It is intended that by 2010 10 % of Germany's overall terrain will make up a representative and functioning biotope network. (NBS, ch. B 1.1.3)

In 2020 the proportion of forests reflecting a natural development of its species composition amounts to five percent of the entire forested area. (NBS, ch. B 1.2.1)

By 2020 it is intended that once again nature will be undisturbed in its development on 2 % of Germany's overall terrain. (NBS, ch. B 1.3.1)

Building industry

It has always been the purpose of buildings to provide permanent protection to the inhabitants and their household effects or the building's functions from the adversities of the weather and the vagaries of changeable weather patterns. Apart from available construction materials and the functions of buildings, it is especially the traditional methods of construction and regional characteristics of urban construction which reflect the locally prevailing climatic conditions. Nowadays building standards and regulations ensure that buildings meet a great variety of climate-related challenges and that predictable damage can be avoided as far as possible. In this context, regional differences in climatic conditions are described which must be taken into account in designing buildings for zones susceptible to heavy snow loads, wind loads and driving rain.

In view of the considerable range of possible interpretations of existing standards, it is particularly the increase in frequency and greater intensity of extreme events which will present challenges to the building industry. Hot periods, hail, storms, driving rain and floodwater, but also various forms of soil subsidence and landslides may in future lead to increased damage to buildings.

Apart from impacts on individual buildings, discussions in the building industry refer to changes to be expected regarding urban climatic conditions and potential adaptation measures. One of the major topics is the increasing overheating of inner cities where rising average temperatures and increasing temperature extremes are to be expected

Effects of climate change

Adaptations

Heat stress in city environments

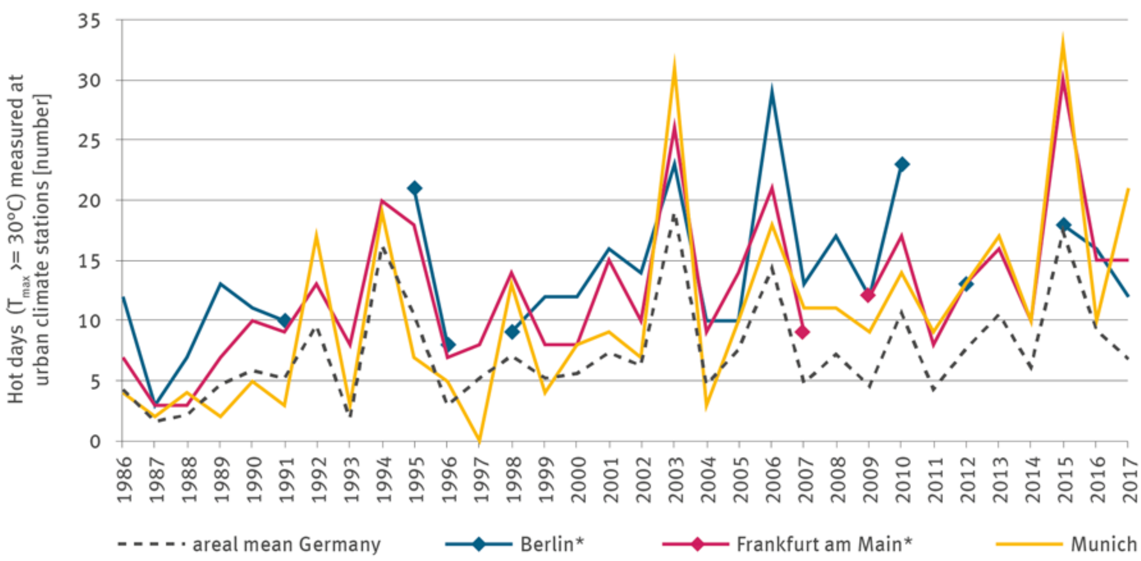
Cities are often subject to climatic conditions which are very different from the climate prevailing in their periphery. For example, the relative air humidity tends to be lower, and the mean temperature tends to be higher. In respect of temperature differences between urban and rural areas, climatologists refer to 'urban heat islands'. The intensity of the urban heat island effect is largely dependent on the size of the town or city, the density of buildings, their height, the proportion of green space and the construction materials used. Also cloud cover and wind patterns play important roles in terms of urban heat stress.

In hot summer months this can entail health problems for the population in cases where – owing to their characteristics – urban spaces heat up considerably during daytime without cooling down over night to the same extent as their rural periphery. This type of situation may occur more frequently in future. As indicated by climate projections for Central Europe, mean temperatures will rise and the overall weather characteristics will change too. For example, extreme thermal values are expected to occur more frequently. For instance, the frequency of so-called 'hot days' is expected to increase, where maximum air temperatures will reach or exceed 30 °C. Besides, the population will experience stress on so-called 'tropical nights' when the thermometer will not go below 20 °C and there is little chance of enjoying a restful night.

As far as Germany's surface area mean is concerned, the mean number of hot days has increased from approx. 3.5 days in the 1950s to presently approx. 10 days per annum (see p. 22). The time series for city climate measuring stations in Berlin, Frankfurt am Main and Munich do not go back as far as 1951. It is therefore not possible to make any comparisons with the development at a nationwide level. However, there is evidence even from shorter time series that cities are subject to special circumstances. Here, hot days – albeit with regional differences – clearly occur more frequently in most years than compared to the nationwide mean. In years with above-average hot summers, such as 2003, 2006 and 2015, the differences are particularly distinct. This applies even more strongly to tropical nights although these are not illustrated in this context. While Germany's nationwide mean was between 1 and 1.5 tropical

BAU-I-1: Heat stress in urban environments

In most cities examined, hot days and (not illustrated) tropical nights clearly occur more frequently in most years than indicated by the mean for Germany as a whole. Especially in years with above-average hot summer months, records show increased frequencies of situations in big cities, which are liable to expose the population to heat stress.



* insufficient data for Berlin-Alexanderplatz for the years 1992-1995, 1997, 2011, 2013, 2014; ditto for Frankfurt am Main in 2008.

Data source: DWD (selected urban climate measuring stations, German climate atlas) nights for the years mentioned, in Berlin as many as 12 and in Frankfurt am Main up to 14 such nights were recorded.

In contrast with hot days and tropical nights, the time series for urban heat island effects – on the basis of values measured every 10 minutes for the city of Berlin – does not refer to the frequency of times when the threshold value was exceeded. In fact, it refers to the maximum daily temperature differential between the centre and the city's immediate periphery. In the summer months of June to August, these values are on average between 3 and 4 Kelvin. However, on peak days, temperature differences of almost 9 Kelvin are possible. Overall, high temperature differences occur especially in the evenings and at night. In other words, the inner city cools down distinctly more slowly in summer and less so than the periphery. This means that it is often too hot for the city population to get a sufficiently restful night.

Interfaces

GE-I-1: Heat exposure
BAU-R-1: Recreation areas
IG-I-1: Heat-related loss in performance

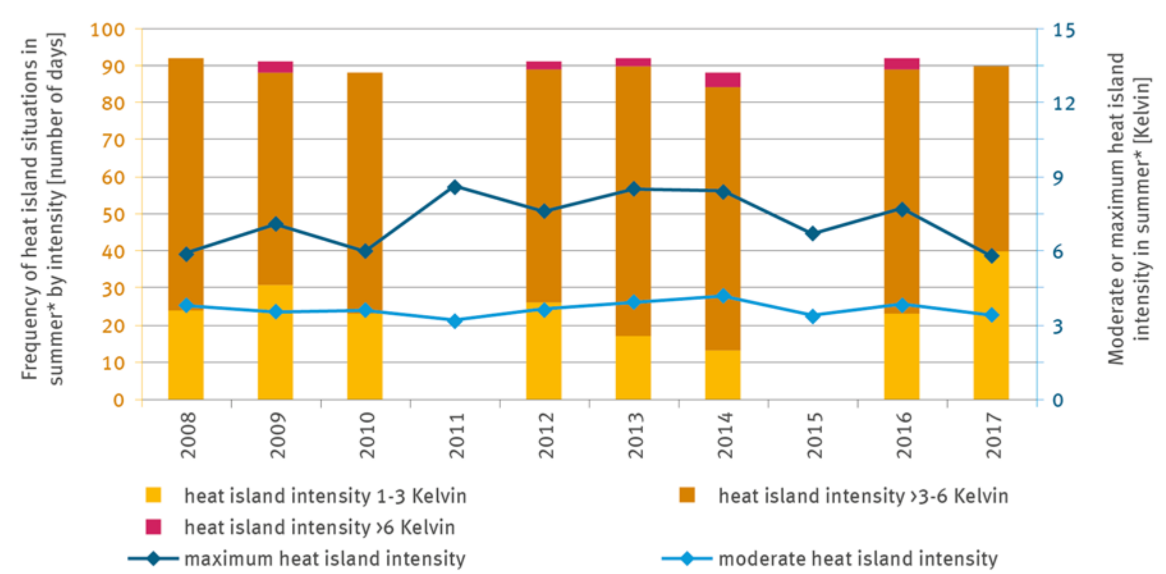
Objectives

Mitigating climate-related increases in the heating effect in cities – as well as any associated heat stress – by means of suitable architecture as well as urban and spatial planning; safeguarding fresh air supply by means of unobstructed fresh-air corridors, especially in inner cities; inhibiting – with regard to urban development – any further sealing of open spaces by overbuilding with residential areas or traffic routes (DAS, ch. 3.2.1)

So far the time series does not make it possible to judge whether climate change exacerbates the urban heat island effect. This may be because heat stress is increasing with equal strength in both cities and their periphery. This is roughly confirmed by indications given by projections for Frankfurt am Main[38]. Even without an increase in the intensity of urban heat islands, this would mean for the future that stressful situations will in all likelihood continue to be most frequent wherever the heat stress is already high at present.

BAU-I-2: Summer-related heat island effect – case study

Between the inner city and the urban fringe of Berlin, a maximum day-time temperature difference of up to 9 Kelvin is possible. It is so far not possible to judge whether climate change is exacerbating the heat island effect. However, even if the air temperatures in the city and its vicinity rise 'only' with equal strength, heat stress, especially among the city population will very frequently be high.



* Meteorological summer: June, July, August; insufficient data for determination of frequency in summer months of 2011 and 2015

Data source: DWD (climate measuring stations Berlin Alexanderplatz and Schönefeld)

Cooling degree days

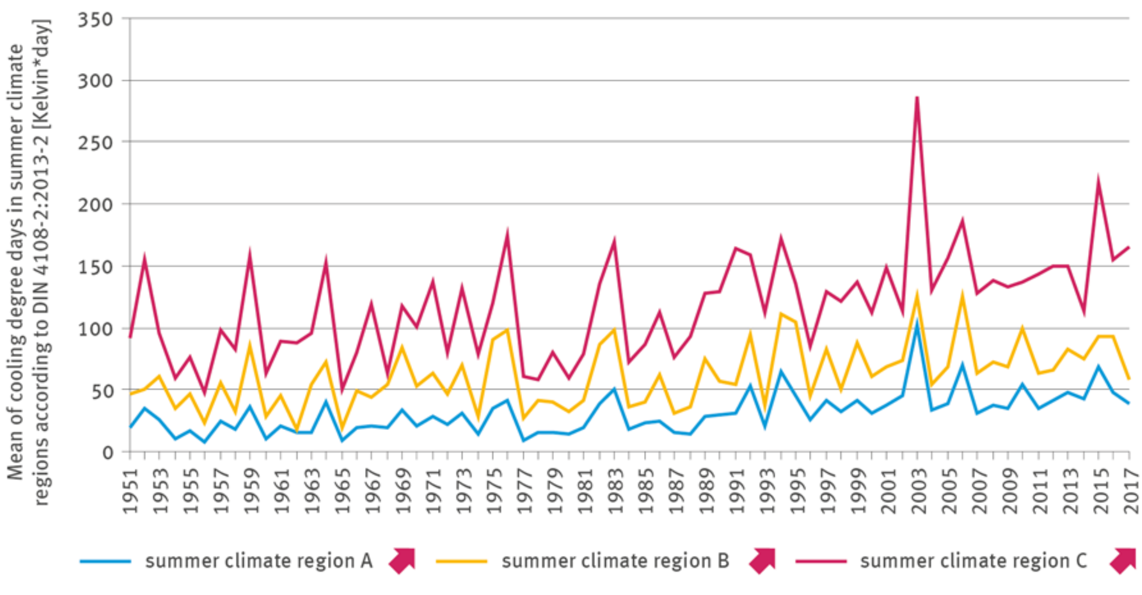
In Germany 2018 was the warmest year since weather recording began, and never before, compared to the nationwide mean were there as many hot days with temperatures of 30 °C and more. The manufacturers of air-conditioning equipment and fans were blessed with a bumper summer in terms of revenues as in many offices and homes, temperatures were clearly beyond the comfort zone.

Heat protection by means of building design is to ensure amongst other things that this type of situation remains the exception to the rule and that the interior climate of buildings remains bearable even when the external summer temperature is high. The Minimum Requirements for Protection from Heat (Mndestanforderungen an den Wärmeschutz) including heat protection in summer are described in the relevant DIN (standard) 4108-2:2013-02 which bears the same name. In order to meet these minimum requirements at a large scale this DIN standard divides Germany into three summer climate regions, i.e. A, B and C. The summer climate region A comprises the coastal areas of North Sea and Baltic Sea as well as the upland areas of the Alps, i.e. areas which tend to be relatively cool. Summer climate region C comprises areas which tend to be warmer. This includes Lake Constance and the Upper Rhine Graben (rift valley), the Rhine-Neckar and the Rhine-Main areas, the Moselle and the Middle Rhine Valley, the Ruhr Valley and the urban regions of Leipzig/Halle and Dresden. The other regions are comprised in Region B.

These three summer climate regions make up the background for the time series illustrated for cooling degree days which were calculated according to the process developed by Spinoni et al., 2015.[39] The evaluation of cooling degree days was used as a basis for estimating the temporal development of cooling requirements or the extent of heat protection required in these regions in summer. The cooling degree days are a (fictional) value; in this case 22 °C, which is calculated by totalling the amount of exceedance per day for all days of the year in a weighted form. The lowest weighting is allocated to days on which the maximum day temperature alone exceeds the threshold. In this case the difference between the

BAU-I-3: Cooling degree days

In the three summer climate regions according to DIN 4108-2:2013-02, which is the authoritative standard for summer heat protection of buildings, the number of cooling degree days is increasing thus reflecting a significantly rising trend. Since 1999 the cooling degree days in the three regions have been consistently above the mean of the climate normal period 1961-1990. The requirements made for summer heat protection are increasing throughout Germany.



Data source: DWD – Regionales Klimabüro Essen (own calculation) maximum day temperature and the threshold value is counted as a quarter. The highest weighting is allocated to days on which the daily minimum temperature lies above the threshold value. In this case the difference between the threshold value and the daily mean temperature is counted. In between are days on which the mean temperature lies above the threshold value. The data for the time series of summer climate region A were provided by the DWD stations Bremerhaven and Stötten in the Swabian Alps. For the summer climate region B the values from the DWD stations Potsdam, Essen and Hamburg-Fuhlsbüttel were used while Region C is represented by the Mannheim station.

Since 1951 all three time series have shown a significantly rising trend. A comparison shows that the cooling degree days in summer climate region C (i.e. the Mannheim station) increase faster than in the two other regions. Notwithstanding the above, a comparison with the climate normal period 1961-1990 shows that the cooling degree days in all three regions were consistently above the mean of the period 1961-1990. This means that the requirements in terms of heat protection are increasing throughout Germany. Judging by current climate projections, this development will continue for the rest of the 21st century.

In the light of this perspective and bearing in mind the necessity to further reduce carbon dioxide emissions also in respect of the building industry, it is imperative for building design circles to keep a constant eye on the increasing requirements of heat protection in the future. However, the DIN standard 4108-2:2013-02 defines only the requirements to be fulfilled by new buildings, building extensions and add-on modules such as conservatories, referring only to the climate prevailing between 1988 and 2017. This standard is currently being enhanced in order to give more adequate consideration to the projected climate warming and associated consequences, for the appropriate adaptation of minimum requirements to heat protection in summer. In the meantime it behoves developers to take adequate precautions and make appropriate provisions that go beyond the minimum requirements laid down in this standard. Starting points are, for instance, the proportion of window space, adequate window tilt and orientation, the type of nocturnal aeration and the use of solar control glass and passive cooling systems. If supported by preventative urban planning and neighbourhood-based planning practices – including the provision of appropriate aeration and adequate green space in cities – the interior climate of buildings is then able to remain in the comfort zone even if temperatures keep rising.

Roller blinds and window shutters, awnings and louvred blinds, a balcony or a tree in front of the house – there are numerous options for reducing the influx of solar energy into a home. (Photograph: © U. J. Alexander / stock.adobe.com)

Interfaces

GE-I-1: Heat exposure
BAU-R-1: Recreation areas
IG-I-1: Heat-related loss in performance

Objectives

Taking into account the adaptation to climate-related changes should be an integral part of planning a building's design and technical equipment. [...] By contrast, it will become essential in building design and technology, especially with regard to attic flats, to make provision for a more distinct adaptation to higher average summer temperatures and occasional longer heat periods. (DAS, ch. 3.2.1)

Flash floods – high damage potential for residential areas

In recent years images such as the disaster in Berlin in July 2017 or Braunsbach in May 2016 have been featured repeatedly in the media. It can be a matter of minutes for torrential rain to make sewers overflow, flooding entire street networks. Torrential rain can cause flash floods engulfing cars and devastating streets and buildings. Such events can cause immense damage to property and, in individual cases, even cost lives.

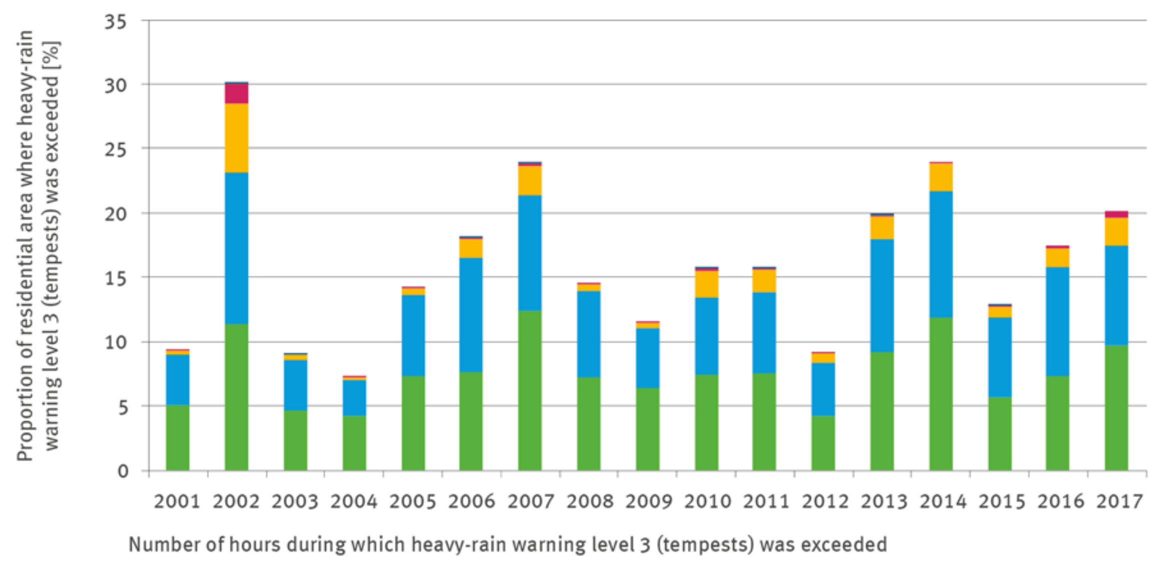
Heavy rain is a weather event in which massive amounts of rain fall within a very brief period of time. The DWD (DWD) issues torrential rain warnings when it is expected that within one hour more than 25 litres per square metre (l / m²) or in six hours more than 35 l / m² rain will fall. Amounts of rain of more than 40 l / m² or 60 l / m² falling in these time periods are classed as extremely severe weather. Frequently these cloud bursts occur when massive clouds – formed as a result of convection – open their floodgates causing torrential rain to fall on mostly small areas. However, persistent rain falling on extensive areas can also temporarily exceed the warning thresholds for heavy rainfall.

During or after heavy rainfall, damage is caused primarily by so-called flash floods. These are extreme floodwater events as a result of heavy rainfall. They occur in lowland areas when rainwater cannot drain or seep into the ground fast enough. In those cases water accumulates on the surface or it dams up owing to overburdened sewage and drainage systems as their ultimate design loads are exceeded. Water levels can rise very rapidly then, especially in hollows and underpasses. On sloping terrain this can cause so-called 'mountain flash floods'. The quick-draining water will accumulate in gutters or stream beds and can swell extremely rapidly forming surge-like floodwater waves. These waves are able to reach areas where no rain had fallen previously.[40] When such mountain flash floods sweep away material such as tree trunks or rocks, they can cause massive damage to houses or culminate in the complete loss of buildings.

Heavy rain and flash floods can, however, damage buildings in other ways too. For example standing water can reach levels which exceed the design threshold thus enabling water to enter the building e.g. through

BAU-I-4: Heavy rain in residential areas

In 2002 the high number of hours of heavy rain in the south and east of Germany was one of the causes of floodwater disasters in the river basins of Elbe and Danube. High amounts of damage can, however, be inflicted even at distinctly lower exposure to heavy rain. For 2016 the amounts of insured damage caused by heavy rainfall is estimated at just under 1 billion Euros.



Data source: DWD (RADOLAN-Climatology), Bundesamt für Kartographie und Geodäsie (DLM250) entrance doors at ground level, cellar windows or due to tailbacks in the sewage system. The ingress of water then leads to the distribution of mud and detritus which may be polluted additionally by a mixture of mineral oil, chemicals and faeces. Above and below the earth's surface, standing water or high soil humidity can cause typical floodwater damage to the fabric of buildings, such as moisture penetration and linear water level marks, efflorescences on surfaces, detached coatings or fungus.[41] In order to prevent damage, house proprietors can take a number of measures, possibly by placing building apertures at a sufficient height above ground level, the use of waterproof building materials and suitable drainage systems with backflow preventers.[42]

Climate researchers and meteorologists expect that the incidence of heavy rainfall will increase in future. One reason for this is that at higher temperatures the air can absorb more water – at a temperature increase by one Kelvin approximately seven per cent more water.[43] Furthermore, it is to be expected that owing to changed meteorological circumstances during the formation of showers and thunderstorms, the formation of cloud and precipitation will intensify.[44] During the second half of the 21st century, Germany – albeit with major regional and seasonal differences – will experience a distinct increase in the incidence of daily precipitation amounts compared to the relatively infrequent occurrence at present. The comparatively strongest increase is expected for events which are currently still infrequent.[45]

It is hard to forecast how frequent and how intense heavy-rain events will be and whether global warming may already be impacting on this phenomenon. In view of the fact that such events are often relatively localised, heavy-rain events are not always recorded by the nationwide network of measuring stations. This is one of the reasons why the DWD developed a radar-based service for detecting precipitation levels which has been providing precipitation data at an almost nationwide level since 2001.[46] This data set contains nearly all heavy-rain events which occurred in Germany since 2001. In future the temporal extension of this data collection process will also enable trend analyses regarding the frequency of events when the warning levels used by DWD are exceeded. (see p. 25).

In the illustration for the indicator concerned, the annual data from the radar-based precipitation measurements were superimposed with the data for Germany's residential terrain. The outcome makes the year 2002 stand out. In that year, numerous heavy rainfalls over an extended period caused the flooding disaster in the Elbe and Danube river basins. Not one of the other years examined reflected a greater extent of residential areas affected by heavy precipitation for the same amount of hours. However, those two factors are not always of crucial importance for the extent of damage. For example in 2016 – a less eye-catching year in this time-series – the amount of insured damage was just under 1 billion Euros.

Flash floods due to heavy rain can present considerable threats to residential areas.
(Photograph: © Tom Bayer / stock.adobe.com)

Interfaces

BAU-I-5: Claims expenditure for property insurance
VE-I-3: Heavy rain and roads
VE-I-5: Impacts on roads from extraordinary weather events and disasters
BS-I-1: Person hours required for dealing with damage from weather-related incidents

Objectives

The objective of a common (joint) management of heavy-rain risks is to reduce the risks caused by adverse effects of heavy rain or flash floods on human health, buildings and infrastructure, the environment, cultural heritage and commercial activities.
(LAWA-Strategie Starkregenrisikomanagement, ch. 1)

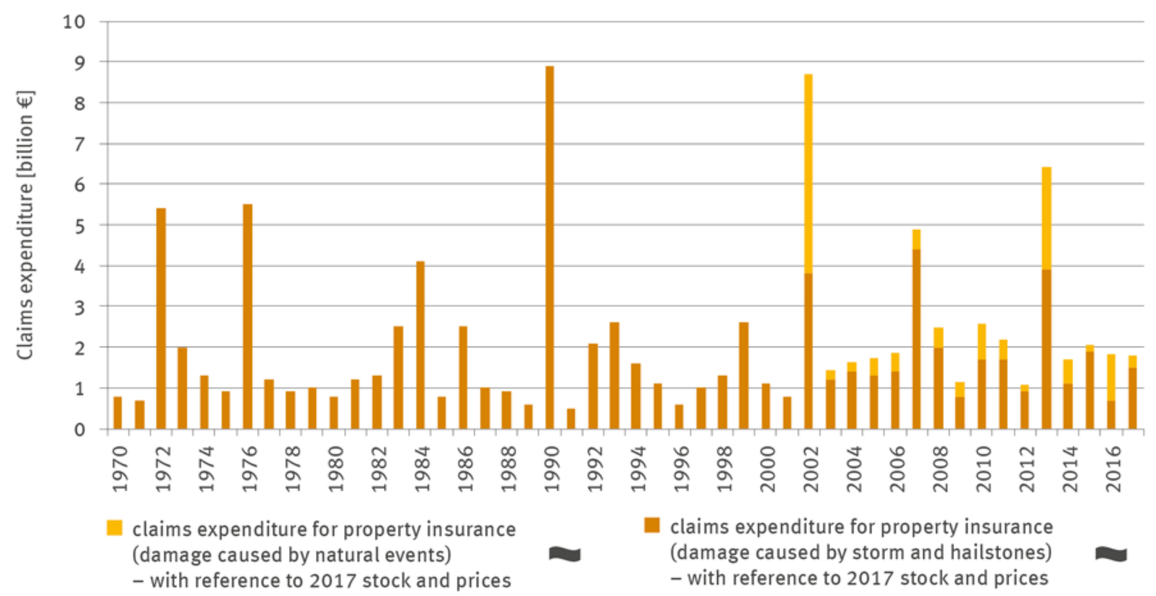
High weather-related damage in terms of property insurance

According to the current state of scientific knowledge, collated by the IPCC in its 2018 Special Report entitled ‘Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation’, progressive climate warming will change the intensity, incidence, spatial expansion and duration of extreme weather events. It is to be expected that in future, apart from other events, more extreme heavy precipitation events will occur with greater frequency and intensity thus causing flooding. As far as the development of the incidence and intensity of storm events is concerned, it has not been possible to discern a distinct trend for Germany. Likewise, other than with regard to temperature, projections into the future have remained difficult. Nevertheless, several scientific studies have shown meanwhile that the violence of the most vigorous storms and consequently, the extent of storm-related damage, will increase. Winter storms are becoming particularly violent. Friederike was the last of five destructive hurricanes of the 2017/2018 winter season. In Germany, they claimed the lives of 21 people and caused damage to property worth more than 1 billion Euros.

Weather-related extreme events can damage a building’s envelope and the interior of a building. Typical storm damage to buildings includes e.g. torn-off roof tiles and ripped-off parts of cladding as well as broken glass panes in windows or doors. Indirectly buildings can be affected by fallen or broken trees and masts or by damage to buildings in the neighbourhood. Compared to their size, hailstones can have enormous powers of impact capable of damaging roofs, window panes or facings. Especially if water penetrates to the interior of buildings – either due to floodwater or heavy rain – this can also cause considerable damage to buildings’ contents, in particular to household effects. In the case of such extreme events, the damage caused to a single one-family house can cause claims for more than 100,000 Euros worth of damage.

BAU-I-5: Claims expenditure for property insurance

Damage caused by storms and hailstones as well as damage due to weather-related natural hazards such as flooding after heavy rainfall and floodwater lead to high costs incurred by insurance companies in respect of property insurance. The time series examined is strongly marked by extremely severe individual weather events. So far, it has not been possible to identify a significant trend for claims expenditure in property insurance.



Data source: GDV

The extent of damage to buildings and their interiors caused by extreme events is reflected by the amounts of money involved in claims settled by the insurance industry. In particular with regard to high insurance densities as e.g. in the insurance of private buildings against storm and hailstorm damage (in view of 94 % density, it would be correct to speak of near-saturation of the market), even regionally limited damage events are reflected well in statistics. Any change in reported claims and associated damages settled by insurance companies with policyholders can therefore be linked directly to changes in the frequency and intensity of damage events.

In respect of damage covered by customary property insurance, the amounts claimed due to fire, lightning strike, explosion and tapwater have remained more or less consistent over the years. In cases of storm and hail damage and other natural events, caused by earthquakes, landslides, subsidence, snow pressure or avalanches as well as flooding due to a river breaking its banks or heavy rain, damage amounts fluctuate strongly from year to year. In some years damage events can be cumulative as a function of weather patterns, and some, particularly violent events can cause major damage. By comparison, other years are relatively 'quiet'.

Included in claims expenditure for property insurance – apart from private residential buildings and their household effects – are also commercial and industrial premises and associated contents as well as operational interruptions due to damage events. This expenditure covers payments and provisions for any damage caused in the relevant business year including any expenses for claim settlements. Regarding the time series, the stock and prices valid in 2017 were extrapolated in order to offset any inflationary effects or changes regarding the stock insured and to permit a comparison of the figures recorded for individual years.

The time series examined with regard to claims expenditure for property insurance has so far not shown any significant trend either for damage from storm, hailstones or other natural events. However, from time to time there are years when individual extreme events push up the claims expenditure. After the turn of the millennium this applies in particular to 2002 when the August floodwater as well as several hurricanes (especially hurricane Jeanett) caused massive damage. In January 2007, the low-pressure system Cyril affected public life in large parts of Europe claiming 47 lives. In late February 2010, the low-pressure system Xynthia caused damage in Germany totalling 500 million Euros. In 2013 there were as many as four major hailstorms which pushed up the total amount of claims: Manni and Norbert in June as well as Andreas and Bernd in July with focus on Lower Saxony and Baden-Württemberg. In addition, the June floodwater in the same year caused damage totalling 1.95 billion Euros.

Nowhere near the total of buildings have so far been insured for risks of floodwater damage.
(Photograph: © Mykola / stock.adobe.com)

Interfaces

WW-I-3: Floodwater
BAU-R-5: Insurance density of extended natural hazard insurance for residential buildings

Objectives

Active management of risks and opportunities by banks and insurance companies (DAS, ch. 3.2.10)

Supporting the personal provision of floodwater protection (DAS, ch. 3.2.3)

Urban green spaces – cooling oases

Exposure to thermal stress can cause health problems in the population and, in extreme cases, can increase mortality figures. Categories at risk are primarily older people, people with chronic illnesses, children and people who live in isolation. However, other population categories may also be affected if thermal stress becomes more frequent in future. For example, when temperatures at the workplace become excessive, employees may suffer from fatigue, impaired concentration and stress on the cardio-vascular system. In addition, potential consequences of high nocturnal temperatures can prevent or restrict the chances of people having a restful night.

It is expected that climate change will further intensify urban climate effects, potentially leading to an increased incidence of heat-related health problems. Measures can be taken at various levels to counteract or pre-empt such impacts from climate change. The appropriate design of urban spaces and residential areas can make important contributions to this effect, by ensuring – both in terms of quantity and quality – the provision of 'green' and 'blue' infrastructures, i.e. green spaces and water bodies.

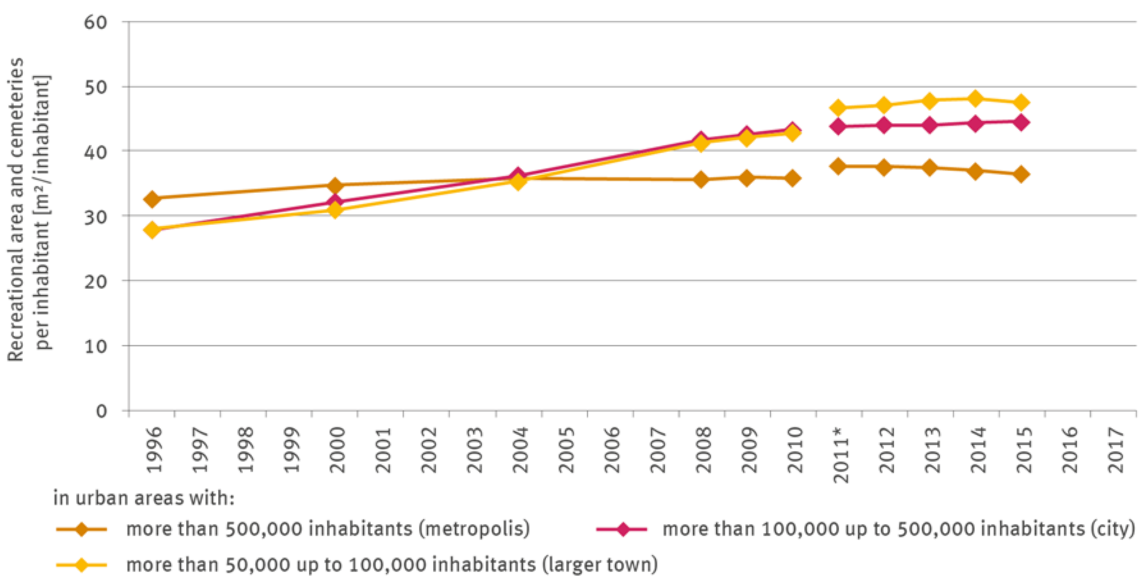
Mostly green, predominantly unsealed terrain such as recreation areas dedicated to sports and games, park-like areas and campsites or even cemeteries fulfil important functions in localised micro-climates.

The positive impact of green spaces on the urban climate and air quality as well as noise abatement depends on the size, structure and composition of areas enhanced by vegetation. Compared to the built environment, even areas just covered in grass achieve positive changes in terms of radiative and heat regimes, provided there is ample provision of water. Shrubs and shade-giving high trees enhance the bioclimatic effects. Compared to the built environment, lower surface and air temperatures develop. In addition, green spaces containing trees have greater air humidity than sealed areas.

Municipalities bear particular responsibility for the climate in residential areas. They can create positive effects for instance by retaining extant green spaces, by networking them and by creating additional green spaces. Ideally green spaces should be connected by

BAU-R-1: Recreation areas

In recent years, the provision of recreation areas in metropoles and in larger medium-sized towns has been declining. This may be associated with increases in population figures and increasing population densities in urban areas. It is precisely the population of metropoles for whom it is essential to have sufficient areas which will maintain the urban climatic equilibrium thus maintaining high quality of life.



* as per population statistics based on 2011 census

Data source: Länderinitiative Kernindikatoren (indicator C4 – recreation areas) fresh-air corridors to areas such as meadows and fields in the rural environment where cold air is produced. This way, municipalities enhance the ecological functions of residential areas thereby increasing the area's quality of life and housing quality.

In Germany's larger towns with population sizes of more than 50,000, the public recreation area available to each inhabitant is inversely proportional to its size. The current provision of recreation areas in metropoles with population sizes of more than 500,000 is actually smallest. The larger medium-sized towns with population sizes between 50,000 and 100,000 currently enjoy, quantitatively speaking, the best provision of recreation areas available per inhabitant.

In contrast with the status quo for 2015 the calculation of which is based on Germany's Amtliches Liegenschaftskatasterinformationssystem (ALKIS/Authoritative Real Estate Cadastre Information System) introduced in December 2015, the temporal development of the time series is difficult to interpret. Reasons for this are to be found in changes regarding the assignment and valuation of land adjusted when ALKIS was first introduced. This process has led to changes in land use statistics which are not based on actual changes of use. Especially in 2000 and 2008 some Federal States (Länder) carried out massive reassignments which have impacted on the data series. That notwithstanding, the data series for the years subsequent to 2011 show that the extent of provision of recreation areas in the metropoles and larger towns was ultimately in decline. One reason for this might be that the population size in those urban areas is increasing. For example, if the population density in inner cities increases without an increase in the provision of additional recreation areas, the inhabitants have on average less green space available to them. Especially in metropoles it is of vital importance to keep an eye on and control these developments in order to avoid that this growth does not occur at the expense of the urban climate thus affecting the local quality of life.

Inner-city green spaces such as here in Munich serve as cooling oases in cities at the height of summer temperatures. (Photograph: © Ernst August / stock.adobe.com)

Interfaces

GE-I-1: Heat exposure
BAU-I-1: Heat stress in urban environments
BAU-I-3: Cooling degree days
RO-R-4: Priority and restricted areas for special climate functions

Objectives

Mitigating climate-related increases in the heating effect in cities – as well as any associated heat stress – by means of suitable architecture as well as urban and spatial planning; safeguarding fresh air supply by means of fresh-air corridors, especially in inner cities; inhibiting – with regard to urban development – any further sealing of open spaces by overbuilding with residential areas or traffic routes (DAS, ch. 3.2.1)

Keeping any areas or corridors free from obstructions to the creation and supply of the free flow of fresh air and/or cold air in the design of housing developments (DAS, ch. 3.2.14)

As a rule, public access to green spaces with multiple qualities and functions must be available in walking distance (NBS, ch. B 1.3.3)

Greened buildings – good for adaptation to climate change and for biodiversity

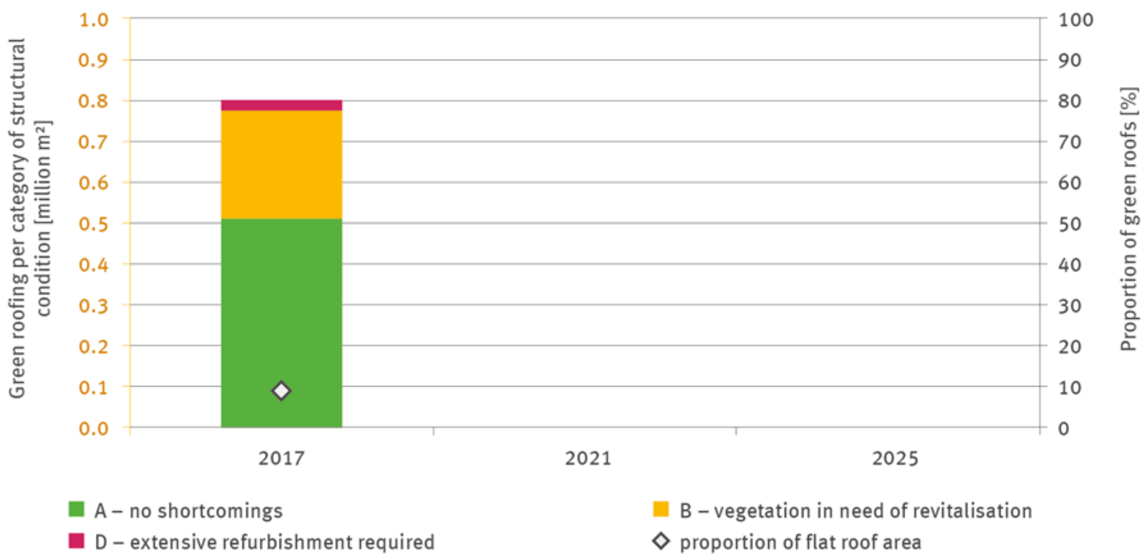
The greening of urban areas is not restricted to parks and park-like areas or to the greening of roadsides and private gardens. Façades and rooftops of buildings also provide a lot of space for greening. For façades there is a range of greening options from climbing plants to densely planted vertical gardens. Building statics permitting, roofs can also be planted extensively with a great variety of largely self-maintaining vegetation ranging from mosses, herbs and grasses to dense planting schemes with crop species, shrubs or trees.

Resilient greening schemes on roofs and façades can have multiple effects which are capable of mitigating adverse impacts of climate change thus benefiting individual buildings and properties. In urban areas these beneficial effects can also be transmitted to the environment of the buildings concerned.

This applies for instance to the cooling effects of greened buildings. By reducing the irradiation of sunlight and plants evaporating water through their leaves, greened roofs and façades effectively cool down buildings as well as the surrounding air. On one hand, this is beneficial to users of buildings on hot summer days or during periods of great heat. On the other, the urban environment also benefits from the absorption of irradiated energy and the transpiration processes taking place in greened buildings resulting in a reduction of the warming process, especially in densely populated and built-up urban areas. NB: The evaporation effect and any associated urban climate effects can only materialise provided the substrate of 'greened' roof vegetation contains moisture. This has to be taken into account especially, where greening is done extensively, because as a rule, this type of greening is maintenance-free; however, in hot summer months it may require watering. Another beneficial impact is the air-quality effect of greened roofs and façades. The vegetation surface slows down the air current so that particulate matter and pollutants can easily precipitate.[47]

BAU-R-2: Green roofing of federal buildings

Providing roofs and façades with vigorous vegetation systems can have several beneficial effects – for the climate in residential districts and within buildings, for buffering heavy rainfall, for air quality and for biodiversity. It can help to mitigate localised impacts of climate change. Where appropriate, the incorporation of greening systems in new – or in the refurbishment of extant – federal buildings could step-by-step extend their currently small proportion.



*assessment level C embedded in the BImA's property management system does not apply to greenroofing

Data source: BImA (electronic property management system)

Green roofs also serve a useful purpose in downpours. Depending on their design, green roofs can potentially store considerable amounts of rainwater for gradual evaporation once precipitation stops. With a view to potentially frequent and more intensive heavy rainfall, greening systems provide a buffer which absorbs rainwater like a sponge thus slowing down the water cycle. This helps to take the pressure off drainage systems for individual properties or urban districts and protects them from overload situations.

Furthermore, greened roofs and façades contribute to the protection of components of buildings and entire modules. For example, they can reduce damage from heavy rain and hailstones to façades and roofs, and they slow down or prevent the weathering of roof seals. As a 'bonus', greened roofs and façades also provide habitats for flora and fauna. Such greening systems provide nesting and foraging spaces for birds, wild bees, butterflies and ground beetles thus increasing biodiversity.

Numerous towns and cities therefore subsidise the greening of roofs and façades either directly or indirectly and have incorporated relevant regulations in their development planning. For its part, the Federal Government has adopted an objective regarding real estate under its own remit, to explore and – where appropriate – implement more greening systems in future development projects.[48] In doing so, the Federal Government has also adopted the function of role model for other stakeholders in its capacity as developer and proprietor.[49]

There are no meaningful data available on the distribution of greened buildings or on municipal funding programmes. Against this background, the indicator represents a makeshift aid intended to illustrate the status and proportion of green roofs, or more precisely, greened flat roofs on federal buildings. To this end, the indicator is based on data provided by the Institute for Federal Real Estate (BImA) which owns more than 18,000 premises and 30,000 buildings, thus administrating the major part of federal real estate used for military and civilian purposes. The data represent the outcome of the simplified assessment of structural condition as used by the BImA continuously in assessing the structural preservation of all buildings in its remit.

The initial status illustrated for 2017 shows that currently only a minor part of federal buildings are fitted with green roofs, i.e. approximately 9 % of the flat roof area or just under 5 % of the overall roof area. The successive extension of this coverage in terms of new buildings and refurbishment projects might provide a starting point for the Federal Government – in individual cases – to get gradually closer to achieving the goals set for the adaptation of federal buildings and properties to climate change and to promote biodiversity.

Greened façades and roofs have beneficial effects on urban climates and the building itself.
(Photograph: © Martin Debus / stock.adobe.com)

Interfaces

GE-I-1: Heat exposure
BAU-I-1: Heat stress in urban environments
BAU-I-2: Summer-related heat island effect
BAU-I-4: Heavy rain in residential areas

Objectives

Reducing the increasing climate-related heating effects in towns and cities and associated heat stress by means of appropriate architectural design and spatial planning (DAS, ch. 3.2.1)

Distinct increases in greening entire housing estates including the immediate environment of residential buildings (e.g. greening courtyards, small green spaces, greening roofs and façades by 2020 (NBS, ch. B 1.3.3)

Striving for an exemplary building industry by 2020 guided by standards compatible with biodiversity conservation (NBS, ch. B 2.2; StrÖff, ch. D.7)

Climate-adapted buildings – heat is kept out

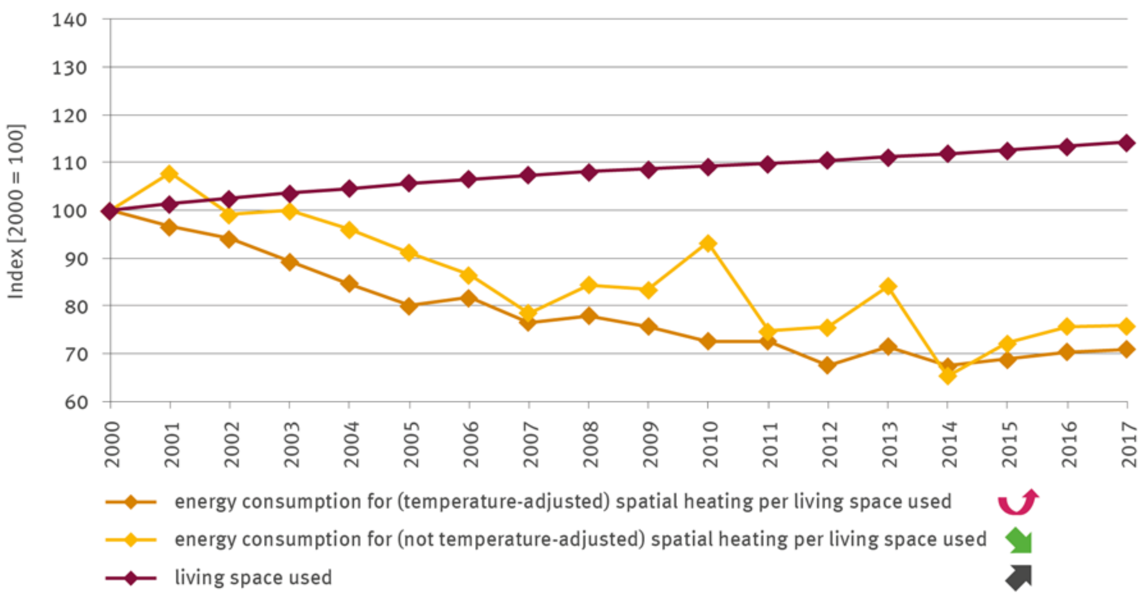
Climate-compatible urban planning and design safeguarding the retention and enhancement of inner-city green space is one approach towards avoiding or at least mitigating heat stress. Other measures approach the issue by tackling the extant building stock.

In order to protect interior rooms from overheating, active technical cooling methods are used in living and working premises. During the hot summers of recent years, this response was also applied in Germany. There was an exceptionally high turnover in mobile air-conditioning units for active cooling in apartments and houses. It must be said however that the use of air-conditioning is associated with increased electricity consumption which, in turn, leads to increased CO_2 emissions, in cases where the energy system is still mostly based on fossil fuels. This obviously runs contrary to climate protection efforts. In addition, the abstracted air from air-conditioning systems warms up the local urban atmosphere thus exacerbating bio-climatic problems. Passive cooling measures should therefore be given greater priority both in refurbishing extant housing stock and in the design of new developments.

In order to safeguard the interior climate and protect it from summer heat by means of structural measures, developers and architects will have to pursue two strategies concurrently. The first strategy is that the interior of a building is prevented from heating up in the first place, while the second ensures that warmth existing indoors is discharged to the outdoors with a minimum of energy expenditure. The latter can be achieved e.g. by natural aeration or ventilation systems, controlled nocturnal aeration, or counter-cyclical storage / discharge of hot or cold air. Examples for a pre-emptive protection of buildings from summer heat – the first strategy – include the careful design of window surface area proportions as well as the orientation of the buildings, to use external shade-giving elements and anti-sun glass, to green the façades and roofs of buildings or to provide buildings with good heat insulation, and last not least, to ensure conformity with high construction standards.

BAU-R-3: Specific energy consumption for space-heating by private households

The decrease by 2014 in temperature-adjusted energy consumption for space-heating suggests that apart from behavioural changes and the increasing use of more efficient heating systems, there has also been a successful implementation of construction measures for heat protection. These measures also have beneficial impacts on the protection of buildings from overheating in summer. Since 2015 the temperature-adjusted energy consumption for space-heating has increased again.



Data source: StBA (environmental-economic accounting)

Measures taken to ensure structural heat protection also serve to reduce the energy consumed ín the heating and cooling of buildings. In new buildings, requirements regarding heat protection are taken into account in the design and construction stages. In older buildings, energy-related refurbishment improves heat protection: in Germany approximately 1.4 % of building stock dating back to before 1979 are currently being modernised in this way.[50] These and other passive measures are capable of pre-empting the overheating of interior rooms. Alongside efficiency-enhancing measures and behaviour-related savings resulting from an increasing awareness of rising costs and environmental concerns, such developments are reflected in distinctly reduced energy consumption by private households in respect of space-heating. The reduced energy consumption in respect of space-heating may also suggest that there has been a change in the prerequisites for cooler indoor temperatures during periods of great heat.

Whether all measures mentioned above are implemented successfully, will be revealed by an examination of the progress made nationwide after adjusting for temperature differences, i.e. an arithmetical examination of the mean progress made in terms of private households adapting their heat energy consumption to the prevailing air temperature. However, it is not possible to make any other than rudimentary statements regarding the resilience of residential buildings in respect of overheating in periods of great heat. The same applies to premises not used for residential purposes which are not covered by this indicator.

In 2000, households still used (after adjustment for differences) more than 580 terawatt hours of heating energy; by 2016 the energy consumption had temperature decreased to 471 terawatt hours. With reference to the living space which increased markedly over the same period, this constitutes a significant decrease in temperature-adjusted energy consumption for space-heating by just under 20 %.

Good building insulation also provides protection from summer heat. (Photograph: © mitifoto / stock.adobe.com)

Interfaces

BAU-R-1: Recreation areas
BAU-R-4: Funding for building and refurbishment adapted to climate change

Objectives

Better adaptation to higher average summer temperatures and occasional extended hot periods in terms of building design and building technology (DAS, ch. 3.2.2)

Promotion of construction and refurbishment adapted to climate change

The improvements achieved in the course of recent years with regard to heat protection and the associated reduction in energy consumption in respect of buildings are partly due to a targeted funding policy. While maintaining comfortable living conditions during periods of great heat is not part of the funding criteria laid down in federal funding programmes, some of the structural measures supported also contribute to protection from summer-related overheating of buildings thus forming the basis for synergy effects between climate protection and adaptation.

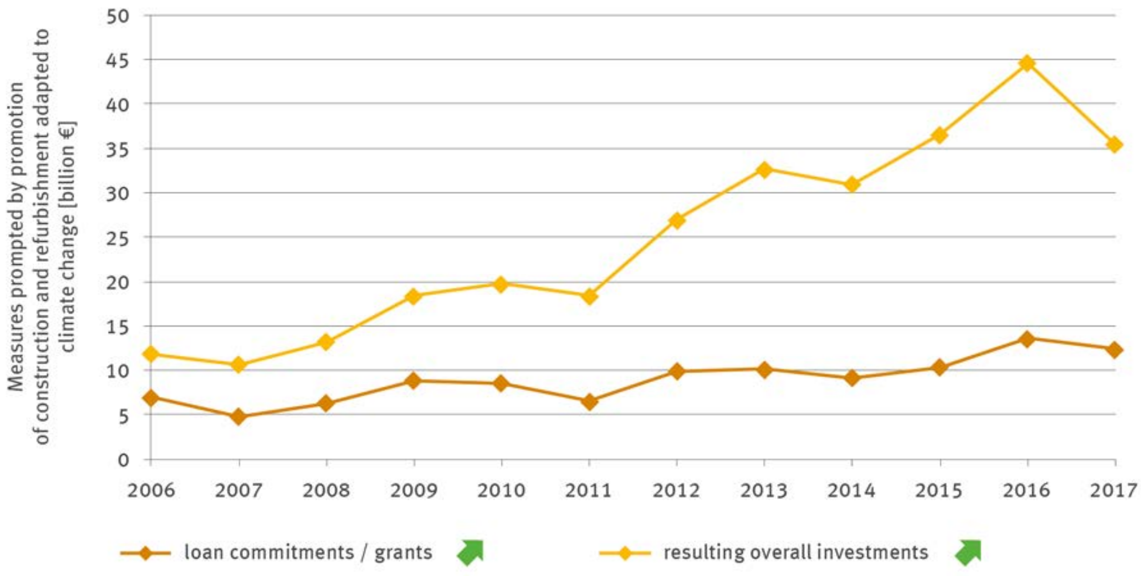
The federal funding programmes administered by the KfW make up another essential pillar of financial support for measures aimed at refurbishing buildings in terms of energetics and to achieve energy-efficient new buildings.

Between 2006 and 2017, the KfW provided funding in the amount of approximately 107.6 billion Euros, in 2017 approx. 12.3 billion Euros. These programmes are used to fund energy efficiency measures by means of investment grants or by loans at low interest rates in connection with repayment grants where these measures go beyond the legal requirements laid down in the German Energy Conservation Regulation (EnEV). By 2017, the funding scheme initiated a total investment volume of approximately 300 billion Euros.

In respect of KfW programmes financed by federal funding for the adaptation to climate change, loan commitments or grants amounting to between 4.8 and 13.6 billion Euros were approved annually in the past twelve years. Only such KfW programmes are considered relevant to climate-adaptation where two thirds of the funding is dedicated to measures which protect building from overheating in summer, e.g. by means of insulation or sun protection or measures which serve to control room climate and fresh-air supply. In 2017 these programmes led to the funding of more than 35.4 billion Euros worth of investment, which as a secondary function

BAU-R-4: Funding for building and refurbishment adapted to climate change

Every year the KfW awards federal funding in terms of loan commitments and grants amounting to between 4.8 and 13.6 billion Euros for energy-related construction and refurbishment measures which – subject to appropriate design – can also reduce the risk of problems with buildings overheating. Loan commitments and grants and associated investments have been increasing significantly since 2006. The indicator is unable to make any statements regarding precautionary measures against other influences of climate change.



Data source: KfW (funding report)

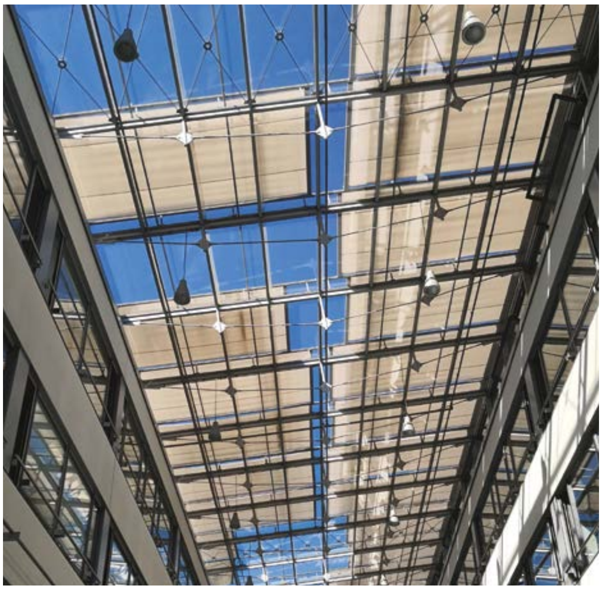
also supported the adaptation to climate change. There is no funding available in Germany targeted specifically and directly at the adaptation of buildings to climate change.

The protection of buildings from overheating as a result of climate change is a requirement which developers, proprietors of real estate and architects are obliged to fulfil. Summer-related overheating problems in buildings can be avoided to a considerable extent by implementing the measures mentioned above as well as other measures such as reducing the impact of internal sources of heat, incorporating a carefully considered design of large areas of glass or the use of solid components for temperature equilibration.

In addition, it is essential to adapt and protect buildings structurally from the increasing incidence of extreme events such as heavy rainfall and driving rain, storms and tornados, hailstones or snow loads. It is true that the high standard of building design, technology and construction prevailing in Germany essentially ensures that buildings and construction practices fulfil a wide range of requirements regarding the challenges of weather and weather-related changes. However, the precautions provided within the framework of this standard will not be adequate to all impacts caused by the afore-mentioned extreme events.

Individual buildings can be fitted with elements of protection from extreme heat or they may be fitted with protective wire guards and protective glass to ward against damage from hailstones, or properly fastened roofing material or integrated solar thermal or photovoltaic systems fitted inside the roof structure for storm protection. There are numerous measures available for protection from flooding and heavy rain. They range from waterproofing by means of bituminous sheeting or waterproof concrete structures over drainage units, or pumps, to backflow preventers in sewage systems. However, it is particularly difficult to protect individual buildings from flooding. This is why building projects proposed for areas with increased damage potential from such hazards are avoided in precautionary spatial and urban planning.

As far as new buildings are concerned, appropriate adaptation requirements can be taken into account already at the design stage, for instance by selecting robust materials and using methods to achieve stable construction. Naturally, this will result in increased construction costs. The implementation of adaptation measures for extant buildings by means of retrofitting waterproofing to cellars as protection from water pressure is usually difficult and costly. In all probability it will be possible, however, to resolve most climate-related problems by means of refurbishing and modernisation measures.



Likewise, sun protection measures can also be funded under the auspices of KfW.
(Photograph: © Armin Hering / stock.adobe.com)

In principle it is up to the developer or proprietor of the premises concerned to implement such measures and to ensure that their premises are adequately protected from climate-related risks.

Interfaces

BAU-R-3: Specific energy consumption for space-heating by private households
RO-R-3: Priority and restricted areas for (preventive) flood control

Objectives

Long-term reduction of heating requirements in building stock with the aim to achieve a virtually climate-neutral building stock by 2050. (Energiekonzept 2010, p. 22)

As far as possible, measures for adaptation to climate change should not counteract any efforts made with regard to climate protection, or in other words, priority is to be given to alternatives which concurrently contribute to the lowering of greenhouse gas emissions and, by the same token, to investments in retrofitting buildings with appropriate insulation. (DAS, ch. 3.4)

Still not enough insurance deals to cover natural hazards

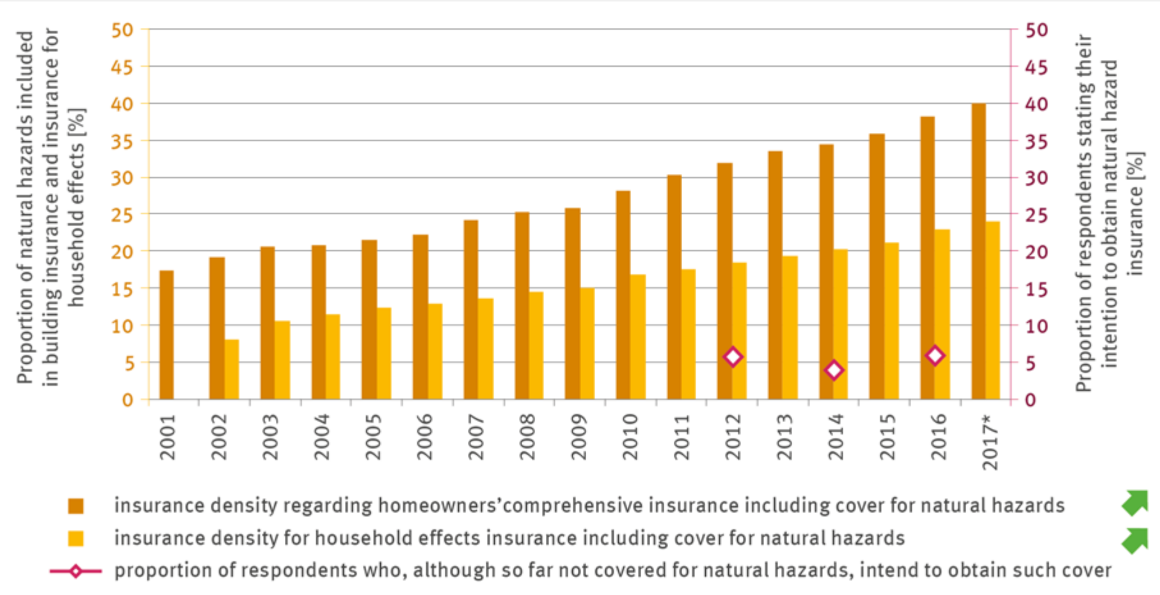
By now, taking out homeowners insurance for storm and hailstone damage is almost a matter of course among homeowners. By contrast, the necessity to conclude insurance contracts for other extreme natural hazards such as heavy rain and floodwater has not yet met with broad acceptance even though precisely in respect of these hazards it is feared that there will be an increase owing to climate change, and that heavy rainfall events are bound to occur regardless of location. Such events can therefore happen anywhere causing damage to a homeowner's building and household effects.

In past cases of damage both private individuals and traders who incurred the damage, used to receive government and non-governmental aid. This happened for instance after the extreme floodwater event in August 2002 which caused damage totalling more than 11 billion Euros. Only some of these premises were insured. A trust was set up entitled 'Reconstruction Aid' (Aufbauhilfe) for reconstruction and damages. The Trust was financed with 3.5 billion Euros from federal funds and from 3.6 billion Euros from Länder funds. From these amounts, 923 million Euros alone were awarded to the refurbishment of damaged residential buildings and for the replacement of damaged or destroyed components of buildings. The damage caused by floodwater in June 2013 in which the Länder of Saxony-Anhalt, Saxony, Bavaria and Thuringia were most affected, amounted to approximately 8 billion Euros. In this case the Federal Government and the Länder awarded floodwater aid amounting to 3.7 billion Euros for the Länder in the central part of Germany.

In view of the considerable sums spent on floodwater aid and because government aid cannot cover all privately incurred damage, the Federal Government is appealing to homeowners and tenants to make largely their own provisions thus reducing both the damage incurred and the demands made on government aid. Any person who might at some stage become affected by floodwater is legally obliged to take the necessary precautionary measures. In addition to structural measures, it is part of this personal provision to make sure, above all, that adequate insurance cover is in place. In 2017 the Minister-Presidents of the Länder agreed that in future only those homeowners can expect to receive aid beyond emergency relief, who had been unsuccessful

BAU-R-5: Insurance density of extended natural hazard insurance for residential buildings

The insurance for natural hazards (eEV) complements the home-owners' comprehensive insurance and the insurance for household effects covering damage e.g. caused by flooding, heavy rain, snow load and avalanches. Although the eEV insurance density has increased significantly in recent years, looking at it nationwide, it is still relatively low, i.e. with 43% for building insurance and with 24% for household effects insurance.



* preliminary value

Data source: GDV; BMUB & UBA (Umweltbewusstsein in Deutschland) in securing an insurance deal or if they had been offered a policy at economically unreasonable terms and conditions.

Extended insurance against natural hazards (eEV) – which covers so-called damage from natural hazards – is now acknowledged as a well-established product in the insurance market. However, by late 2018 only 43 % of residential buildings were covered by eEV. As far as tenants are concerned, it is relevant to conclude insurance policies covering household effects for damage caused by natural hazards, because damage to buildings – caused by natural hazards, especially if this damage occurs in rooms at ground level or in cellar rooms – can also be caused to a tenant's household effects. By 2017, however, a meagre 24 % of all policies for household effects incorporated insurance cover for natural hazards.

Even if the number of policies concluded were to rise continuously, the awareness of the necessity to have eEV insurance has still not penetrated the consciousness of sufficiently large parts of the population. The hazards are underestimated by the public, and their knowledge regarding which kind of damage is actually covered by an insurance policy they may have concluded is woefully inadequate. In the past, extreme events used to produce a temporary surge in the public's willingness to take out insurance cover. The outcomes of a representative public survey carried out every two years on behalf of the UBA, entitled Environmental Awareness in Germany (Umweltbewusstsein in Deutschland)[I] indicate that even for the next few years it is futile to expect any sharp rise in the density of insurance cover. In 2012 just under 6 % of respondents stated that although they had not yet concluded an eEV policy, they would like to conclude such an insurance policy in future. Two years later this percentage had declined to just 4 %. A recent survey carried out in 2016 resulted in an outcome of 6 %. It is therefore obvious that so far there is no distinct trend discernible.

In an effort to appeal to the public's sense of responsibility and to promote an increase in personal provision, politicians, the insurance industry and consumer protection organisations in several federal states are all acting in concert. By late 2018, already ten Länder had implemented or started campaigns to inform the public and to inspire people to conclude appropriate insurance deals.

I The representative population survey (of German-speaking residents aged 14 or more years) entitled Environmental Awareness and Behaviour in Germany (Umweltbewusstsein und -verhalten in Deutschland) (has been carried out every two years since 2000 on behalf of the BMU and the UBA. Since 2012, questions were incorporated in the survey intended to supply data for the DAS monitoring indicators; from 2016 onwards, these questions were asked every four years in the environmental awareness surveys.

A natural hazards policy provides cover including for damage caused by floodwater and heavy rain.
(Photograph: © elmar gubisch / stock.adobe.com)

The underwriters are in a position to insure almost all buildings and homes in Germany and, most of them would also be able to offer cover for natural hazards at affordable prices. Exceptions are only made in respect of a few areas where the hazards are particularly great. But even in those cases individual insurance solutions can be found, i.e. by incorporating high elements of 'excess' (a pre-determined amount deducted from the total settlement received by the claimant) and higher, risk-congruent insurance premiums.

However, in addition to taking out insurance policies, every citizen ought to take the necessary precautions to protect themselves from potential damage. This includes taking measures with regard to construction and systems technology appropriate for the protection of homes (houses/flats) both before, during and after an extreme event.

Interfaces

WW-I-3: Floodwater
BAU-I-5: Claims expenditure for property insurance
BAU-R-4: Funding for building and refurbishment adapted to climate change
RO-R-6: Settlement use in flood-risk areas

Objectives

Supporting the personal provision of floodwater protection (DAS, ch. 3.2.3)

Active management of risks and opportunities by banks and insurance companies (DAS, ch. 3.2.10)

© Stefan Loss / stock.adobe.com

Energy industry (conversion, transport and supply)

In view of the expansion of renewable energies and coal-fired generation as well as nuclear energy being phased out, essential structural and infrastructural adaptations are required which affect all sectors of the energy industry. This includes the expansion of transmission and distribution networks, the modernisation and decarbonisation of the power plant fleet and the flexibilisation of the energy system by means of various options. Current energy management planning decisions are, by various options, linked to long-term investments. In order to safeguard stable energy supply under changed climatic conditions, these requirements must take account of adaptations to climate change.

Numerous companies have already been affected by the consequences of weather extremes and extreme weather patterns, which in future, as a result of climate change, are likely to become more frequent and more intensive. The spectrum of aspects likely to be affected ranges from resource extraction and logistics to energy conversion and distribution to consumers, involving all links in the energy management and production chain. At present, the consequences of hot periods e.g. in 2003, 2006 and 2018 are still remembered, when electricity generation by nuclear and thermal power plants was heavily restricted due to low water levels. Grid operators, in particular, had to bear the brunt of impacts from winter storms.

The nationwide analysis of climate impacts and vulnerability carried out between 2011 and 2015, entitled 'Netzwerk Vulnerabilität'[51] gave a low ranking to the vulnerability of the energy industry to impacts of climate change based on high adaptation capacity. Exempted from this assessment was the availability of coolant water for thermal power plants. However, as a result of the energy 'revolution' and the associated declining importance of thermal power plants as well as technical adaptations made in coolant technology, the availability of coolant water has also become less important.

Effects of climate change

Adaptations

Germany's power supply – despite climate change one of the world's safest

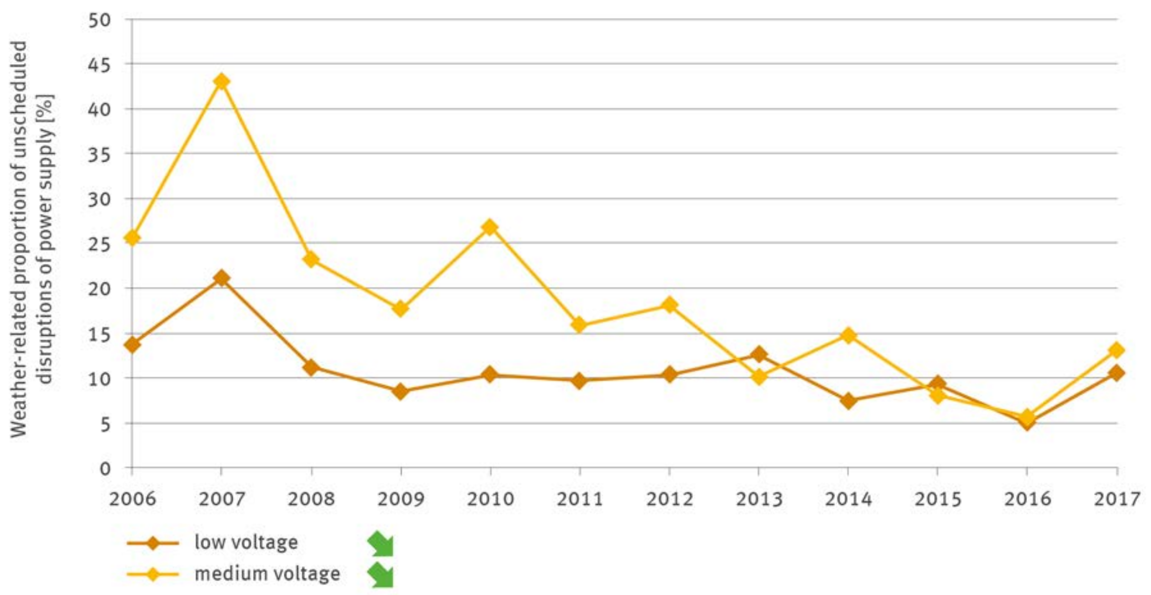
The fact that disruptions in power supply are infrequent and very brief shows that Germany has a very reliable power supply. In Germany, the Federal Network Agency (BnetzA/Bundesnetzagentur) is responsible for any disruptions in power supply. As part of its remit the BNetzA evaluates reports made by grid operators on disruptions of more than three minutes' duration regarding medium and low voltage supply which make up the distribution network. The BNetzA differentiates between various causes of disruption in the supply network. For example, the agency categorises wind and temperature effects or overvoltages due to lightning strikes collectively as 'atmospheric impacts'. Events of particular severity such as extraordinary floodwater or hurricanes are classed as 'force majeure'. Such events can entail prolonged adverse effects, for when grids are disconnected over long distances, essential repairs can sometimes take a long time.

Germany has one of the world's most stable electricity networks. Nevertheless, extreme weather events and certain weather patterns can affect the transmission and distribution of electricity. The impacts of hurricane Cyril in 2007 were particularly striking. In that year, the number of disruptions was twice as high as recorded in most previous years. Owing to the weather or certain weather patterns, end consumers were in that year left without electricity for on average just under 22 minutes. By comparison, this value fluctuated between 3 and 7.5 minutes in subsequent years. In 2010 higher figures can be attributed to hurricane Xynthia, and in 2017 the storms named Herwart and Xavier caused disruptions in power supply.

If extreme weather situations – above all severe storms and hurricanes – become more frequent owing to climate change, associated disruptions in power supply may become more frequent too and their duration may increase, unless networks are appropriately engineered and maintained. Whether electricity networks become affected depends, apart from atmospheric impacts,

EW-I-1: Weather-related disruptions of power supply

Extreme weather events such as the hurricanes Cyril (2007), Xynthia (2010) and, latterly, Herwart and Xavier (2017) became notable markers in the power supply disruption statistics. The proportion of atmospheric impacts in all these cases of disruption and force majeure was clearly striking in those years. Looking at the overall time series, weather-related disruptions indicate falling trends.



Data source: BNetzA (failure statistics) also on the quality, maintenance status and age of technical components used in the network. Since 2010 investments in and expenditure on new installations, expansion, extensions, maintenance and upgrades have increased continuously. This is why grid lines, transformers and circuit breakers used in the German transmission network are considered to be fully functional.[52]

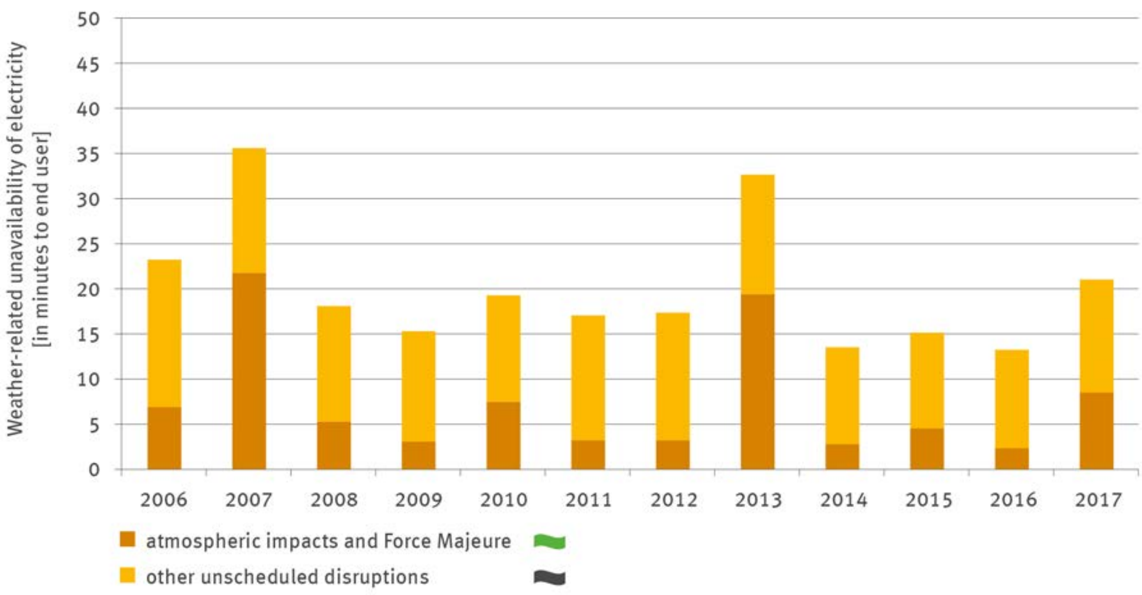
Likewise, the network structure is also one of the key determinants. So far, approximately 95 % of extra-high and high-voltage transmission lines are routed above ground thus being directly exposed to wind and weather. However, the nodes of this grid are interconnected (meshed). A high degree of meshing contributes to high reliability of supply. In case of the failure of individual lines, the supply can usually be re-routed via other, so-called redundant lines (n-1- safety). This is why the ultimate consumer does not usually suffer loss of electricity supply from disruptions in the transmission network. Effective protection from storms, snow loads or ice loads can be achieved by routing electricity lines (cabling) underground. An Act passed in 2015 on changing the regulations governing the construction of energy networks legalised the underground routing of new extra-high and high voltage cabling by prioritising this type of construction as a planning principle in federal planning regulations. Besides increasing the acceptance of network expansion[53] underground cabling also contributes to a higher resilience of networks to climate-related impacts. Concurrently, there is ongoing research on selected pilot routes to establish to what extent underground cabling might be used with regard to three-phase current lines.

Objectives

Operators' commitment to operate a safe, reliable and efficient energy supply network (EnWG, § 11 (1))

EW-I-2: Weather-related unavailability of power supply

Compared to other years, hurricane Cyril in 2007 caused severe and extensive damage to the electricity networks. In 2007, this led to a cumulative duration of disruption in power supply of just under an average of 22 minutes per client connected to the grid owing to weather-related events.



Data source: BNetzA (failure statistics)

Heat impacts on electricity generation in conventional power plants

In recent years, the energy transition associated with phasing out nuclear and coal-fired energy production, has resulted in thermal power plants becoming less important in the energy system. Its role will decline further for years to come. By contrast, renewable energies were able to increase their share of gross electricity consumption to almost 38 %.[54]

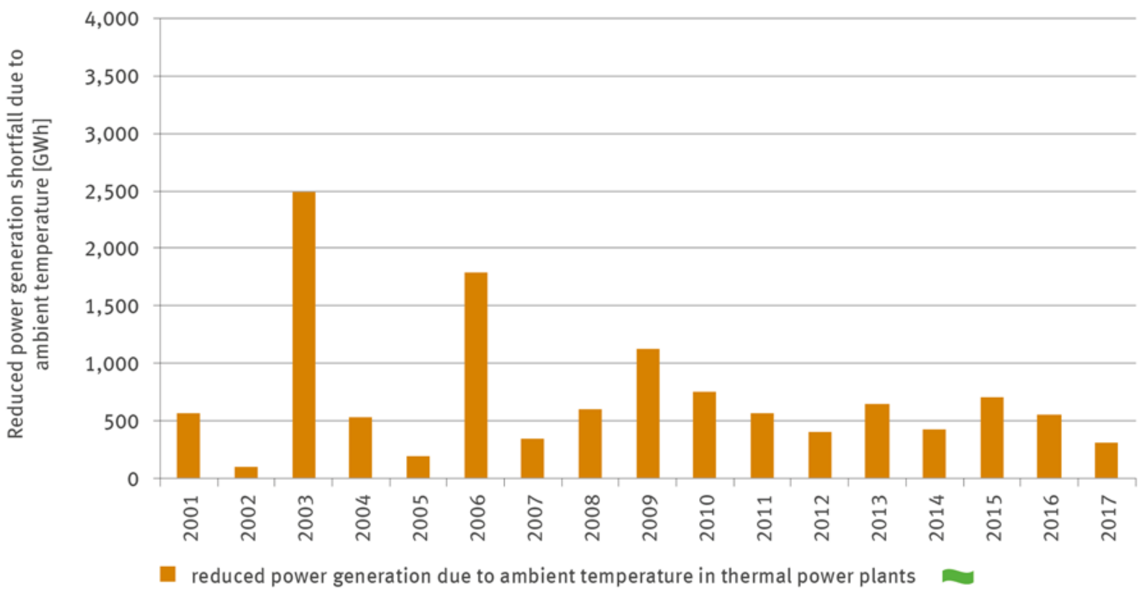
Despite the considerable increase in the contribution of renewable energies to electricity supply in recent years, thermal power plants will continue to play an important role in the German energy supply system for some time.

Owing to their operating principle, thermal power plants depend on the discharge of process heat by means of cooling. Usually, in water-rich Germany water is used for cooling purposes. In the case of freshwater cooling systems the water abstracted from a river is cooled down either directly by means of continuous-flow cooling or fed back into the water course after the cooling process in a cooling tower (drainage cooling). Circulatory cooling systems require a distinctly smaller supply of water from water courses.

If ambient heat and drought prevent process heat from being discharged in sufficient quantities, the degree of efficiency of cooling systems and thus also of power plants declines. Above all however, low water levels and increased temperatures in water courses may trigger the imposition of legal restrictions on water usage. These regulations stipulate how much freshwater for cooling purposes may be abstracted from water courses and to what extent and at what temperature heated coolant water is permitted to be discharged back into the water course. This can mean that in hot weather and drought conditions, the operator has no option but to reduce electricity generation in the power plants in question or even to cease production entirely.

EW-I-3: Reduced power generation due to ambient temperature in thermal power plants

Heat and drought can restrict electricity generation in thermal power plants by impairing the degrees of efficiency or as a result of problems with coolant water abstraction or the discharge of coolant water into water courses. Although the hot summers of 2003 and 2006 resulted in striking deficiencies, a significant trend has so far not been discernible. Detailed data for 2018 have not yet become available.



Data source: VGB PowerTech e.V. (non-availability-module of power plant-information system KISSY)

In recent years, the hot summers of 2003, 2006 and 2018 have demonstrated the consequences that electricity generation may be exposed to as a result of heat and drought. In 2018 there were not just problems owing to temperature-related restrictions on the availability of coolant water; there were also difficulties with the supply of coal, as low water levels restricted the availability of transport.

In 2003, 38 nuclear power plants were forced all over Europe to cut their electricity generation during the summer heat. In Germany this applied e.g. to power plants in the Isar and Rhine basins. In 2006, there were restrictions to electricity generation owing to coolant water temperatures in thermal power plants on the banks of the rivers Weser and Elbe. In those years, the competent water authorities had to grant exemptions from legal regulations in some cases in order to safeguard the reliability of supply.

The time series on restricted electricity supply illustrates the amount of electricity which thermal power plants were unable to generate owing to temperature-related external influences. This illustration is based on data regarding just under two thirds of the installed capacity of thermal power plants in Germany. So far, the most incisive restrictions were recorded in the hot summer of 2003. In that year the deficit in electricity generation totalled 2.6 terawatt hours.

Hot and dry summers may give rise to difficulties with the abstraction or discharge of coolant water.
(Photograph: © Markus Volk / stock.adobe.com)

Interfaces

EW-R-4: Water efficiency of thermal power plants

Objectives

Increasing the safety of supply especially in cases of extreme events by complementary decentralised and diversified generation structures which include renewable energies (DAS, ch. 3.2.9)

Determining and assessing potential supply risks and establishing measures for the reduction of any such risks (DAS, ch. 3.2.9)

Energy supply – spread among several sectors and increasingly renewable

Especially in view of the increasing frequency and intensity of extreme weather events and their consequences, there is hardly an energy carrier who is likely to remain unaffected by the impacts of climate change. The potential impacts of climate change vary depending on the energy carrier concerned and therefore require different adaptation measures. In order to minimise the risks pertaining to the reliability and quality of the energy supply system as a whole, a reduction in the total end energy consumption and risk-abating spatial distribution of energy infrastructures are required, thus serving as essential building blocks. Likewise, the energy supply structure which makes use of several energy carriers and types of power plants, plays a part in helping to distribute – thus reducing – the risks of future impacts from climate change among various sectors.

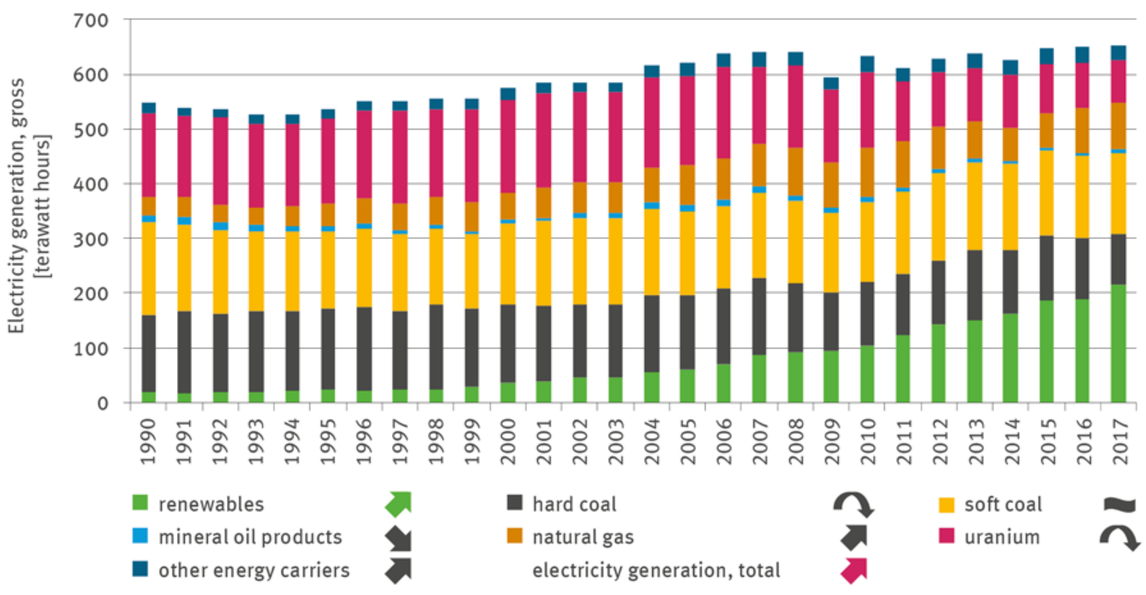
The framework for the future mix of energy carriers in Germany is set by energy and climate protection policies which lay down the requirements for achieving the ultimate replacement of all fossil-fuel and nuclear energy carriers by climate-compatible renewable energies. Even so, the question of how the future mix of various energy carriers might be structured in view of climate change remains to be clarified.

Guidelines issued over recent years by energy and climate policies have triggered high dynamics in the energy industry and caused a shake-up in the energy carrier mix. This is true in particular for electricity generation where the share of renewable energies has risen sharply. Declining tendencies in electricity generation were observed especially with regard to hard coal and nuclear energy whereas the share of gas, and in recent years increasingly also soft coal (known for high CO_2 emissions) experienced gains.

As far as end energy consumption for heating (spatial heating, hot water, process heat) as well as refrigeration (air conditioning, process cooling) is concerned, the

EW-R-1: Diversification of electricity generation

While electricity generation is still increasing, guidelines set in recent years by energy policies, have produced a structure that is more firmly based on renewable energies thus aiding the distribution of risks at the same time as supporting the adaptation to climate change. In this way, the goals of climate protection and adaptation to climate change can be combined, especially by the increased use of renewable energy carriers known for emitting less CO_2.



Data source: Arbeitsgemeinschaft Energiebilanzen (gross electricity generation) share of renewable energy also posted gains. However, in this case the transformation process is progressing more slowly and differently compared to electricity generation. For example, there were no clear trends discernible with regard to district heating and CO_2-intensive soft coal, whereas the use of mineral oil and gas – the foremost energy carrier in this type of applications – posted a significant decline. In the final analysis, the overall energy supply, especially with regard to electricity generation, is nowadays distributed among more sectors than in the beginning of the 1990s.

In an assessment of developments towards a more environment-compatible, reliable and economical energy system which is low in greenhouse gas outputs at the same time as being climate-resilient, it is important to analyse in particular the climate-related risks faced by energy carriers and to account for these risks in development concepts for the energy landscape of the future. That notwithstanding, the increase in renewable energy carriers in both electricity generation and end energy consumption for heating and refrigeration purposes has led towards a more diversified energy carrier mix which contributes to climate protection by means of avoiding the emission of greenhouse gases, at the same time as helping to achieve a more wide-ranging distribution of risks as it supports the adaptation to climate change.

Interfaces

BAU-R-3: Specific energy consumption for space-heating by private households

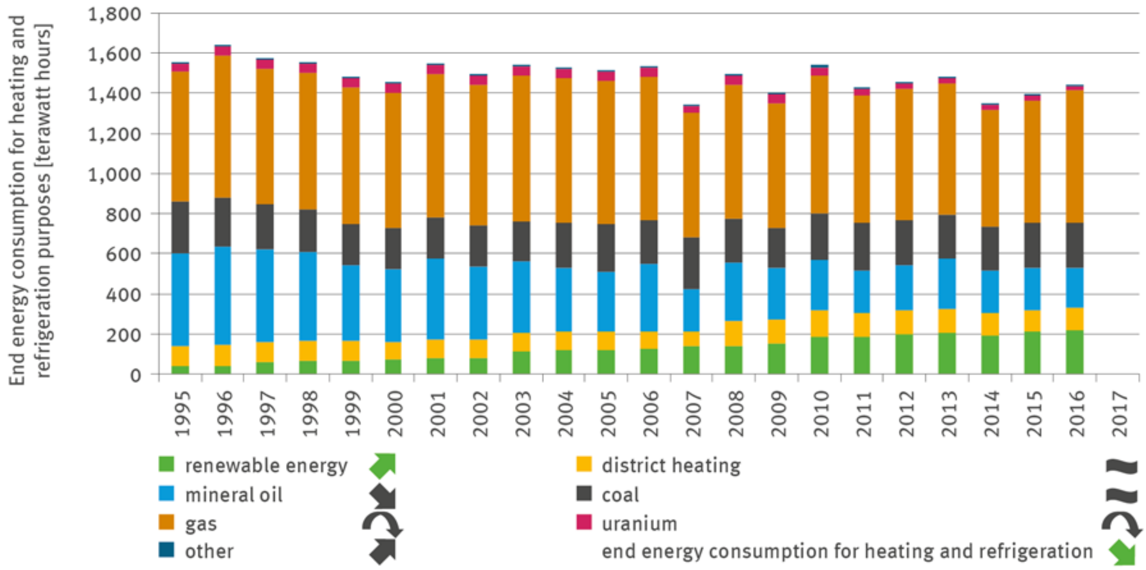
Objectives

Increasing the safety of supply by complementary [...] diversified generation structures which include renewable energies (DAS, ch. 3.2.9)

Safe [...] supply of electricity and gas to the public, based increasingly on renewable energies (EnWG, § 1 (1) 1)

EW-R-2: Diversification of end energy consumption for heating and refrigeration

For several years, more intensive, especially seasonal fluctuations have been observed in the end energy consumption for heating and refrigeration, with developments differing markedly between energy carriers. A positive development also in this case is the more wide-ranging distribution of risks owing to the rising trend for renewable energy carriers which, at the same time, contributes to climate protection.



Data source: Arbeitsgemeinschaft Energiebilanzen (application balances, gross electricity generation); Arbeitsgruppe Erneuerbare Energien-Statistik (time series on renewable energies)

Flexibilising the electricity system

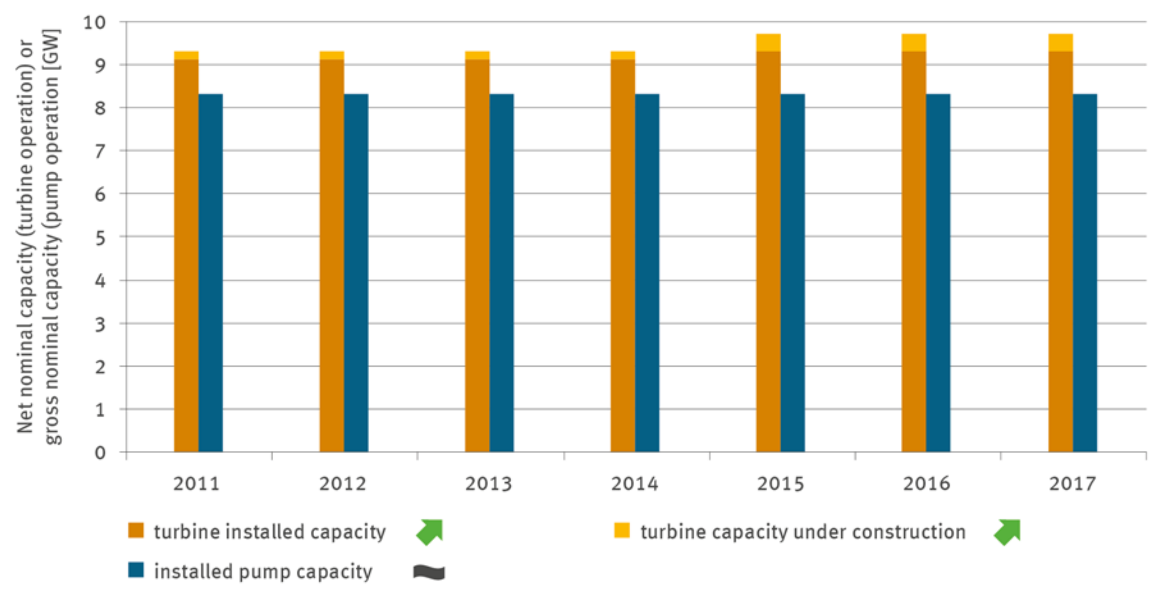
While conventional electricity generation used to respond to demand, electricity systems nowadays have to integrate the weather-dependent infeed of electricity from renewable energy sources. The requisite flexibilisation of the overall system is achieved by the expansion and enhanced utilisation of electricity networks, by competition among flexible electricity producers and by means of storage within the electricity market. In order to achieve a large-scale equilibrium of generation and demand, the expansion of electricity networks is being promoted. In this way and by means of intensified links with the networks of European neighbours, it is possible to access the most economical locations of electricity generation. This approach also supports the adaptation of the electricity supply system to climate change, for instance in future cases when temporarily increased as well as regionally occurring imbalances between electricity supply and demand may arise. When there are bottlenecks in grid operation, network operators have to adopt the most efficient remedy available at that particular time. To that end, they might, for instance, access suitable generation and storage facilities (within the scope of Redispatch) as well as flexible loads (within the scope of regulations on interruptible loads).

The demand for electricity is met by flexible generators, load and storage facilities competing in the electricity market. When as many providers as possible – open to various technologies – compete in the electricity market with regard to meeting a specific demand, or – as the case may be – for utilising overcapacities, this will spread the risk of individual shortfalls thus ensuring that in each case the most favourable provider secures the deal.

Through the abstraction of electricity, i.e. the electricity consumption required for filling storage facilities and subsequently feeding this electricity back into the electricity system, storage technologies can cushion increasing fluctuations in electricity generation from renewable energies. For example, apart from battery storage facilities, power-to-gas (PtG) facilities can contribute to the flexibility of the electricity system. To a minor extent, the hydrogen produced in this process as well as methane, to a major extent, can be fed into the extant natural gas

EW-R-3: Electricity storage options

At present, pumped-storage power plants are the most important technology for the storage of energy on a major scale. For generating electricity, these power plants have a turbine installed capacity of approximately 9 Gigawatt; for filling the storage facilities, pumps are installed with a total capacity of approximately 8 Gigawatt.



Data source: BNetzA (monitoring according to § 35 EnWG, power plant list) network where they can be stored. On demand, the gases fed into this network can be reconverted. Compared to the direct use of electricity, PtG is more expensive owing to the loss of efficiency, and it requires additional renewable energy capacities. However, this option is limited due to lack of space and lack of public acceptance.

In Germany, the storage technology with the greatest productivity and capacity is currently embodied in pumped-storage power plants. During the storage process, water is transported by pumps from a lower to an upper reservoir using electrical energy. At a later stage, the energy stored in the water is used during the process of discharging water from the upper into the lower reservoir, to drive a turbine and to generate electricity in a generator. In Germany, pumped-storage power plants have a turbine installed capacity of 6.2 Gigawatt (GW); in addition, power plants in Luxemburg (1.1 GW) and Austria (1.8 GW) are linked to the German electricity network. In theory, the turbine installed capacity is available for as long as the turbine operation in all power plants can be fed by the water from the upper reservoirs, i.e. for approximately three to four hours. After that point, the capacities of the storage facilities are successively exhausted which means that the turbine capacity becomes less and less available for electricity generation.

A further expansion of pumped-storage power plants in Germany would come up against a variety of objections thus limiting its likelihood. Such projects often meet with massive public resistance among residents and people looking for rest and recreation, not least in view of substantial encroachments on nature and landscape. Furthermore, potential sites for pumped-storage power plants are usually not located in places where a surplus of renewable energy is produced. However, there has also been a change in terms of economic circumstances. High infeeds of electricity from photovoltaic units at lunchtime mean that lunchtime peaks in electricity prices at the electricity exchange tend to bottom out, thus decreasing revenue streams from pumped-storage power plants.

Against this background, the technological advancement of storage technologies, alongside increased flexibilisation of electricity generation and demand, would make good economic sense in order to achieve essential cost savings. Currently, various technologies are being scrutinised and there is ongoing work on the advancement of hydrogen and other gas and battery storage facilities.

Pumped-storage power plants such as these at Edersee can contribute, both in terms of consumption and generation, to controlling the electricity supply system.
(Photograph: © parallel_dream / stock.adobe.com)

Objectives

Medium-term access to available German potentials for pumped-storage power plants within the scope of technical and commercial opportunities; intensification of research into new storage technologies and providing support for the achievement of market maturity (Energiekonzept 2010, p. 21)

Water shortage as a problem for conventional thermal power plants

In hot and dry summers, the supply of freshwater for cooling purposes can become a bottleneck for electricity generation in thermal power plants which are dependent on the availability of coolant water. However, thermal power plants make a minor contribution to electricity generation in the course of energy transition. The demand for coolant water will therefore play a diminishing role in the future progress of energy transition.

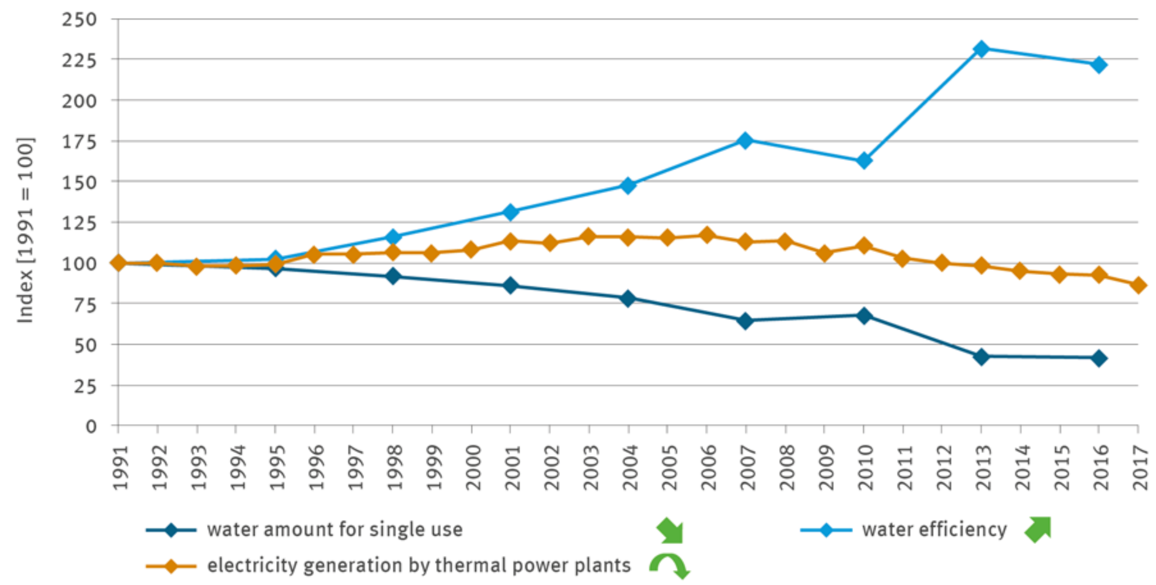
So far the energy industry is still by far Germany's largest consumer of water. More than half of all the groundwater and surface water abstracted in Germany is used in the process of energy supply, especially for refrigeration purposes in thermal power plants.

Just under 95 % of the water used for cooling purposes in energy supply is used in continuous-flow cooling systems. Commercially speaking, continuous-flow cooling systems were considered the most efficient; that is why this became the most common type of cooling system applied in German power plants. On the other hand, this is also the most water-intensive cooling system. The coolant water is abstracted from a water body and used for cooling just once in the power plant's steam cycle. Subsequently, the heated water is returned to the water body. Dependent on the location, cooling towers may be used in this process in order to reduce the temperature of coolant water and to avoid any undesirable or prohibited heating effects in rivers into which the water is returned.

In order to pre-empt shortages, it is possible for instance to decrease the coolant water demand for thermal power plants by means of technical measures. The use of circulatory cooling systems can result in a distinct decrease of water demand in thermal power plants. In this case, cooling can take place in an open system (wet cooling) or a closed system (dry cooling). In open systems, water abstraction from water bodies is required only for the compensation of evaporation losses; compared to continuous-flow cooling, this amounts to just 2 to 3.5 %.

EW-R-4: Water efficiency of thermal power plants

As a result of increased efficiency and measures such as multi-use or recycling, the application of freshwater for cooling purposes declined significantly. In 2010 it had decreased by a third compared to 1991 figures. Overall, the demand for coolant water for use in thermal power plants will play a diminishing role in the course of energy transition.



Data source: StBA (environment statistics; monthly report on electricity supply)

In dry cooling the heat is discharged to the air by means of convection using a heat exchanger. In this case, there is no evaporation loss, i.e. the requirement for water is minimised. It is also possible to combine the two systems in so-called hybrid coolers.

Alongside the increasing use of water-saving technologies, the technical optimisation of thermal power plants plays an important part in water efficiency. In past years it was possible to achieve a considerable increase in the degrees of efficiency of power plants by using fossil-fuel energy carriers. As a result of such developments water efficiency increased continuously. At the same time, nuclear power plants and hard-coal power plants make a minor contribution toward electricity generation. Consequently, it is not quite foreseeable at present what importance might be attributed to a water-saving application of coolant water.

Water-efficient cooling systems are less dependent on freshwater and less vulnerable to drought periods.
(Photograph: © fototrm12 / stock.adobe.com)

Interfaces

EW-I-3: Reduced power generation due to ambient temperature in thermal power plants
WW-R-1: Water use index
WW-I-4: Low water

Objectives

Consideration of technical methods and enhancements to achieve more efficient cooling in power plants in line with the principle of proportionality (DAS, ch. 3.2.3)

Determining and assessing potential supply risks and establishing measures for the reduction of any such risks (DAS, ch. 3.2.9)

Transport, transport infrastructure

In recent years, extreme weather events and weather patterns have repeatedly caused major traffic disruptions. These events are increasingly associated with changing climatic conditions thus indicating that potential impacts from climate change will affect transport carriers such as road and rail as well as inland and marine shipping in equal measure.

Whenever rail services and municipal transport organisations have to suspend operations in respect of local and long-distance traffic, the consequences often affect large contiguous areas. In autumn 2017, for example, triggered by the low-pressure system Xavier, this affected the short-distance traffic from Berlin and Hamburg as well as all rail routes in the areas of Schleswig-Holstein, Lower Saxony, Bremen, parts of Mecklenburg-Vorpommern and the important long-distance routes between Berlin and Hamburg as well as between Berlin and Hanover. Again and again, it is necessary to close route sections damaged by heat resulting in so-called blow-ups. This occurs in older motorways of concrete construction where concrete slabs expand and due to the resulting tension jerk up suddenly. Flooding events are another cause of road closures, as for instance in connection with the floodwater from Danube and Elbe in 2013 where long sections of motorways A3 and A8 in Bavaria had to be closed owing to flooding. In late summer 2018, inland shipping on the Rhine was subjected to severe restrictions owing to low water levels.

So far there are still major uncertainties whether the nature of impacts from climate change will be of particular relevance to transport. This is why various federal authorities use specific research programmes to address potential climate change impacts on the transport industry in order to examine potential options for action. One objective of this research is to clarify which measures should be given top priority to ensure that the transport system will continue to cope with the demands of a mobile society.

Effects of climate change

High and low water levels – problems for shipping on the Rhine

In meteorological terms, 2018 was an extraordinary year which demonstrated how dependent Rhine navigation is on the weather and prevailing weather patterns. Great amounts of precipitation fell in the mild month of January, especially as rain, making streams and rivers swell. The Rhine's water levels exceeded the relevant floodwater marks so that shipping had to be suspended temporarily on all sections of the river. As the year progressed, temperatures remained high and precipitation largely failed to materialise. On the Rhine, this led to an unusually long low-water phase in late summer and autumn which was associated with draught restrictions being imposed on inland shipping. As far as consumers were concerned, they had first-hand experience of these impacts in terms of rising petrol prices. As it was no longer possible for tank barges to navigate the Rhine owing to the maximum permissible draught and because, at around the same time, a major fire put a Bavarian refinery temporarily out of operation, petrol became rather scarce and expensive at filling stations in the south of Germany.

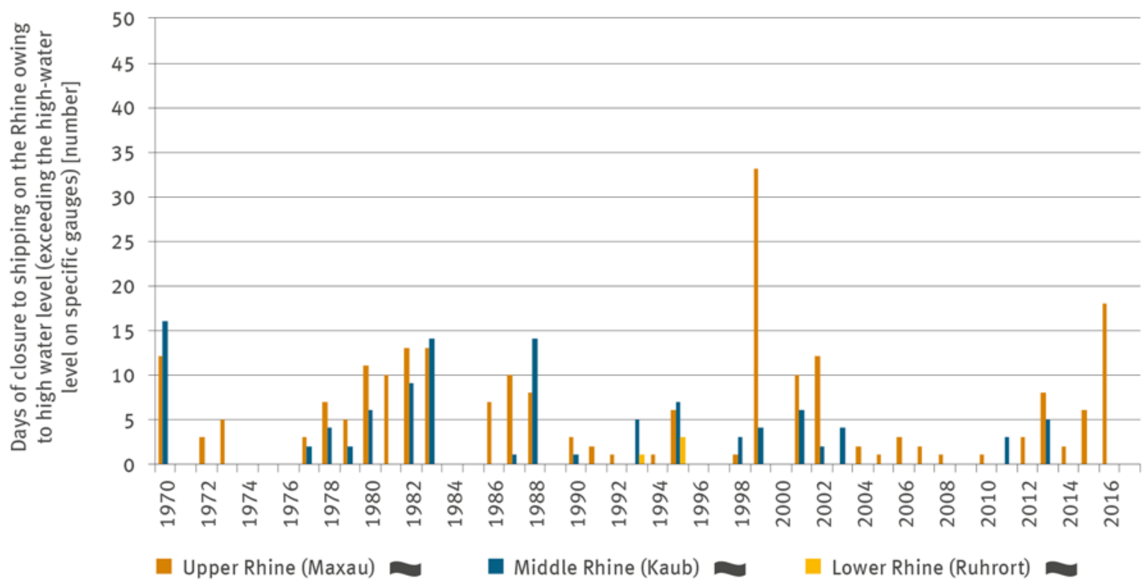
In 2018, the total freight carried by Germany's inland vessels was down by 25 million tonnes compared to the previous year, representing a decline by 11.1 %.

The Rhine is Germany's most important inland waterway. The river enables cost-effective and environmentally sound transport of goods, facilitates imports and exports via North Sea ports in Belgium and the Netherlands, and it links important industrial centres within Germany.[55] More than 80 % of goods transported by Germany's inland shipping are conveyed via the Rhine. Whenever high and especially low water levels lead to restrictions imposed on Rhine shipping , this can entail – in some cases considerable – impacts on individual companies or complete production and delivery chains. Such impacts can range from increased transport costs to production losses in companies operating just-in-time production.

The rules governing Rhine shipping are contained in the pertinent police regulation (Rheinschifffahrtspolizeiver

VE-I-1: High-water closures to shipping on the Rhine

Over the past 30 years high-water closures have affected Rhine shipping, especially on the Upper Rhine. In 1999 and 2016 inland shipping was unable to navigate the Rhine for an extended period due to high water.



Data source: Generaldirektion Wasserstraßen und Schifffahrt (closures to shipping) ordnung). According to this regulation, ships will have to reduce their speed and must be equipped with a radio telephone installation in cases where the water level exceeds the high-water mark I. In cases where the highest navigation level (HSW) is exceeded, the sections affected will be closed to shipping.

In the past, there have repeatedly been extended closures which were particularly incisive in the late winter and early spring of 1999 when the Upper Rhine was closed to shipping for several weeks owing to two high-water events. Latterly there were extensive closures on the Upper Rhine in June 2016 owing to persistent and heavy rainfalls. On the Middle and Lower Rhine, there were brief closures, above all in 2001, 2003, 2011 and 2013 although it was possible to rescind those in most cases after less than a week . So far no significant trends regarding high-water closures have been discerned for the Rhine.

In cases where water levels fall below a threshold set for a specific section of the river – on the Rhine if the water surface is level with the mark – shipping is usually still permitted. However, in that case navigation is subject to restrictions which depend on the specific draught of inland ships. On the Rhine such low-water phases usually occur in late summer from August until October. However, there has been an increase in the frequency of low-water phases lasting well into November or December. This is true for 2011, 2015 and latterly 2018. It was not possible, however, to discern any statistically significant trends.

Interfaces

WW-I-3: Floodwater
WW-I-4: Low water

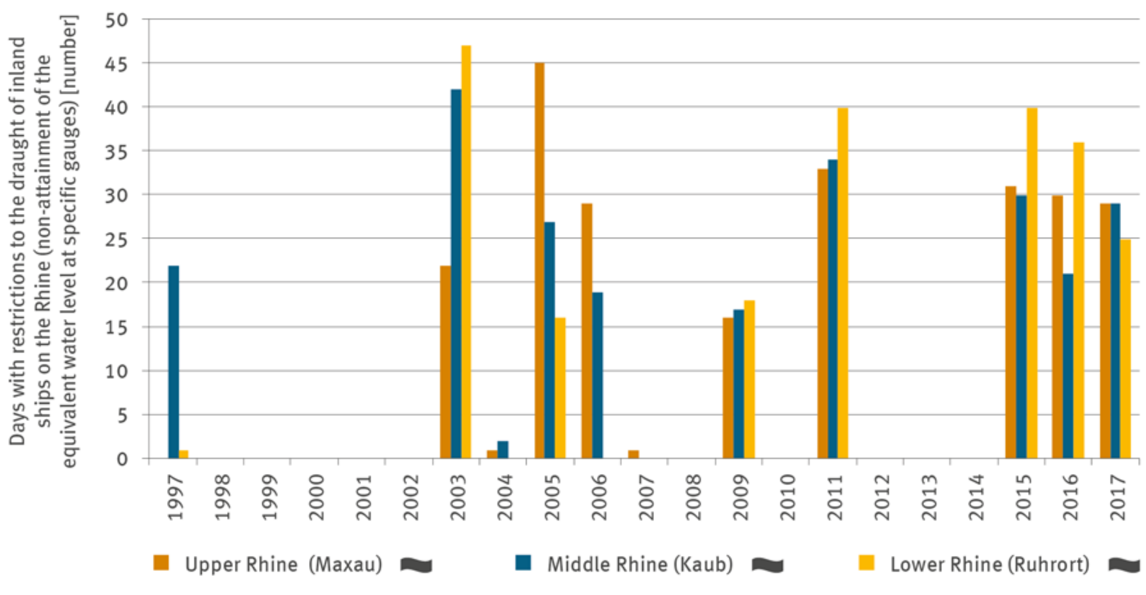
Objectives

Narrowing the bandwidth of uncertainties regarding the development of the availability of water and deducing tangible impacts on the infrastructure of waterways and shipping (DAS, ch. 3.2.11)

Avoiding the development of high water levels by adequate provision of decentralised opportunities in the entire catchment area of rivers for precipitation to seep away (DAS, ch. 3.2.1)

VE-I-2: Low-water restrictions to shipping on the Rhine

Prolonged low-water phases have repeatedly placed incisive restrictions on shipping in the Upper, Middle and Lower Rhine sections. This was usually caused by summer drought and heat. In some cases, the impacts lasted well into December.



Data source: Generaldirektion Wasserstraßen und Schifffahrt (restrictions to shipping)

Heavy rain – brief but violent

Even though many people will remember 2018 especially for prolonged periods of heat and drought, there were, in many parts of Germany, violent tempests with substantial amounts of rainfall which caused massive damage and obstructions. In many places, road traffic was affected too. In late May, for example, a belt of road closures extended from North Rhine Westphalia to Saxony, because roads were either flooded or covered in mud.

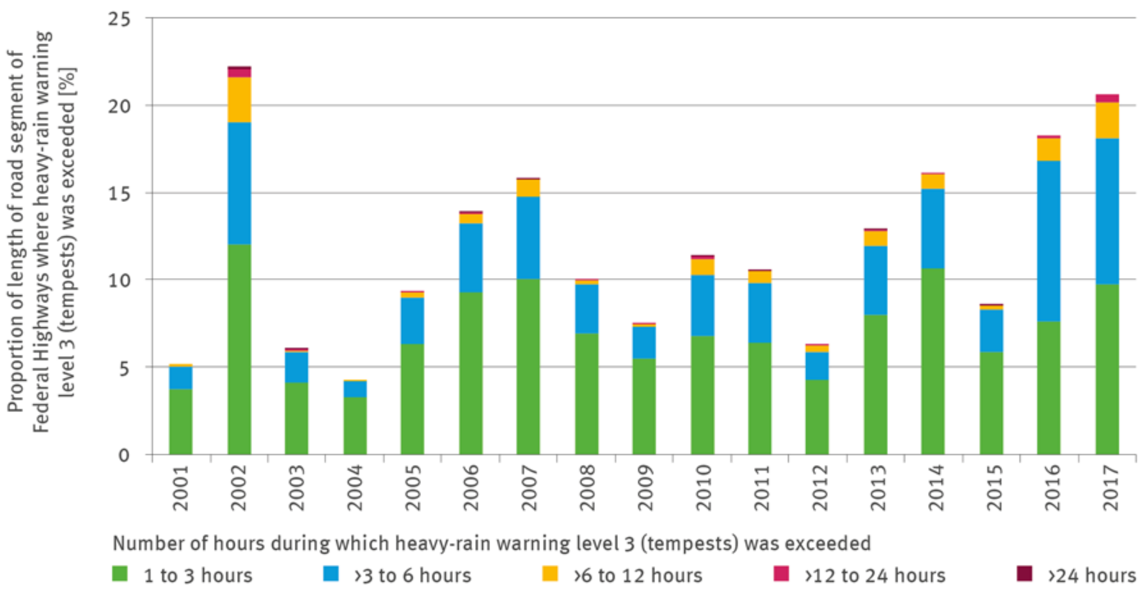
These road closures were caused by so-called heavy rainfalls. These are events with brief intensive rainfall usually in a localised area. In summer months they are frequently associated with violent thunderstorms. These are usually referred to as convective precipitation events. These events occur when humid air at ground level warms up quickly causing a strong uplift, with the vapour rising up into the atmosphere. Rising to cooler air layers higher up, the vapour contained in the air condenses and freezes. Given the requisite combination of air currents, temperature and air humidity, convective storms (thunderstorms) and heavy rain can build up within a few hours.

Brief and violent rainfalls can have severe consequences. The nature of these consequences and the specific damage caused, depend on the location as well as the intensity and duration of rainfalls. On level ground the water cannot run off quickly, and the soil will eventually run out of capacity to absorb it. The result can be long-term flooding of roads in hollows and underpasses. That is where water will collect which can no longer be absorbed by drainage systems and conducted away. As a rule, in upland or alpine regions, depending on the incline, water tends to run off the surface quite rapidly. Very violent heavy rain can turn minor streams into torrential rivers, where rising flood waves force their way through the narrow bed of a stream. Time and again, the tail ends of these flash floods reach areas which had not actually been affected by heavy rain. In extreme cases, the flow of the water masses or high water pressure can damage infrastructures.[56]

More frequent are cases where bad roads and poor visibility increase the risk of accidents, e.g. from aquaplaning or

VE-I-3: Heavy rain and roads

Heavy rainfalls can have serious consequences impacting on road traffic. In Germany, from 5 to more than 20% of federal highways are affected every year by heavy rain at warning level 3. For most of the road sections affected, the overall temporal extent of these events amounts to between 1 and 6 hours per year.



Data source: DWD (RADOLAN-climatology), Bundesanstalt für Straßenwesen (BISStra) from obstacles in the road, for instance when driftwood or other flotsam gets stuck in a bottleneck at bridges or underpasses causing a logjam and congesting the traffic network. Obstructions can also occur when after heavy rainfall slopes and embankments start slipping or are washed out thus covering roads in mud or damaging them in some way.

Between 2001 and 2017 heavy rainfalls have occurred practically all over Germany. It seems obvious therefore that this phenomenon is not limited to upland or mountain areas. Here you see the outcome of an evaluation of radar data[57] by the DWD. In future the temporal extension of this data collection process will also enable trend analyses of the frequency of events when the warning levels used by DWD are exceeded. (see p. 25).

It is expected by climate researchers that in future the frequency of heavy rain and its intensity will in general increase. One reason for this is that at higher temperatures the air can absorb more water – approximately 7 % more water at a temperature increase by one Kelvin. Furthermore, the changing meteorological conditions give rise to intensified formation of clouds and precipitation.[58] As far as Germany is concerned, it is expected that especially in the second half of the 21st century, there will be – albeit with major regional and seasonal differences – more instances of daily rainfall in quantities which are relatively infrequent at present. The comparatively strongest increase is expected for events which are currently still infrequent.[59] If these developments materialise, the risk of road traffic disruptions and – in extreme cases – damage to roads and infrastructures will increase. So far, there are no data in the public domain which might enable a reliable and cause-related assessment of the extent of such disruptions and damage. Therefore, the indicator illustrated here in this context only provides an insight into the temporal extent to which the network of federal highways was affected by torrential heavy rainfalls as recorded by means of radar data for specific spatial areas.

It is not very likely that infrastructures are damaged in all heavy rain events covered by the indicator. The DWD issues warnings against torrential heavy rain whenever rain amounts of more than 25 litres per square meter (l / m²) are expected to fall in one hour, or when more than 35 l / m² are expected to fall in 6 hours. If these warning levels are exceeded in only moderate amounts, the intensity of heavy rain is usually not likely to damage traffic infrastructures.

Heavy rain puts road safety at risk and can make roads impassable. (Photograph: © Animaflora PicsStock / stock.adobe.com)

However, the DWD ranks weather situations at warning level 3, 'tempests' when they are categorised as very hazardous, in which case the DWD recommends that people avoid staying outdoors. Anyone who has been overtaken by heavy rainfall – whether on foot, on a bicycle or in a car – will be able to relate to this.

Interfaces

VE-I-4: Weather-related road traffic accidents
BAU-I-4: Heavy rain in residential areas

Objectives

The Federal Government will examine whether and – where appropriate – to what extent [...] the dimensioning of drainage infrastructure requires adaptation to more abundant precipitation levels. Where necessary, the Federal Government [...] will adapt the relevant regulations for dimensioning the drainage infrastructure. (DAS, ch. 3.2.11)

The objective of a common (joint) management of heavy-rain risks is to reduce the risks caused by adverse effects of heavy rain or flash floods on human health, buildings and infrastructure, the environment, cultural heritage and commercial activities. (LAWA-Strategie Starkregenrisikomanagement, ch. 1)

Travelling safely, come snow or ice, rain or heat

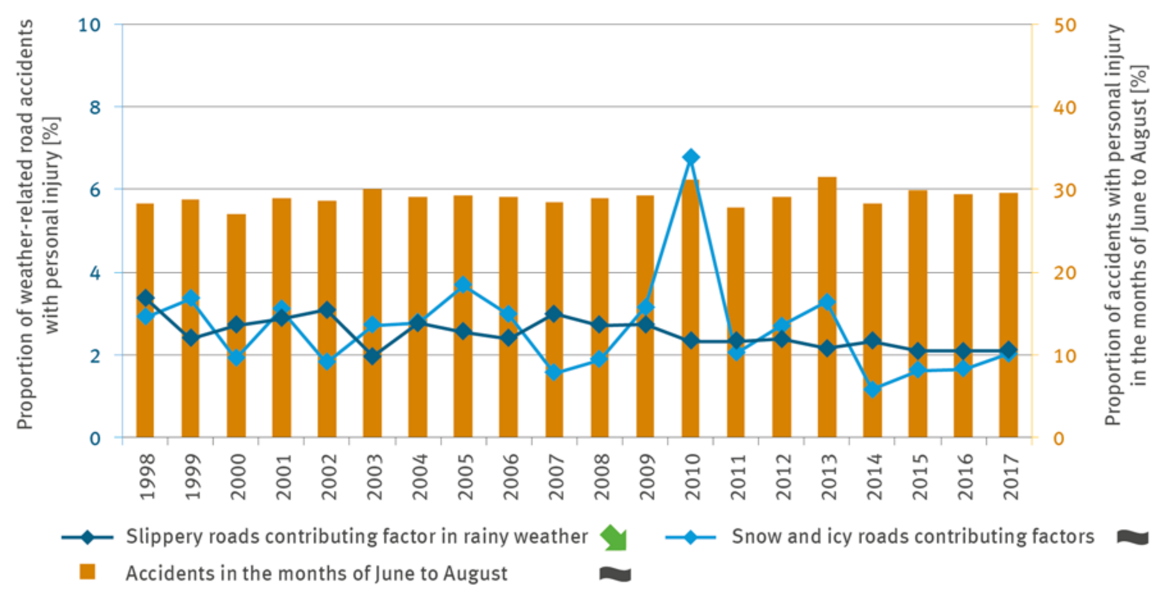
Road safety and accidents on Germany's roads depend on numerous factors of influence. Apart from the existing infrastructure as well as the density and structure of traffic and the behaviour of road users, these also include the weather and prevailing weather patterns. Rain and snow, as well as ice and hailstones impact on roads, making for adverse driving conditions such as aquaplaning or slippery roads, pavements and cycle lanes. Precipitation and fog reduce visibility. The risk of accidents is therefore usually greater in the autumn and winter months than in spring and summer. Overall, there are more accidents in those months. However, as road users tend to adjust their speeds to hazardous conditions, there are fewer accidents causing personal injury during that time than in the warmer months. This situation is furthermore influenced by the choice of one's mode of transport: Humans prefer travelling by car or public transport. The latter reduces the number of unprotected and particularly vulnerable road users being exposed to road traffic.

During the warm season, it is possible to observe contrary behavioural patterns. People make use of pleasant temperatures and longer days. They move about more in public spaces and do more errands on foot or by means of a bicycle or two-wheeled power-driven vehicle. The motoring environment is becoming generally more complex while the proportion of weaker road users is increasing. Moreover, in good, dry weather road users with power-driven vehicles tend to drive faster than in slippery or wet road conditions, thus provoking more serious accidents. Although over the summer months the number of accidents – compared to the year as a whole – is average, the proportion of accidents where people are injured or killed, is particularly high at that time of year.

According to an evaluation carried out by the Federal Bureau of Statistics (Statistische Bundesamt), the accident situation exemplifies[60] – in what way the weather and prevailing weather conditions can influence road safety. During the months of January, February and December, the prevailing road conditions tended to be very wintery. Snow and black ice were joint causes of almost twice as many accidents involving personal injury as in other years during the period in question. Nevertheless the

VE-I-4: Weather-related road traffic accidents

In 2010, very wintery road conditions both in January and February but also in December, were the cause of an unusually high number of accidents as a result of slippery conditions on roads covered in snow and black ice. Roads made slippery by rain as a contributory factor in accidents have shown a significant decline. Regarding the other time series, no significant trends have been observed so far.



Data source: StBA (statistics of road traffic accidents) relative proportion of accidents involving personal injury was in those months at its lowest level since 1991. Overall, the number of accidents was much higher, but thanks to basically more cautious driving, the accidents involved only material damage. By contrast, the proportion of accidents involving personal injury was above-average high in the summer months of 2010 and 2013. As far as 2010 is concerned part of the blame can be apportioned to the weather, because June and July of that year were generally very sunny and, more importantly, hot. Compared to the past ten years, in 2013 there were overall fewer accidents involving personal injury. The relatively hot July of 2013 was, in fact, the most accident-prone month of the entire period examined and it accounts for the high proportion of accidents in the summer months of that year

In view of the influence which weather and prevailing weather patterns can have on accidents happening, it is currently under discussion whether climate change might have relevant impacts on road safety and the incidence of accidents. In this context, wintery hazards are expected to diminish in future whereas in spring, summer and autumn it is expected that greater heat and increased heavy rainfall might contribute to increasing the frequency of accidents. In some regions dust and sandstorms contributed to accidents in recent years. As the intensity of soil desiccation increases, such storms might occur more often in future. So far, no significant trends have been observed in the time series illustrated for road accidents involving snow and black ice as contributing factors, or indeed for road accidents in the summer months. However, accidents involving slippery roads in rainy weather as contributing factor show a significant falling trend since 1998.

It is up to road users to inform themselves of prevailing hazards, to take note of warnings and to behave correctly and appropriately in extreme situations. On the other hand, they do rely, in principle, on transport infrastructures functioning even under extreme conditions and that no damage is caused by prevailing weather patterns. It is part of the remit of the Federal and Länder governments, to adapt transport infrastructures to changing climatic conditions. In order to lay the appropriate foundations, a research programme was initiated by the Federal Highway Institute (Bundesanstalt für Straßenwesen). This programme is entitled 'Adaptation of road transport infrastructure to climate change' (AdSVIS/Adaptation der Straßenverkehrsinfrastruktur an den Klimawandel)[61]. For example, in this light a project was carried out under the title 'RIVA – risk analysis of important transport routes in the federal trunk road network with regard to climate change' (Risikoanalyse wichtiger Verkehrsachsen des Bundesfernstraßennetzes im Kontext des Klimawandels). The purpose of this project was to develop a methodology which would make it easier to assess climatic risks facing the federal trunk road network. Other research projects address e.g. the development of appropriate indicators for the RIVA tool, for instance on the subject of heat, involving the mapping of potential flood areas or regarding the resilience of the road transport infrastructure.

Heavy rain increases aquaplaning hazards thus increasing accident risks. (Photograph: © chokchaipoo / stock.adobe.com)

Interfaces

GE-I-1: Heat exposure
VE-I-3: Heavy rain and roads
VE-I-5: Impacts on roads from extraordinary weather events and disasters

Objectives

Monitoring the contrary impacts of possibly decreasing accident risks in winter and possibly increasing accident risks in summer (DAS, ch. 3.2.11)

Storms and heavy rain – busy times for highway maintenance

The early summer 2016 created a lot of work for Rhineland-Palatinate's Highway Maintenance services. In late May and early June, the low-pressure systems Elvira, Friederike and Gisela – summarised as the Central European low-pressure system – brought tempests and thunderstorms combined with heavy rainfall which triggered localised flash floods and produced record high-water levels. This phenomenon occurred again in late June. These events caused flooding which culminated in washing away cars, undermining roads and damaging additional infrastructures such as rainwater retention basins.

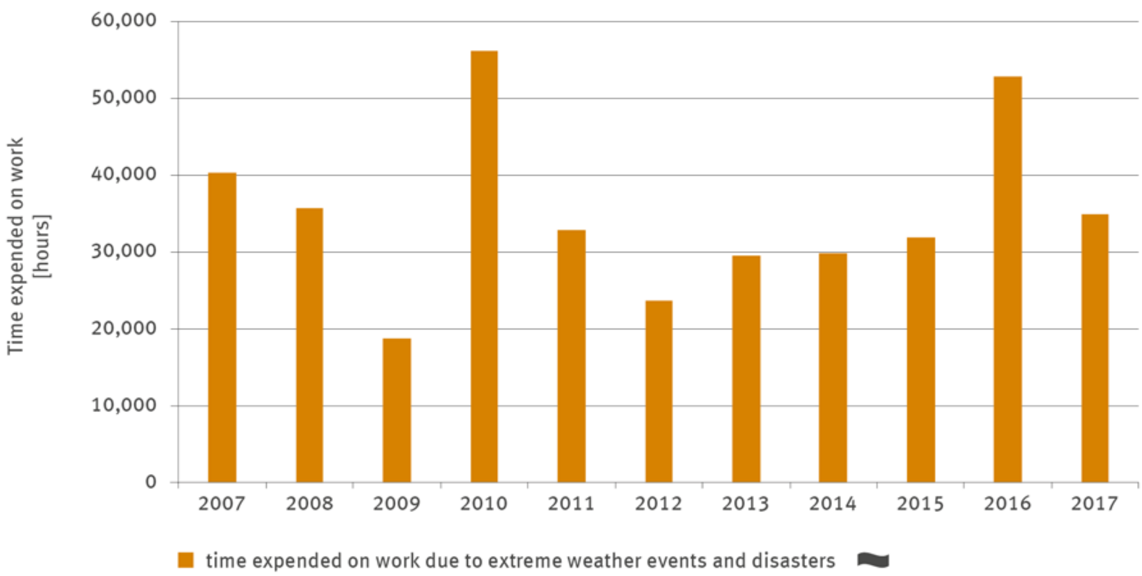
The total extent of damage to roads and infrastructure often does not reveal itself until a tempest has passed or the high-water level has receded. It is up to Highway Maintenance to repair such damage. Major restoration work on buildings or embankments is usually entrusted to private companies. Minor repairs and cleansing jobs are carried out by highway maintenance services.

Highway maintenance work is carried out by employees of motorway and road maintenance depots. They make sure that the road network is safe and functioning. All measures required to ensure adequate control, servicing and maintenance of Germany's roads are implemented under the premise that the smooth flow of traffic is affected as little as possible.

The new version of a specification detailing the requirements for work to be carried out by highway maintenance services on federal trunk roads (Leistungsheft für den Straßenbetriebsdienst auf Bundesfernstraßen) is about to be published. This publication specifies the work to be undertaken by Highway Maintenance during and after storms and hurricanes, high water levels, flooding after heavy rain as well as other disaster-related events. According to item 6.1.3 entitled 'Measures to be taken in cases of extraordinary weather events or disasters' (Maßnahmen bei außergewöhnlichen Witterungsereignissen und Katastrophenfällen), it is the remit of Highway

VE-I-5 : Impacts on roads from extraordinary weather events and disasters – case study

Highway maintenance services in Rhineland-Palatinate were extraordinarily busy in 2007, 2010 and 2016. In 2007 and 2010, it was above all windthrow and consequential damage by hurricanes Cyril and/or Xynthia which had to be remedied. In 2016, it was the impacts of tempests and heavy rain that kept the highway maintenance services exceptionally busy.



Data source: Landesbetrieb Mobilität Rheinland-Pfalz

Maintenance to remedy without delay any road damage which might affect road safety. Highway Maintenance is also required to remove any obstacles from roads, such as tree branches or limbs, and to remove any detritus or pollution, to restore any damaged roadsigns or markings, to restore road banks and to clear ditches. Where specific road sections are impassable, Highway Maintenance will handle traffic control using appropriate signage and barriers or cordons.

The time series shows the amount of work expended on services rendered within the remit of the Rhineland-Palatinate Office for Mobility (Landesbetrieb Mobilität Rheinland-Pfalz). With the exception of 2016, the amount of time expended on dealing with extraordinary weather events and disaster-related cases was particularly high in the years 2007 and 2010. In those years Rhineland-Palatinate and other parts of Germany and Europe were stricken by hurricanes Cyril and/or Xynthia. In forested areas, a great number of trees were uprooted and branches were ripped off. This resulted in obstructions and damage to roads which had to be remedied by Highway Maintenance. The labour involved caused a distinct amount of additional time expenditure.

It is feasible to create an indicator for Rhineland-Palatinate because this Land has kept records since 2007 on the amount of time expended on remedial work required as a result of tempests and flood damage. These records include the work carried out in connection with road closures, cleansing operations and operations management.

The introduction of an enhanced specification for all federal Länder or Germany nationwide, will make it possible in future to make comparable statements on time expenditure incurred by highway maintenance services as a result of extraordinary weather events and disaster-related impacts. To that end, the Federal-Länder Working Group BEKORS (Calculation of operating costs of highway maintenance services/Betriebskostenrechnung im Straßenbetriebsdienst) has revised and enhanced the relevant specification to incorporate the collation of data on time expenditure in a homogeneous and comparable manner. For this purpose, the services rendered were described in detail including a clarification stating that the time expended under item 6.1.3 'Measures to be taken in cases of extraordinary weather events or disasters' is to be attributed not only to initial but also to follow-up measures.

On this basis, the scope of this indicator can be expanded to apply to the whole of Germany in future. This will make it possible to observe whether the labour expended on highway maintenance is increasing because Germany as a whole is experiencing a greater amount of road damage and obstructions as a result of extreme weather events. This is one of the crucial impacts which is expected to materialise in the transport sector as a result of progressive climate change.

Weather-related damage to roads must be remedied by highway maintenance services.
(Photograph: © peuceta / stock.adobe.com)

Interfaces

VE-I-3: Heavy rain and roads

Trade and industry

Climate change is indeed capable of opening up new opportunities for trade and industry, albeit associated with unprecedented or quite different risks. Nevertheless the heterogeneity of the ways in which companies will have to adapt to changing climatic conditions, or the demand for their products or services, will vary as widely as the vast range of companies in this sector. Depending on a company's size. offerings, location and the extent to which it is integrated in regional, national or even international production and/or delivery chains, it will face very disparate challenges.

It would be in a forward-thinking company's own interest to analyse the potential of opportunities in order to gain a competitive advantage. Such opportunities present themselves for instance in cases where products encounter changes in demand due to climate change or where early on products or processes might be optimised or enhanced in an innovative way. When attending to climate risks, most companies are primarily concerned with regulatory risks associated with changing legal and fiscal frameworks resulting from concerns relating to climate change adaptation. Any physical risks associated with extreme weather events and gradual climate change (such as sea-level rise) enter more slowly into the perception of companies and investors even though such risks might affect the functionality of their own premises or infrastructures, the smooth operation of their production and delivery chains or the efficiency of their employees.[62] In any case, adaptation in the sense of the DAS strategy begins with the consideration of physical risks. In addition to construction or technology, the basic approaches to strategy and organisation also play an essential role. By incorporating for instance the issue of climate change in their own risk management or by embracing continuity management to address any disruptions in their operations, companies ensure their capacity to deal with climate risks in a systematic manner.

Effects of climate change

Adaptations

Reduced efficiency in summer heat

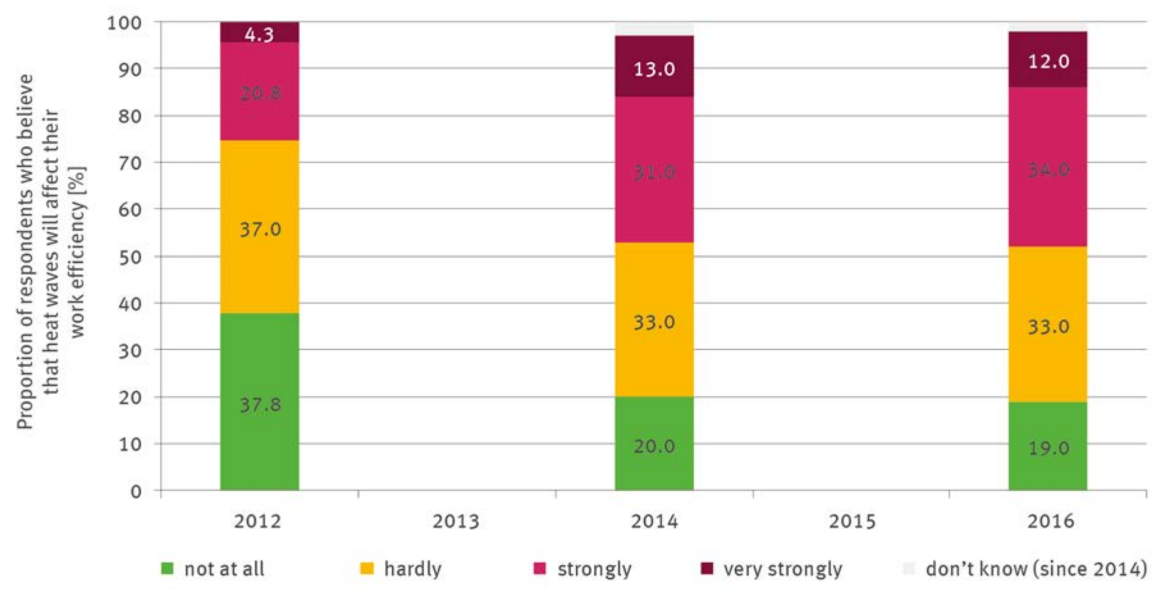
Rising temperatures and increasing absolute air humidity impact strongly on health and work efficiency. The effects arising are not limited to increased morbidity: diminished concentration is an effect that can make employees more prone to making mistakes or having accidents thus also affecting productivity.[63] Extreme heatwaves entail additional health risks such as heatstroke, extreme dehydration or exhaustion while body temperatures in excess of 40.6 °C can be fatal.[64]

In respect of indoor work places many studies showed a significant link between efficiency and the so-called thermal comfort zone. If room temperatures depart from this optimum either downwards or upwards, efficiency will decrease. The climate of a room is termed thermally comfortable when a human being perceives air temperature, air humidity, air circulation and heat radiation in their immediate environment as optimal and does not wish for the air in the room either to be warmer, colder, drier or more humid. For the summer months temperatures between 23 °C and 26 °C are considered comfortable for employees in sedentary occupations. Measures to provide heat protection in summer (e.g. shading or air conditioning) in indoor work spaces can help to keep temperatures within this range.

In Germany there are approximately 2 to 3 million people who work predominantly or at least some of the time outdoors. They are exposed to prevailing weather conditions and weather patterns all year round. Increasing heat exposure – often causing heat stress – and other climatic changes clearly affect these people more directly than people who work indoors. These activities contribute approximately 10 to 15 % of value added to the economy – primarily in the sectors of agriculture, forestry and building industry and in some segments of the industrial and services sector.

IG-I-1: Heat-related loss in performance

Climate change may in future increase exposure to summer heat at the work place, both indoors and outdoors. An increasing number of respondents to the survey researching environmental awareness expect to suffer adverse effects on their performance at their work place.



Data source: BMUB & UBA (Umweltbewusstsein in Deutschland)

A comparison of the outcome of surveys 'Umweltbewusstsein in Deutschland'[I] conducted in 2012, 2014 and 2016 shows that an increasing number of respondents expect any future increase in heat stress to impact strongly or very strongly on their work efficiency. While in 2012 the percentage of respondents expecting impacts on their work efficiency had amounted to only a quarter of all respondents, this figure had increased to 44 % by 2014 and 46 % by 2016 respectively.

An employee's thermal comfort determines their working capacity thus impacting directly on a company's productivity and on the productivity of the entire economy. Studies are based on the assumption that for periods of major heat stress in Central Europe productivity losses amount to between 3 and 12 %.

These figures were used as a basis for estimating the impact on the national income. Accordingly, in view of hot days occurring already nowadays and compared to years without hot days, the productivity losses mentioned above might result in losses to the national economy amounting to approximately 540 million to 2.4 billion Euros.[65] It is true to say, however, that estimating the national economic productivity is subject to considerable uncertainties. In fact, some studies suggest, especially for the building industry, that productivity might even rise as climate change increases the length of time available in the course of a year during which working outdoors is feasible.[66]

The relevant work place regulations stipulate various requirements to be met in order to maintain employees' good health and thus their efficiency while working indoors even while outside air temperatures might be more than 26 °C. In cases where room temperatures exceed the threshold of 26 °C or 30 °C respectively, remedial action should or must be taken. Employers can, for example, ensure that suitable sunshading is installed and is used to best advantage, that the premises are adequately aired in the early mornings, interior heat loads are reduced, working hours are adapted and refreshing drinks are offered. It may also be appropriate to relax existing clothing instructions.

In particular people working outdoors, but also people working in offices, will have to protect themselves from impacts of summer heat.
(Photograph: © Monika Wisniewska / stock.adobe.com)

For working outdoors, industrial safety legislation also requires that measures be taken to protect employees from adverse impacts on their health resulting from heat stress. For example, on building sites employers can give instruction for shading or aeration units to be installed in order to provide adequate working conditions. Above all, employers can take organisational measures by adapting working hours to the prevailing weather conditions, by arranging for sufficiently long breaks, making sure there is an adequate supply of refreshing drinks and ensuring that employees, as part of their training, are made aware of potential hazards and any appropriate countermeasures they can take for their own protection.

I The representative population survey (of German-speaking residents aged 14 or more years) entitled Environmental Awareness and Behaviour in Germany (Umweltbewusstsein und -verhalten in Deutschland) has been carried out every two years since 2000 on behalf of the BMU and the UBA. Since 2012, questions have been asked in the survey, intended to supply data for DAS monitoring indicators; from 2016 onwards, these questions were asked every four years in conducting the environmental awareness surveys.

Interfaces

GE-I-1: Heat exposure
GE-R-2: Successes of the heat warning system
BAU-I-1: Heat stress in urban environments

Intensity of water consumption in the manufacturing sector

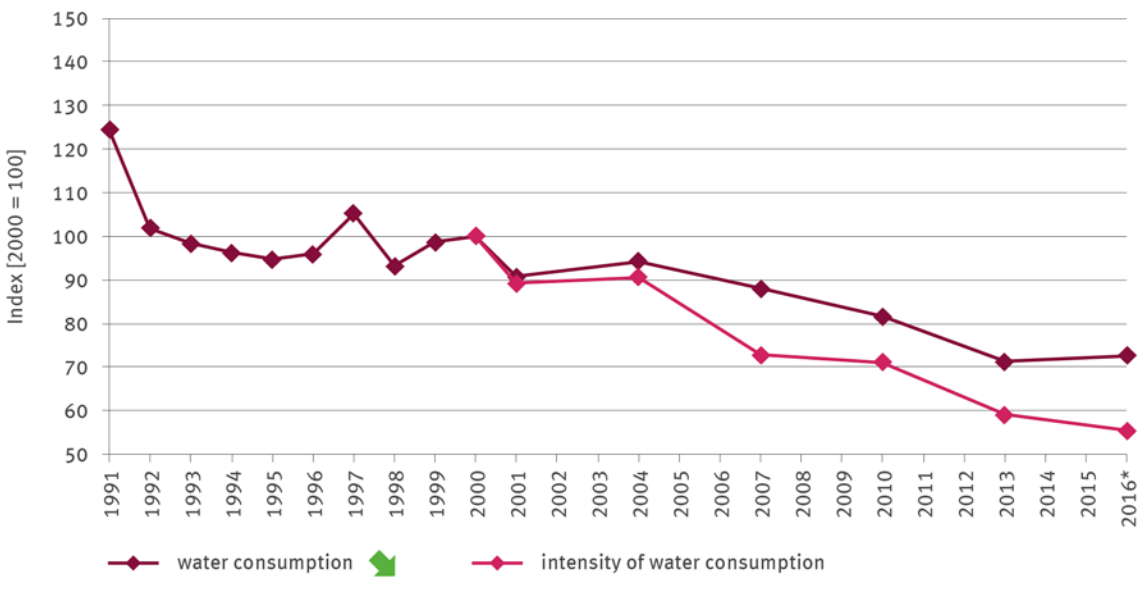
As a matter of principle, any thermal discharge from manufacturing or processing plants into water bodies is subject to the same legal regulations as energy plants. Therefore, manufacturing and processing companies may encounter situations where they have to decrease their thermal discharge thus reducing their output in order to comply with the discharge conditions laid down in their licence. This occurred, for example, in the hot summers of 2003, 2006 and 2018, when owing to prolonged heat and drought, restrictions were imposed on thermal discharge into various water bodies.

Changed climatic conditions may result in such dry and hot phases occurring more frequently in future, becoming more intensive and lasting longer. It is therefore expected that in the summer months, temperatures in watercourses will rise in the long term and flow rates will decrease. It is likely that situations will occur more frequently where feeding back used coolant water into watercourses or the abstraction of water for cooling purposes will be permitted only in limited amounts. Industrial processes that are largely independent of water resources are better equipped for the impacts of climate change than processes which require a lot of water. In order to use as little water as possible for raw or processing material, and in order to use the abstracted water as efficiently as possible, companies might for instance consider embracing an in-house water management system, using water in a circulatory system, employing water-saving technologies or using other substances such as emulsions instead of water.

An important starting point for the manufacturing sector is, above all, the economical use of coolant water in production processes and in the process of in-house electricity generation. This is because the use of coolant water accounts for approximately three quarters of the sector's total water consumption. Besides, the abstraction of water for refrigeration purposes and the discharge of used coolant water are subject to temperature-related regulations which may lead to restrictions being imposed on production during hot summer months. The abstraction of water for production-specific or personnel-related purposes, however, is less dependent on temperatures.

IG-R-1: Intensity of water consumption in the manufacturing sector

Water-efficient enterprises are better equipped to cope with the impacts of climate change. Since the 1990s, the use of water in the manufacturing sector has shown a significant decline, i.e. a clearly falling trend. Since 2000, there has also been a declining trend in the intensity of water consumption, i.e. it was possible to increase the creation of added value while using the same amount of water.



* preliminary data

Data source: StBA (environmental-economic accounting)

Between 2000 and 2016 water consumption declined in the manufacturing sector by approximately 27 % overall. In 2016, the intensity of water consumption in many parts of the manufacturing sector was also distinctly below the value recorded for 2000, i.e. it was lower by on average 45 %.

This means that it was possible to attain a considerable increase in the efficiency of water use and that the lower consumption of water achieved greater added value. The strongest decline in water use and intensity of consumption was observed in the manufacture of chemical and pharmaceutical products as well as food production. A distinct increase, however, was noted in respect of manufacturing processes in the paper industry.

Operations in the fields of chemistry or paper manufacture require large amounts of water or water vapour for their manufacturing processes and for in-house electricity generation. (Photograph: © hgoldenporshe / stock.adobe.com)

Interfaces

WW-I-1: Groundwater level
WW-I-4: Low water
WW-R-1: Water use index
LW-R-6: Agricultural irrigation
EW-R-4: Water efficiency of thermal power plants

Objectives

Considering technical methods and enhancements to achieve more efficient use of water, e.g. by using greywater, rainwater captured from roofs, or process water for technical and industrial purposes or by enhancing water-saving methods (DAS, ch. 3.2.3)

Promoting sustainable water use on the basis of long-term conservation of extant resources (WFD, Art. 1(b))

Obtaining commitments to exercise the appropriate caution when implementing measures that may impact on water bodies, in order to safeguard the economical use of water as required for the conservation of a healthy water regime (WHG, § 5 (1) 2)

Tourism industry

Germany's tourism industry is a lucrative sector with high turnover, and consequently, its economic importance should not be underrated. In 2015 the demand for goods and services in tourism – regardless of any indirect or induced effects – produced a gross value added totalling 105 billion Euros.[67] The structure of the tourism sector is characterised by medium-sized businesses and composed of accommodation and catering businesses, travel agencies, tour organisers, companies providing touring and transport services as well as operators of tourism infrastructures or centres in the fields of sports, culture, health and wellness. Federal Länder, administrative districts or municipalities engage in tourism in the endeavour to position their region or location as a desirable destination in the tourist market. On the other side of the equation are the interests of travellers or people seeking relaxation who make enquiries about the products and services on offer.

The discussion on the potential impacts of climate change on Germany's tourism industry is focused on potential impacts on various destinations, above all the coasts and winter sports regions. Another focus is the travel pattern of German and international holidaymakers who, apart from many other factors, are assumed to consider, for instance, the climatic conditions and relevant changes when they decide where to travel. In view of the great variety of factors influencing a travel booking decision, it is not easy to ascertain to what extent climatic changes might play a role.

Considering the wide spectrum of supply and demand in tourism, there can be no comprehensive nationwide answer to the question regarding the nature of the challenges climate change may pose for the German tourism industry in future. Impacts will vary considerably between regions and depending on the type of travel offerings.

Effects of climate change

Will North Sea and Baltic Sea beach holidays gain in popularity?

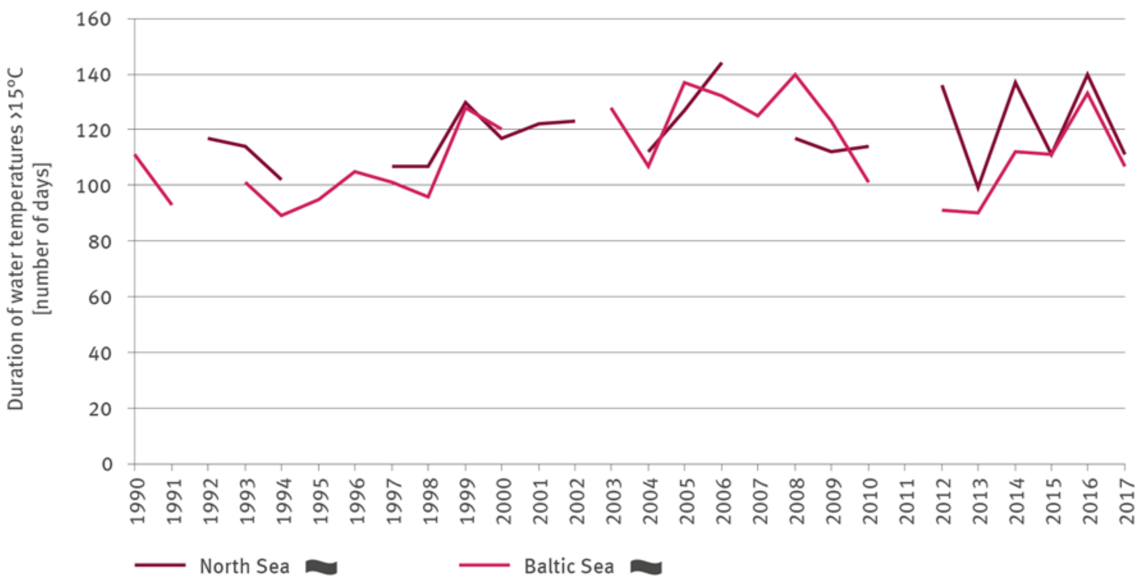
When Germans want to have a beach holiday in order to bathe in the sea or to sunbathe, they primarily travel abroad. In 2018, the most popular summer holiday destinations of people living in Germany were Spain, Italy, Mecklenburg-Vorpommern, Turkey and Schleswig-Holstein. Vacations by the sea account for 12.4 million holidays, thus making them the most popular type of holiday and providing by far the strongest motivation for vacation travel. As far as this type of travel purpose is concerned, Germany has so far played a minor role: In the ranking of domestic holidays, beach holidays – according to a study dating back to 2013 – are in fourth position in the hierarchy of possible motives.[68] As far as foreign visitors are concerned, their reasons for travelling to Germany if they want a beach holiday are negligible.[69] Approximately 55 % of bed nights in coastal areas of the North Sea or Baltic Sea are incurred in the summer months between June and September. In other regions bed night numbers are distributed evenly across the year.

As far as Germany is concerned, there is a thesis according to which a coastal vacation – as the typical form of summer tourism – can benefit from rising air and sea temperatures resulting from climate change. Above all, this might enhance the attractiveness of seaside resorts thus extending the bathing season in future. Evidence for a tendency towards higher sea temperatures in coastal waters of the North or Baltic Sea has already been provided in terms of measurements taken within the station network of the BSH. The temporal development of the mean annual sea surface temperature measured across the entire North Sea is based on analyses which have been conducted weekly by the BSH since 1968. The outcome of these analyses was characterised by a cold regime that lasted until 1987 and by an abrupt temperature jump of 0.8 °C in 1987/1988 signifying a warm regime which has continued ever since.

In order to enable an estimate – based on sea water temperatures – of the potential for bathing tourism in

TOU-I-1: Coastal bathing temperatures

The duration of seawater temperatures prevailing on German North Sea and Baltic Sea coasts, which might benefit a bathing holiday on these coasts, is subject to major fluctuations from year to year. Usually in June suitable temperatures will set in which last into the month of September. So far, no significant trends have been discerned.



Data source: BSH (selected measuring stations) coastal areas, the temporal duration is illustrated in the number of days on which the sea water temperatures of German coastal waters of North and Baltic Sea exceeded a threshold value of 15 °C. On one hand, this threshold value – which seems relatively low for bathing temperatures – characterises the beginning and end of summer bathing temperature conditions. On the other hand, the time series show the results of measurements taken at some distance from the coast which are therefore more homogeneous and independent of short-term influences. Partly due to stronger diurnal variations, sea water temperatures in coastal bathing waters tend to be higher and potentially suitable for bathing. Owing to the fluctuation margins observed, it has so far not been possible to discern any significant trends for the time series starting in the 1990s thus fitting in perfectly with the recent warm regime.

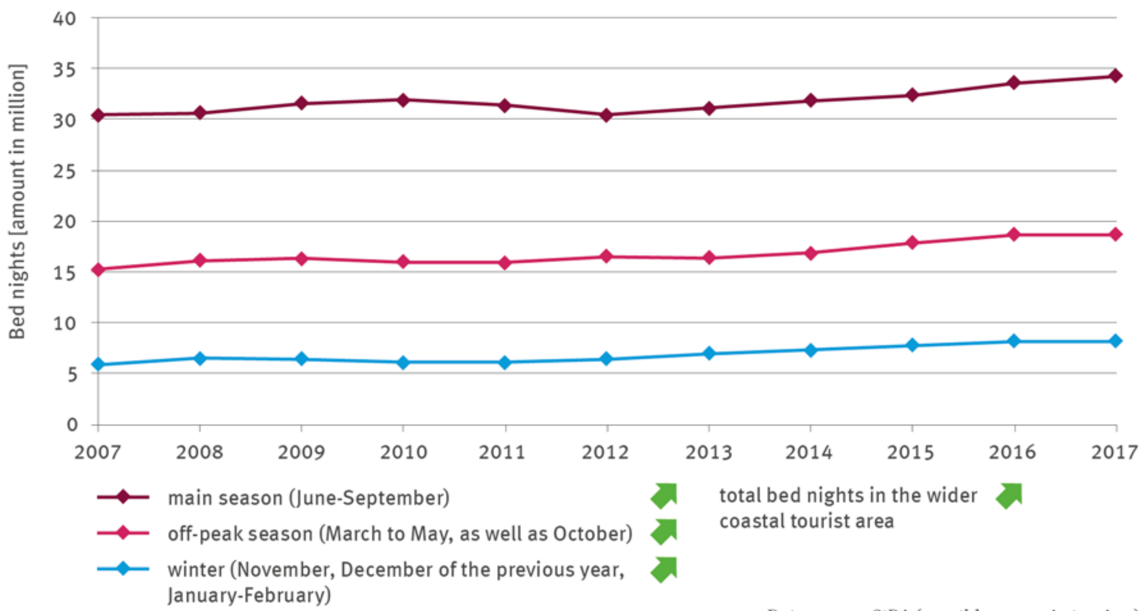
So far it has not been possible to detect a link between the bathing temperatures observed and the development of bed-night figures in German coastal regions. It would be difficult to establish such a link in any circumstances. On one hand, there are numerous general factors, such as the economic development, the travel pattern and the demand in tourism, which influence bed-night figures. On the other hand, water temperatures are only one aspect among numerous climate-related cause variables that represent the attractiveness of the coasts of North and Baltic Seas as a destination for beach and bathing tourism. Other factors not taken into account in this analysis are e.g. duration of sunshine, air quality and bio-climatic conditions interacting with air temperature, wind, radiation conditions and air humidity[70] and, last not least, the occurrence of seaweed or jellyfish on the beaches.

Interfaces

WW-I-7: Water temperature in the sea
TOU-I-6: Seasonal bed nights in German tourist areas
TOU-I-7: Holiday destination preferences

TOU-I-2: Bed nights in coastal tourist areas

The demand for tourism in the travel areas on Germany's coastlines is particularly seasonal. Despite rising bed-night figures in all seasons, 55 % of overnight stays on North and Baltic Sea coasts will occur during the summer months, i.e. between June and September.



Data source: StBA (monthly survey in tourism)

Will spas retain their healthy climate?

Holidays in health resorts (spas) play a major role in German domestic tourism. What these spas can offer is not at all limited only to courses of treatments and rehabilitation measures financed by social insurance agencies: health and wellness vacations are steadily gaining in popularity, and they too are spent in health resorts. In 2017. for example, approximately 40 % of all tourism-related overnight stays in Germany took place in municipalities with the requisite designation, i.e. in health spas, seaside resorts, resorts with healthful climates, also known as climatic health resorts.[71] Even in cases where the specific designation or treatments offered are not the decisive factor in overnight stays (e.g. family holidays by the North Sea are probably often influenced by different motivations), the overnight stays in preventative treatment centres and rehabilitation centres nevertheless account for 10 % of all overnight stays nationwide. These centres are particularly dependent on a municipality's designation as a spa.

All health resorts have in common that they have to meet specific demands including bio-climatic and air quality in order to hold on to their designation. It is essential that the climate prevailing in a specific location can be used for therapeutic purposes. Furthermore, climatic health or sea resorts must be suitable for healing, alleviating or preventing human diseases. In other words, stimulating or benign effects must be available in abundance. The stimuli concerned include e.g. cold stimuli, strong fluctuations in temperature or sudden gusts of wind, while benign factors include e.g. extraordinary purity of the air or thermally balanced conditions. Stress factors which might include low intensity of solar radiation, polluted air or heat stress, would be tolerated in the long term only in minimal amounts. Depending on an individual's medical condition or physical constitution, therapies make use of stimuli and benign factors prevailing in a healing climate, which allow their body to regenerate but also to toughen up as a protection from illness or disease.

Heat stress is an important consideration in assessing the bio-climatic situation of health resorts. Heat stress arises typically on days in summer weather with light

TOU-I-3: Heat stress in spas used for their healthy climate

In the two periods of 1971–2000 and 1981–2010 the threshold value for heat stress was exceeded in four each of 62 climatic health resorts. The next evaluation will not be available until preparation of the 2023 Monitoring Report.

* owing to a change in the evaluation method, the mean of days above the threshold value between the periods 1971–2000 and 1981–2010 does not permit a direct comparison

Data source: DWD (health resorts climate assessments) cloud cover, high pressure conditions at high temperatures, high air humidity and light wind. These conditions make it difficult for the body to lose heat; as a result, the body's own thermoregulation system has to work hard to balance its heat regime and to avoid overheating.

Statistical evaluations of climate data for Germany indicate that days and months which are above-average hot have become more frequent in the course of the 20th century and that extreme heat events are on the increase. As a result of climate change, it is to be expected that in future the frequency and intensity and also the mean temperatures of hot periods will increase further. In the course of this development, the bio-climatic factors in climatic health resorts might change, eventually denying spa guests the healing effects from a local climate, and the climate losing its therapeutic role. In a worst-case scenario this might lead to individual municipalities losing their designations as climatic health resorts.

To enable the assessment of the climate prevailing in climatic health resorts, the number of days causing heat stress over a period of 30 years were examined. The days considered were those on which the threshold value of the Perceived Temperature of approx. 29 °C was exceeded. In climatic health resorts this must not occur on more than 20 days over the long-term average. In the period 1971–2000 the threshold value for heat stress was exceeded in four of 62 climatic health resorts on more than 20 days. The maximum value measured occurred in a municipality with a long-term average of 23.3 days of heat stress. However, the designation has so far not been withdrawn from this municipality.

For the period 1981–2010 the evaluation method was fundamentally revised, and the so-called heat stress day was redefined. This involved on one hand attributing greater importance to the impact of sultry conditions on human health, and on the other, the potential adaptation of human beings to a changing climate was introduced, loosely based on the heat warning system adopted by DWD. A heat-stress day is now classified as a day on which the threshold towards strong heat stress or the threshold to moderate heat stress is exceeded while sultry conditions prevail. Based on this definition, the calculation for the same meteorological time series clearly identifies fewer days with heat stress than in the previous type of evaluation. The new definition also changes the regional distribution. In conducting a statistical examination, it is possible to calculate a location-specific reference value for the number of days with heat stress which broadly follows the 20 days used in the previous period. Despite all the changes, this approach enables the assessment of health resorts also for the period 1981-2010 in continuity with former evaluations.

Climatic health resorts make targeted use of climate factors for curing, alleviating or preventing diseases.
(Photograph: © lotharnahler / stock.adobe.com)

Interfaces

BAU-I-1: Heat stress in urban environments
GE-I-1: Heat exposure

Snow guarantee in uplands and mountains diminishing?

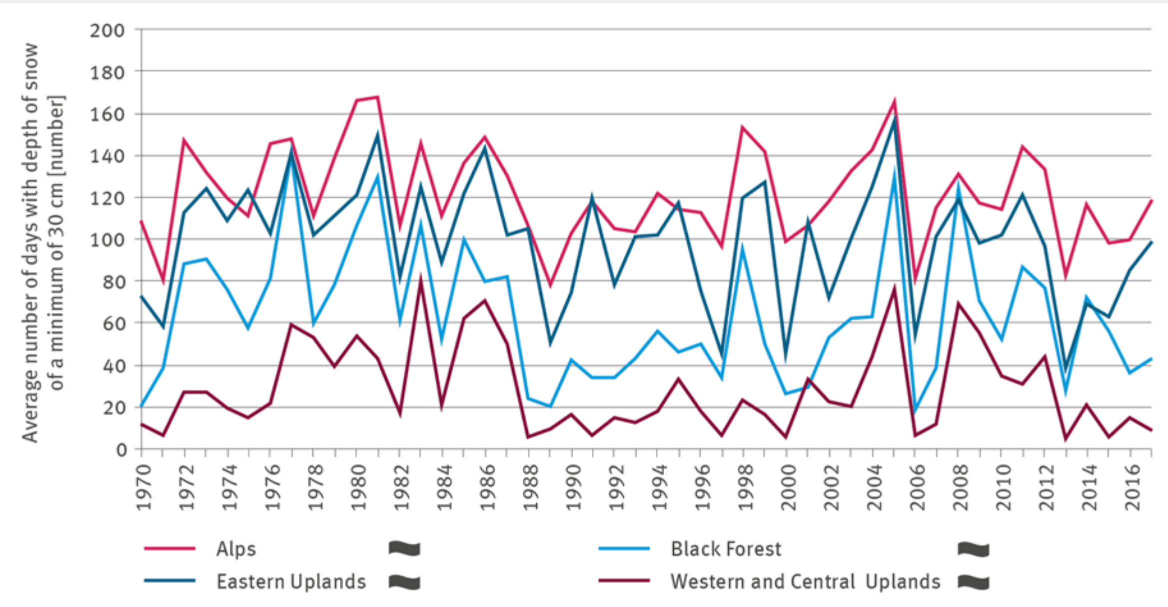
Whether skiing or snowboarding. cross-country, touring or snow hiking – snow-covered mountains, snowy forests and radiant sunshine are the ultimate ideal of winter tourists and winter sports enthusiasts. If there is insufficient snow cover, the foundation for snow-related forms of tourism is undermined. Tourism destinations in uplands and high mountains may suffer distinct commercial losses if the snow cover is in decline, if guaranteed snow is more and more restricted to higher altitudes and if the periods of snow cover become inconsistent or if they shift.

The amount of snow cover required depends above all on the specific activity and the type of terrain. For cross-country skiing, snow depths of 10 to 15 cm are usually sufficient. As far as alpine skiing operations are concerned, it is the specific character of a ski slope which determines what minimum depth of snow is required in order to prepare pistes, to protect the soil, to ensure safe skiing operations and to provide the skier with a pleasant skiing experience. In general, snow in depths of 30 cm is regarded as sufficient, while 50 cm is considered good.[72] However, stony and rocky pistes may require much deeper snow cover of up to 1 m depth to make them skiable. According to the so-called 100-day rule by Witmer[73] the successful operation of a skiing area is only safeguarded, provided such conditions are guaranteed on at least one hundred days of the season.

An analysis of snow depth data recorded for the Alps and selected upland areas over the past (just under) five decades shows that the snow situation between 1970 and 2017 in all ski-tourism areas ('Alps', 'Black Forest', 'Eastern Uplands', 'Western and Central Uplands') was very changeable. The only place which was able, in all years, to boast a natural snow cover on more than 100 days – adequate for alpine ski sports – was the region of the Zugspitze. For reasons of altitude, that region and other skiing regions in the ski tourism area 'Alps' offered the best snow conditions overall. Despite some strong fluctuations between the years, most of these ski regions had sufficient natural snow cover in most of those years. The situation can be compared to conditions in the eastern uplands: in the Erz Mountains in more than half

TOU-I-4: Snow cover for winter sports

For any of the ski-tourism areas in Germany, the number of days with a natural snow cover in depths of a minimum of 30 cm shows no significant trend. In all these areas there were, in the course of the past (just under) five years, occasionally or even periodically, snow-poor or snow-rich winters.



Data source: DWD (snowcover observation) of those years; while in the Bayerische Wald (Bavarian Forest) a little less than every other year. In the Black Forest and in western and central uplands, i.e. the Harz, Sauerland, Rhön, Thuringian Forest and the Fichtel Mountains, the prevailing conditions are fundamentally different. In those uplands the natural snow cover in most skiing regions reached the minimum depth of 30 cm on one hundred days only in particularly snowy years. Whereas snow cover in the Sauerland or the Rhön never reached those conditions.

It must be stressed that these data refer only to the natural potential of winter sports tourism in ski-tourism areas and their various regions. These findings do not permit any statements on the actual snow conditions in skiing areas. In those places the snow cover required for winter sports can be created or supplemented significantly by technical snowmaking. In response to a sequence of several snow-poor winters in a row, but also with a view to comparable activities offered by the international competition, the operators of skiing resorts have in some cases set up extensive infrastructures for artificial snowmaking. Artificial snow is the most wide-spread measure used to extend the season or to maintain skiing operations when faced with strong fluctuations in weather patterns. For the Alps in general, approximately half of the skiing areas can be supplied with artificial snow, while in the Bavarian Alps in 2009 approximately one sixth had artificial snow generation plant available.[74] Between 2005 and 2017 the surface area in Bavaria where it is possible to apply artificial snow by 530 hectares to approx. 944 hectares.

Nevertheless, applications of artificial snow are bound by physical and economic limitations. Without the use of additives not licensed in Germany, it is necessary to reach temperatures of below –3° C to be able to generate artificial snow. The costs involved in artificial snow generation (investment, operational and maintenance costs) are considerable, and in rising temperatures costs become disproportionate. Besides, if infrastructures such as those in upland areas – owing to frequently snow-poor winters – are not continuously utilised to capacity, the profitability of such plant is seriously threatened. It is therefore obvious that such adaptation measures are bound by limitations of economy. Another limitation is that these measures will affect nature and the environment owing to their high requirements in terms of energy and water, the generation of artificial snow and the construction effort involved. This is one of the reasons why for instance the alpine states who are members of the Alpine Convention – whose objective it is to achieve sustainable development in the Alps – have agreed that the generation of artificial snow is permitted only in cold periods, on condition that the locally relevant hydrological, climatic and ecological conditions are favourable.

In snow-poor and mild winters even technical measures are no longer able to safeguard sufficient snow cover.
(Photograph: © mg1708 / stock.adobe.com)

Interfaces

TOU-I-7: Holiday destination preferences

Objectives

Forward-thinking contributions to spatial planning in respect of spatial adaptation measures in tourism, especially in coastal and mountain areas. Changes in tourism patterns may require new investments and new infrastructures which require appropriate preparations in terms of spatial planning. (DAS, ch. 3.2.14)

As far as possible landscape-compatible construction, maintenance and operation of skiing infrastructure with due consideration of natural systems and the vulnerability of biotopes; linking the licensing of snow generation in cold periods to compatibility with the locally relevant hydrological, climatic and ecological conditions (Alpine Convention Minutes on Tourism, item 14)

How fares winter tourism?

In 2018, Austria, Spain, Southeast Asia, Bavaria and Italy were the most popular winter tourism destinations with German travellers. While many people travel south, for other travellers winter means snow. They either want to enjoy snow-related sports activities or they treasure snowy landscapes and the associated atmosphere.

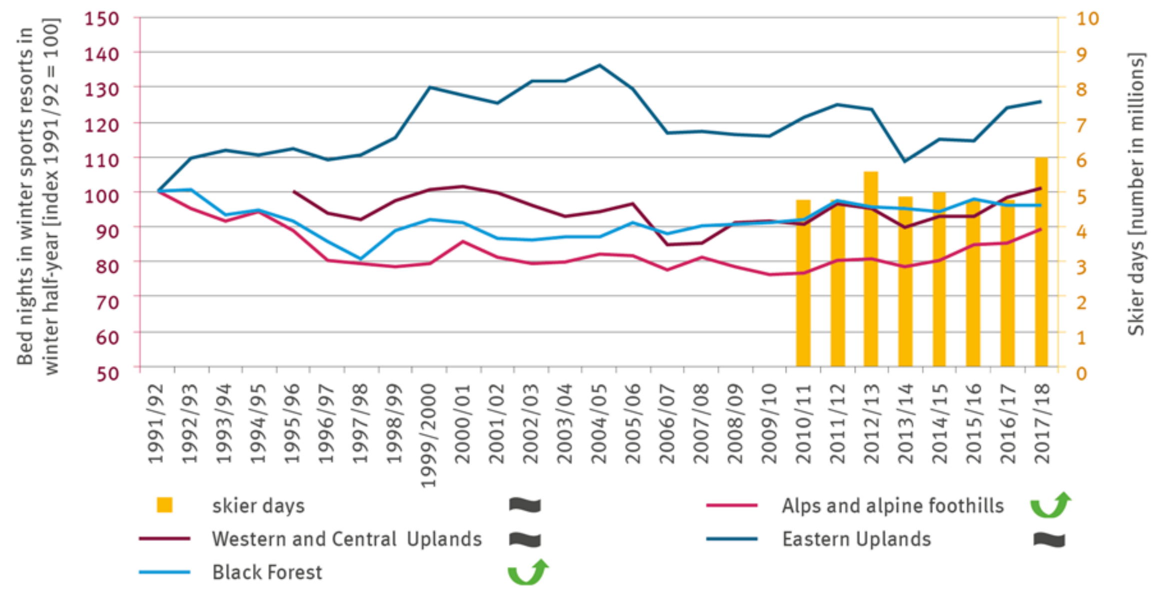
This is why, in view of climate change, the prognoses for winter tourism in Germany are not promising. Important destinations for winter tourism and skiing areas in the German Alps are predominantly at altitudes between approx. 800 and 1,700 m above sea level, i.e. distinctly lower than alpine destinations in Switzerland, Italy, France and parts of Austria. Already today, projection outcomes demonstrate that snow guarantees in the German Alps are decreasing; this situation can only be aggravated as warming continues to increase. In the other alpine countries – except for some of the federal states of Austria – a distinct decline in areas with guaranteed snow cover is not expected until and unless temperatures rise by more than 2 °C.[75]

Particularly snow-poor winters as latterly in 2013 / 2014 mean that in many places winter sports are subject to some restrictions. Apart from other factors such as greater choice of ski slopes – or owing to some wider and longer descents due to other topographical conditions near an alpine ridge – this is the reason why other alpine countries are perceived as more attractive for winter holidays including multi-day vacations offering skiing and other forms of winter activities.[76] This competition from skiing areas with more prospects of snow and more attractive ski resorts in neighbouring alpine countries is presumably also part of the reason why the tourism boom of Germany's post-unification period did not last despite having been so promising in terms of the record number of bed nights recorded in winter 1991 / 1992. From the mid-1990s onwards, the number of overnight stays in winter sports municipalities in German alpine areas went into a decline and stagnated at a lower level until 2014. These figures are now gradually increasing again.

Difficult times for winter tourism are also on the cards for Germany's uplands. Modelling has shown a decline in the

TOU-I-5: Bed nights in ski resorts

Overall, the development of bed night figures varies strongly in different skiing regions. In mild and snow-poor winters such as 2006 / 2007 and 2013 / 2014 accommodation services reported losses in all winter sports regions. In view of the relatively short time series available for Skier Days, i.e. first-time use of cable cars in skiing areas, there are no development trends discernible so far.



Data source: Statistical offices of federal states (monthly survey in tourism), Verband Deutscher Seilbahnen e.V. (Skier Days) number of days with snow depths of at least 30 centimetres in the uplands in view of climate change well into the middle of the 21st century. At higher altitude in the Alps, this decline is not expected to be as pronounced because depending on the geographical situation and the altitude, snow cover can even be deeper in some regions. However, in the long terms distinct restrictions are to be expected.

Individual, particularly snow-poor years an mild winters had a negative impact on bed-night figures in the past. So far, the mildest winter in Germany took place in 2006 / 2007, at an average temperature of 4.4 °C. Compared to previous years, in that year all winter sports regions recorded declining bed night figures; this was particularly pronounced in the Bayerische Wald, in the Fichtel Mountains and in the Rhön uplands. The winter of 2013 / 2014 when bed night figures were relatively low throughout, was comparatively snow-poor as well.

If winter tourists have negative experiences more frequently in German winter sports regions, they will in future at least to some extent change their holiday activities or holiday destinations. In the representative population survey 'Environmental Awareness in Germany' (Umweltbewusstsein in Deutschland).[I] at least a quarter of respondents stated in 2012 that they would adapt their winter sports activities if required by climatic conditions. In the subsequent surveys conducted in 2014 and 2016 this proportion amounted to 17 % respectively. It is therefore conceivable that German winter tourists might in future favour destinations for winter holidays in neighbouring European countries – more so than before.

For local winter sports regions this might mean that their importance to people looking for local recreation activities and for day tourism will continue to increase. The German alpine area and the uplands are both popular destinations for day tourism in the winter months. They are particularly attractive to people who live in greater conurbations nearby. Winter tourism is an important economic factor. If snow conditions in individual years – such as the long winter of 2012 / 2013 – are good, winter sports offerings are readily taken up by day tourists, as demonstrated by the high number of first-time users of ski lift facilities in skiing areas (skier days). However, in order to be well-equipped for mild and snow-poor winters such as 2013 / 2014, tourism regions would be well advised to develop more and more alternative offerings that depend very little or not at all on snow cover.

When snow cover is low, winter hiking can provide an enjoyable alternative to skiing.
(Photograph: Konstanze Schönthaler / Bosch & Partner GmbH)

I The representative population survey (of German-speaking residents aged 14 or more years) entitled Environmental Awareness and Behaviour in Germany (Umweltbewusstsein und -verhalten in Deutschland) has been carried out every two years since 2000 on behalf of the BMU and the UBA. Since 2012, questions have been asked in the survey, intended to supply data for DAS monitoring indicators; from 2016 onwards, these questions are asked every four years in the environmental awareness surveys.

Interfaces

TOU-I-6: Seasonal bed nights in German tourist areas

Are holiday seasons shifting?

The change in climatic conditions is associated with changes regarding the location specifics of tourism regions in Germany. Although traditional winter tourism will mainly entail risks, it seems reasonable to assume that the warm months of the year might produce not just risks but also opportunities regarding holiday destinations in Germany. There are several factors which might prove favourable, such as rising temperatures, lower precipitation from spring until autumn, as well as an increase in thermally comfortable conditions, especially at higher altitude in the mountains and also in coastal regions. Holiday regions might benefit from these changes, e.g. in terms of rising numbers of holidaymakers in the current off-season or by resulting in a longer summer season. On the other hand, changing weather patterns bear new risks such as drought and increased algal growth in bathing waters.

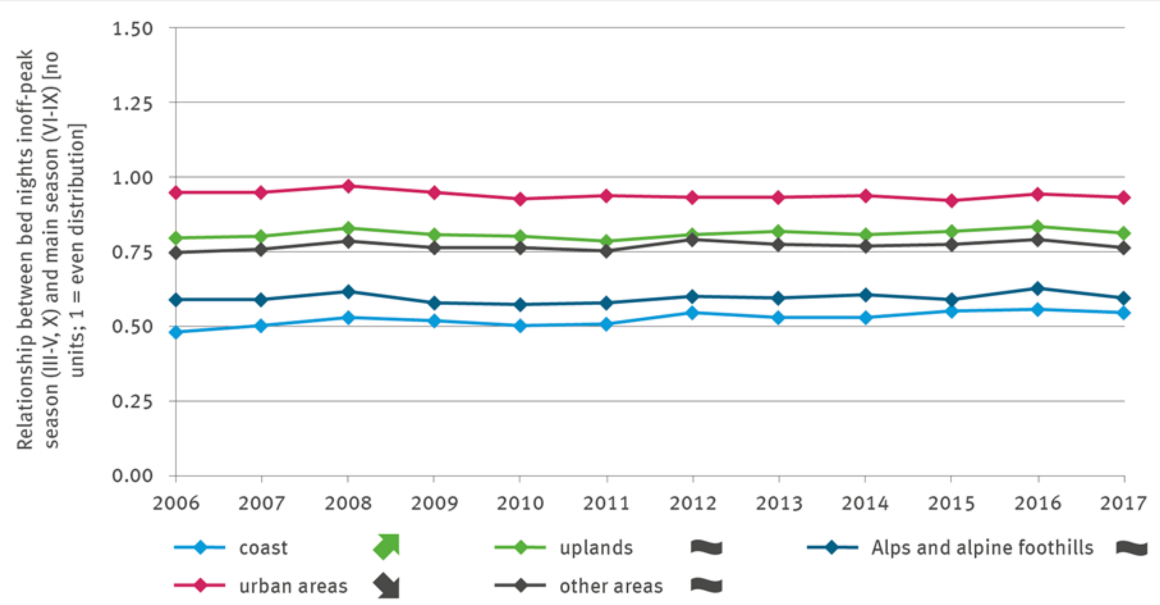
Destinations chosen primarily for the weather-dependent activities they offer and those that are closely bound up with the seasons, are particularly vulnerable to the impacts of climate change. This is true for all travel regions in Germany whereas particular destinations characterised by city and culture tourism will be less affected. Coastal tourism in Germany is predominantly in demand in the main travel season from June until September. The number of overnight guests recorded for that period is almost twice that recorded for the off-peak season.

In the tourism regions of the Alps and the alpine foothills, the main season from June until September is equally important for overnight tourism. The significance of the winter season for alpine tourism manifests itself more strongly in day tourism and associated high value added especially in skiing resorts. The winter season's share of annual bed nights amounts to just over 20%.

The other tourist regions, i.e. the upland regions, urban areas and all other regions clearly enjoy more regular demand for overnight accommodation throughout the year. Especially tourism in urban areas is highly independent of the seasons. These regions benefit from the fact that local offerings are less dependent on the weather and changeable weather patterns and can be enjoyed all year

TOU-I-6: Seasonal bed nights in German tourist areas

Primarily in the main season, the tourism industry exhibits high bed night figures in the Alps, alpine foothills and on the coast. In other tourist regions bed night numbers are distributed evenly across the year. As far as coastal tourism is concerned, there is a trend discernible towards more bookings in the off-peak season.



Data source: StBA (monthly survey in tourism) round. This includes e.g. culture tours, wellness tourism and other themed types of travel.

In all German tourism regions, the number of bed nights increased in recent years, especially in urban areas. So far, the increases in bed nights are distributed evenly over the main, off-peak and winter seasons. It has not been possible so far to identify a significant trend towards a shift in seasonal demand. However, the interpretation of figures in connection with climatic changes should always be approached with caution, because the number of bed nights in German travel areas – far from depending only on climatic conditions and associated changes – also depends on a great variety of other factors.

In connection with a project promoted in 2009 by the BMBF/Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung) research was done into a sustainable development of tourism in view of climate change. This project was piloted in coastal regions and in uplands. The outcomes show amongst other things that so far there is little public awareness of the impacts of climate change; as a result any adaptation required in the field of tourism has so far not been addressed as an important issue. Although there does seem to be a basic willingness to address the issue of climate change, the current focus is still on climate protection. And this factor is used as an opportunity to imbue touristic offerings with an environmentally friendly and innovative image.[77]

In future, spring and autumn might become more important for tourist regions in Germany.
(Photograph: © sasun Bughdaryan / stock.adobe.com)

Interfaces

TOU-I-2: Bed nights in coastal tourist areas
TOU-I-5: Bed nights in ski resorts

Are Germans changing their travel pattern?

Apart from demographic change, holiday period regulations, purchasing power and available leisure time, political crises, increasing competitive pressure, increasing price sensitivity and entitlement mentality – climate change is one of the forces that will influence the national and international travel behaviour of German travellers in the long term. German holidaymakers have many diverse interests and enjoy trying out novel and different travel offerings. Travellers will keep changing their travel habits time and again, possibly also as a result of changing temperature and precipitation conditions. A representative survey conducted in 2013 showed that 22 % of German tourists adapt their travel plans to rising temperatures and intend to travel to cooler regions.[78] In the representative population survey 'Environmental Awareness in Germany' (Umweltbewusstsein in Deutschland)[I] virtually half the respondents stated in 2012 that they would change their leisure or holiday planning, for instance regarding strenuous activities in heat or to avoiding hot holiday regions, whereas in 2014 and 2016 this statement was made by more than two thirds of respondents.

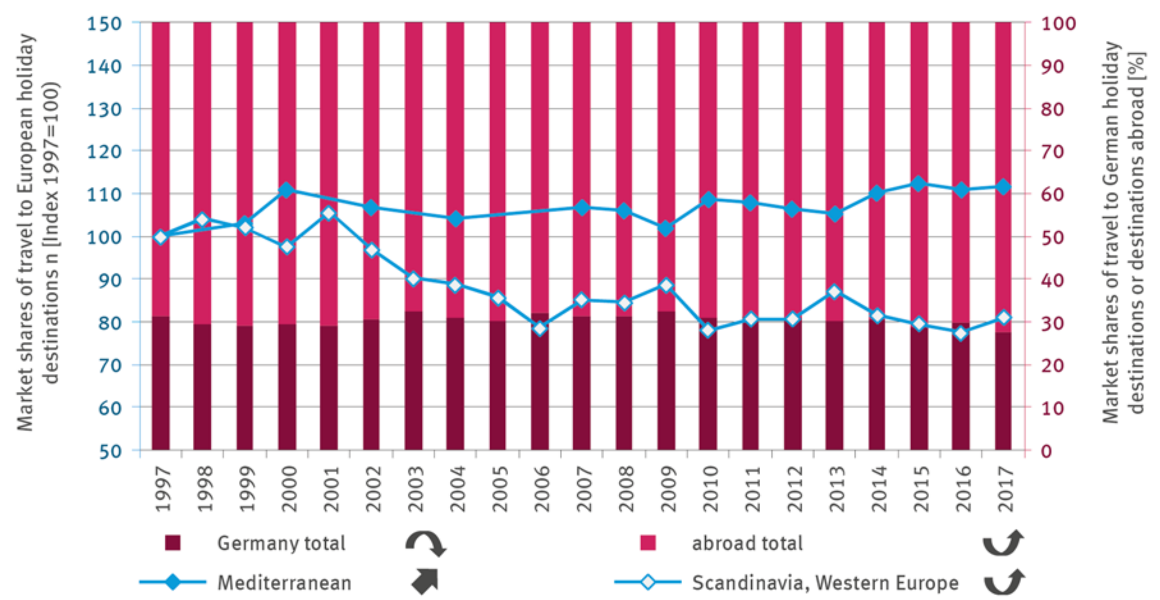
Traditionally beach holidays, bathing and sunbathing have held the leading position at the most beautiful time of the year. In 2010 29 % of all holidays abroad conformed to this pattern.[79] It is therefore no wonder that for Germans the Mediterranean region has been the most popular destination for holidays of more than five days' duration.

Adverse impacts are expected in particular for summer beach holidays in the south and thus the Mediterranean as the traditional destination. In other words, Mediterranean destinations might be perceived as less suitable for summer vacations, for instance when heat waves and drought mean that conditions are often beyond a holidaymaker's thermal comfort zone, or when precipitation fails thus causing problems with water supply and increasing the risk of forest fires. By contrast it is assumed that travel destinations in Central and Northern Europe might benefit from climatic changes, if higher temperatures

I see footnote p. 207

TOU-I-7: Holiday destination preferences

The travel behaviour of Germans so far reflects only few developments potentially associated with climate change. The market shares held by domestic tourism and the Mediterranean area are stable. After an extended period of decline, there are signs of a slow increase in the market share of holidaymakers for Western Europe and Scandinavia to become potential beneficiaries of climatic changes.



Data source: Forschungsgemeinschaft Urlaub und Reisen e.V. (ReiseAnalyse) and lower precipitation levels increase the attractiveness of local bathing resorts, and if the summer season is extended. The outcomes of statistic modelling of the development of tourism in Europe suggest on one hand that for the hitherto cooler countries and in destinations at higher altitudes, a higher number of international visitors can be expected. On the other hand, there might also be an increase in the number of domestic tourists, if there is a shift in tourism demand from foreign destinations to Germany.[80]

At sufficiently high altitude, there might also be benefits for winter sports tourism in Northern Europe. As the amounts of precipitation and snow increase in the winter season, the snow guarantee remains higher in Scandinavia than in many parts of the Alps. Consequently, the region concerned may be able to increase its market share of alpine and nordic ski sports, if traditional winter sport resorts in Germany, but also low-lying skiing areas in Austria become less attractive for winter holidays owing to a diminishing snow guarantee.

Generally speaking it is to be expected that climate-related large-scale changes in the travel behaviour of German travellers will not become apparent in the immediate future. On one hand, the climatic development does not proceed continuously. In fact, unfavourable weather events and weather patterns occur irregularly. It is only when holidaymakers keep having negative experiences with climatic conditions at their specific destination more frequently and more regularly, that the impacts on travel behaviour will become apparent. On the other hand, the prospective holidaymaker still has the option to adapt to changed conditions in the Mediterranean area. They might, for example, travel at a different time, if summer temperatures in the main season become too high. Besides, they have the option to choose other destinations in the Mediterranean area. For example, for the south of France, temperatures are expected to rise more gradually than, say, the south of Spain or the north African coast.

So far the travel pattern of German holidaymakers does not display any developments normally attributed to climate change. Now as before, the Mediterranean is still the most attractive travel destination for German holidaymakers. Leaving aside minor fluctuations, the market share of this segment has remained stable at approx. 35%. The market share of domestic holidays amounting to approx. 30 % also shows only minor changes for the period in question. By comparison, the regions of Scandinavia with 3 %, and Western Europe, i.e. the British Isles, the regions of France not bordering the Mediterranean, the Netherlands, Austria and Switzerland – latterly

If temperatures in the Mediterranean area continue to soar, German coastal resorts in the areas of North Sea and Baltic Sea might be able to outcompete some of the international travel destinations.
(Photograph: Konstanze Schönthaler / Bosch & Partner GmbH)

accounting for 14 % – have been attracting distinctly fewer German holidaymakers. It is interesting to note that only for these regions has it been possible to identify a trend in the past few years. The interest in a holiday in Western Europa or Scandinavia has suffered a significant decline since 1997.

Financial services industry

Insurance companies, credit institutions and other actors in the financial sector are variously confronted with the risks and impacts of climate change. Their clientele, in other words, private individuals and companies, is linked closely to the financial sector in terms of third-party finance and insurance policies. This is why climate risks borne by business partners can easily become risks for the financial institutions themselves.

The business activity of insurance companies is based on the fundamental principle of the collective assumption and sharing of risks. The success of an insurance business is based on the prerequisite that risks can be assessed realistically and that the extent of potential damage can be estimated statistically in order to have the necessary foundation on which to base the calculation of the relevant insurance premiums required. This is why insurance companies have for some time thought hard about the potential impacts of climate change and developed strategies enabling them to cope with major and more frequent damage events in the future.

By contrast, credit institutions consider the physical risks of climate change as controllable, at least for the near future. Adverse effects on the solvency and liquidity as well as the security of debtors or the possibility of losses in the value of asset investments have so far, from their point of view, been considered less risky than from the point of view of insurance companies. This is true in particular for regional credit institutions which are active almost exclusively within Germany, handling a major part of the domestic credit business. As far as credit institutions are concerned, their risks have more to do with regulatory risks, arising from ever-increasing stipulations regarding climate protection to be observed by their clients or in respect of reputational risks which can go hand-in-hand with climate-damaging projects.

Effects of climate change

Things might become expensive for insurance companies

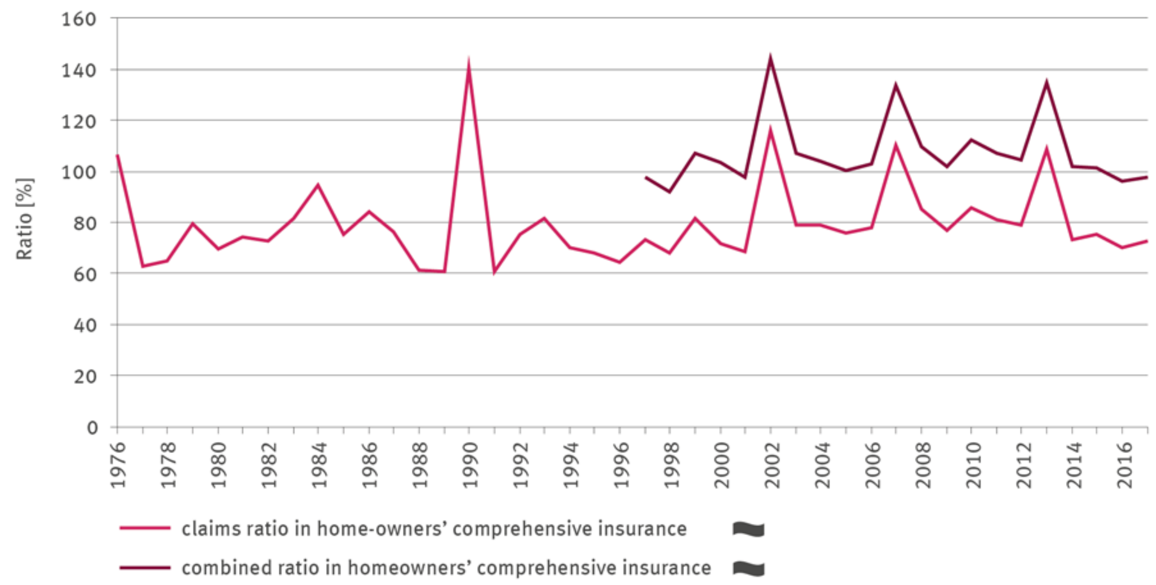
Increasing claims ratio figures signify increasing expectations of damages to be paid by insurance companies in view of the changing relationship of income and expenditure in the insurance segment concerned. Such considerations play an important role in terms of an insurance company's balance sheet. In 2017 storms and hailstones caused damage totalling 2.6 billion Euros, the equivalent of 90 % of insurance damage in the fields of property and motor vehicle insurance.

Whether an insurance segment is profitable is indicated by the so-called combined ratio. The storm events of recent years left their mark on the combined ratio of homeowners' insurance. Where the ratio exceeds 100 %, this indicates that this is a loss-making business for the company. In the segment of homeowners' comprehensive insurance, the combined ratio is usually comparatively high. This regularly causes actuarial losses to insurance companies. Looking back over the past 21 years, for which data covering the German insurance companies in the field of private property insurance are amalgamated in a central database, it becomes clear that up until 2015 German insurance companies were able to make an actuarial profit in only three years (1997, 1998, 2001) in respect of homeowners' comprehensive insurance. Between 2002 and 2014 the insurers of homeowners' properties accumulated an actuarial minus of more than 7 billion Euros. For a long time the competition on price in the field of homeowners' comprehensive insurance was very keen, which made insurance companies hesitant to adapt their calculations to the premiums charged. Since the end of the price war over homeowners' insurance and the resulting increase in premiums, the combined ratio for 2016 and 2017 has reverted to below 100 %. Consequently, in those years it was possible again to achieve an actuarial profit in the field of homeowners' comprehensive insurance. So far it has not been possible to identify a discernible trend in respect of the combined ratio.

By comparison, looking at the time series for the claims ratio – which does not include the costs of administration and contract conclusion thus not permitting any immediate statements on the profitability of the insurance

FiW-I-1: Claims ratio and combined ratio in homeowners' comprehensive insurance

In general, homeowners' comprehensive insurance is a less profitable business for insurance companies. After price responses to increasing amount of damages, the years 2016 and 2017 reverted to actuarial profits.



Data source: GDV

business – the picture is quite similar. There is no discernible trend in this respect either.

If insurance companies want to avoid charging their clients further premium increases, they will probably have to demand more personal provision by the insured themselves. This means that homeowners will have to become proactive themselves by proving that, thanks to architectural measures, they have been able to achieve better protection of their buildings from the impacts of natural hazards. The insurance industry continues to work on the premise that it remains possible to provide insurance in Germany for damage caused by natural hazards despite being faced by climate change.

Homeowners' insurance also covers major damage from hailstones. (Photograph: © Stillkost / stock.adobe.com)

Interfaces

BAU-I-5: Claims expenditure for property insurance
BAU-R-4: Funding for building and refurbishment adapted to climate change

Objectives

Active management of risks and opportunities by banks and insurance companies (DAS, ch. 3.2.10)

Risk awareness – key to adequate provision

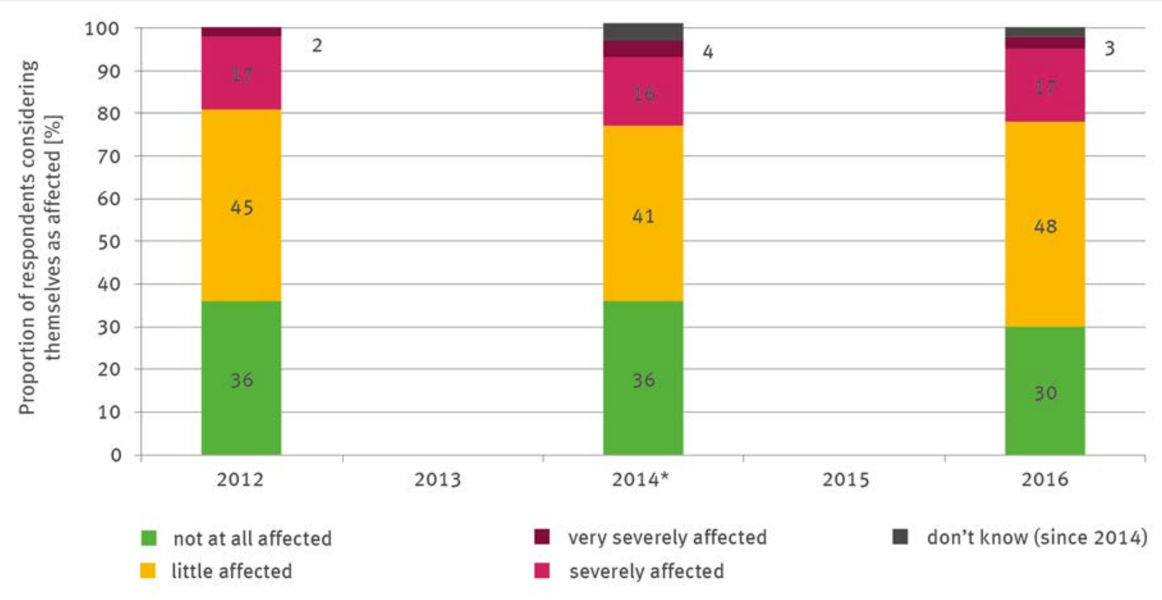
In what way human beings perceive hazards or risks, how they estimate potential impacts and what type of provident action they need to take, varies from one individual to another. Apart from hard facts – scientifically proven and measurable – which determine the extent of risk, there are numerous subjective components that can have considerable influence on the perception of risks. Such perceptions of risk can often be distorted. On one hand, they can be characterised by unrealistic optimism and the illusion to have everything under control, on the other, they can be influenced by impressions derived from current disastrous events which have triggered great concerns and can lead to an overestimate of individual risks.

In a representative public survey carried out every two years on behalf of the UBA, entitled Environmental Awareness in Germany (Umweltbewusstsein in Deutschland)"[I] respondents, since 2012, make estimates (among other statements), to what extent they might be personally affected by the consequences of climate change. In 2012 81 % of respondents stated that they perceive little or no risk that floodwater events and storms might damage their house or home. In the subsequent survey this estimate had changed little: In 2014 77 % and in 2016 78 % perceived themselves little or not at all affected. It is true to say, however, that the values collected permit only restricted interpretation as they are not linked to information on the actual exposure of respondents to the climate change impacts concerned.

I The representative population survey (of German-speaking residents aged 14 or more years) entitled Environmental Awareness and Behaviour in Germany (Umweltbewusstsein und -verhalten in Deutschland) has been carried out every two years since 2000 on behalf of the BMU and the UBA. Since 2012, additional questions have been asked in the survey, intended to supply data for DAS monitoring indicators; from 2016 onwards, these questions are asked every four years in the environmental awareness surveys.

FiW-I-2: Incidence of storms and floods

Despite extreme weather events in recent years, the German population's risk awareness is still very low. Not even a quarter of citizens who responded to the survey appreciate that their house or home is at genuine risk of damage from storms or floodwater. Consequently, their willingness to take out an insurance policy which covers climate-related risks is just as low.



* rounding error due to missing decimal places

Data source: BMUB & UBA (Umweltbewusstsein in Deutschland)

Other, similar types of survey have produced similar outcomes regarding estimated risks.

For example, the GDV, conducted a forsa survey in June 2013, in other words, shortly after the floodwater disaster, to carry out an opinion poll on the population's risk awareness. The outcome showed that as many as 90 % of Germans think there is little risk they might be personally affected by floodwater, storm or other natural hazards.[81]

However, reality paints a different picture, for in 2016 floodwater also affected many people who live far away from those major rivers and considered themselves safe. Even flooding caused by heavy rain can cause severe damage far away from areas at risk from floodwater. In this context, it is worth mentioning the heavy-rain events of summer 2017 which caused flooding and major damage for example in Berlin and Brandenburg.

An awareness of one's own risk and the potential of becoming personally affected – as well as the need to have access to practical everyday courses of action – should motivate individuals to take every possible precaution to minimise their risks and to take adequate precautions to ensure their safety. Consequently, it is important that the actual risks associated with climate change be appreciated by as many people as possible thus enabling them to assess those risks in a realistic manner. To this end, support is available from an internet-based information tool entitled 'Kompass Naturgefahren' (natural hazards compass) which informs tenants, proprietors and companies of the extent their building is at risk from floodwater. This tool will also inform users of any other risks that might emanate from other natural hazards such as heavy rain, storm, lightning strikes or earthquakes. The 'Kompass Naturgefahren' tool is intended to sharpen people's awareness of the risks from natural hazards and summon them to make their own provisions. This service is currently available in the Free State Saxony as well as Saxony-Anhalt, Lower Saxony and Berlin.

For the insurance industry, the population's and companies' appropriate risk awareness is one of the most important foundations of their business. Only if this awareness is widespread and deeply rooted and if consequently many people take out adequate insurance, will it be possible to form sufficiently large risk communities for an insurance company to facilitate affordable insurance premiums.

In addition to having very little risk awareness, many people believe themselves adequately insured for damage caused by climate change impacts on the basis of their existing policies.[82] In those cases, it is often overlooked that the customary homeowners' comprehensive insurance does not cover damage caused by heavy flooding.

The risk that their house or home might suffer damage as a result of climate change impacts is estimated as very low by many people. (Photograph: © Andrey Popov / stock.adobe.com)

Interfaces

BAU-I-5: Claims expenditure for property insurance
BS-R-1: Information on how to act in a disaster situation
HUE-1: Manageability of climate change impacts

Objectives

Increasing clients' and authorities' awareness of climate-related interconnections and creating financial stimuli by means of appropriate contract design on the part of insurance companies (DAS, ch. 3.2.10)

Spatial planning, regional and urban development

Spatial planning, regional and urban development can be used to support the adaptation to climate change in two significant ways. On one hand, these types of planning can provide targeted support for risk provisioning at various planning levels, and they can govern land use in a way that mitigates existing or expected climate risks – for example from extreme weather events and their impacts. On the other hand, planning can help to reconcile diverging claims on land use and changing requirements arising from climatic circumstances as well as reconciling such claims with issues of landscape potential.

To this end, there are different tools available at different planning levels. The essential formal tools of spatial planning – the planning at Länder and regional level which facilitate the overarching governance of spatial development – are the planning categories of priority and restricted areas. As far as priority areas are concerned, spatial types of function or utilisation have priority: Subject to appropriate designation of these areas, this precludes any incompatible type of spatial utilisation, unless the latter is protected as a pre-existing form of land use. In priority areas any relevant issues have already been settled by final and binding decisions. Subordinate planning levels can only be used to reinforce such decisions within the scope of their planning remit. However, they are not at liberty to reassess their validity. By contrast, restricted area designations are less legally binding. It is true to say that the designation of restricted areas imbues them with a certain gravity regarding specific types of spatial function or use with a view to subsequent assessment of other types of land use. However, the importance of conflicting types of land use may be weighted as overriding which means that they cannot be completely ruled out.

Adaptations:

Safeguarding space for evolution – priority and restricted areas reserved for wildlife and landscape

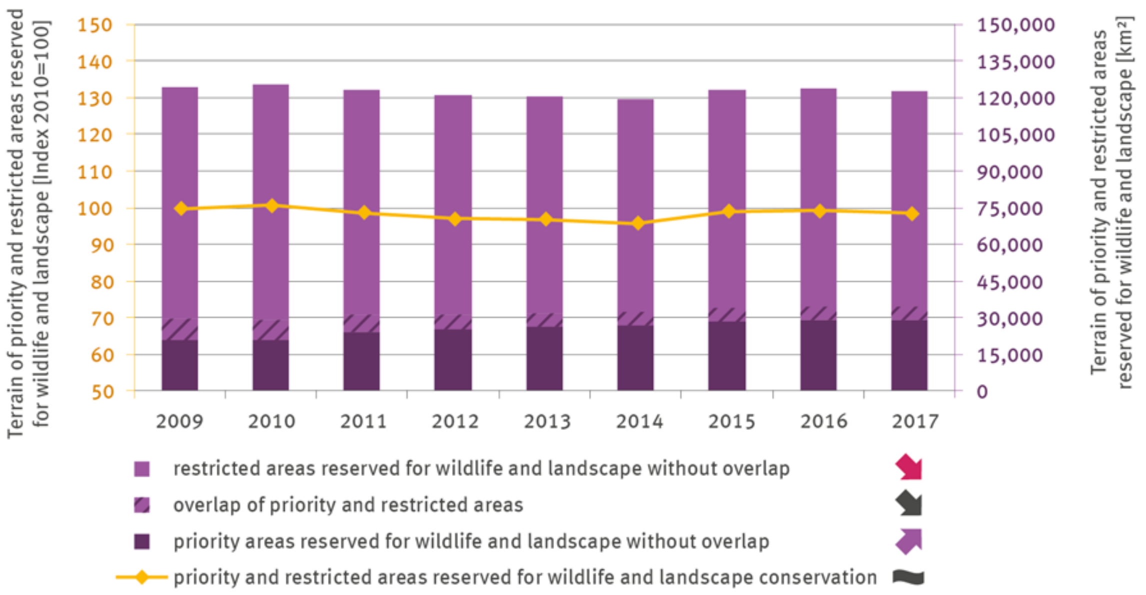
Climate change will have wide-ranging impacts on ecological conditions affecting animal and plant species. Higher temperatures and a changing precipitation regime as well as extreme events affect various components of ecosystems, impacting on functions such as nutrient regime, habitat structures or the availability of food. In the final analysis, this means that the demarcations of habitats available to animals and plants are likely to shift.

In these circumstances, a functioning compound system or network of biotopes is essential for the survival of highly specialised species which require specific locations and habitats. In a contiguous network of ecologically meaningful open spaces, species are able to explore and colonise new, climatically more suitable habitats of sufficient size and content. This is the only way to safeguard the essential genetic exchange among different populations and occurrences.

By designating priority and restricted areas reserved for wildlife and landscape, spatial planning can contribute to building an ecological network. In this way spatial planning is able to safeguard areas or impose restrictions on use which are important for the adaptation of animal and plant species to climate-related changes. In 2017 this was actually achieved on slightly more than one third of the entire terrain of the Federal Republic of Germany. In that year, a total of approximately 122,000 square kilometres were designated as priority and/or restricted areas. It should be borne in mind that the evaluation covers a partly heterogeneous accumulation of designations applied in various Länder, such as spatial planning areas reserved for the protection of wildlife, the protection of landscape and landscape-related recreation as well as areas reserved for the development of an ecological network. This is why in some places, there is a degree of overlap between priority and restricted areas, for example when terrain is reserved as priority areas for species and habitat protection at the same time serving

RO-R-1: Priority and restricted areas reserved for wildlife and landscape conservation

In 2017 Germany had approximately 122,000 square kilometres – roughly one third of its terrain – designated as priority or restricted areas reserved for wildlife and landscape. Länder and regional planning authorities use this measure to support the biotope network thus helping animal and plant species to adapt their specific distribution range to changing climatic conditions.



Data source: BBSR (ROPLAMO – spatial planning monitor)

as restricted areas for the special protection of landscapes. In the time series concerned, these partial areas are taken into account only once.

Between 2010 and 2014, the designated terrain decreased by approximately 6,000 square kilometres. In particular´, restricted area designations were withdrawn and this loss was only partly offset by fresh designations of priority areas. Between 2014 and 2017, the size of designated terrain was increased again by 3,200 square kilometres owing to the designation of priority areas.

Nearly all planning regions avail themselves of the opportunity to designate priority or restricted areas reserved for wildlife and landscape. The large-scale use of designation categories demonstrates the importance which planning regions attach to the protection of wildlife and landscape and, consequently, the creation and conservation of an ecological network. These figures alone, however, do not permit an assessment whether the ecological network fulfils its purpose and whether the landscape is genuinely permeable, allowing the passage of animal and plant species. Such evaluation would have to take into account, above all, how the designated areas are spatially distributed and networked, and what ecological quality they are able to offer. Moreover, priority and restricted areas are not the only areas which ought to safeguard ecological interconnections. The development and safeguarding of biotope connectivity is primarily the remit of nature conservation bodies which, among other things, designate protected areas on the basis of nature conservation law; these bodies plan and implement the management of designated areas. These areas are also part of the biotope network. However, they are only covered by this evaluation insofar as they are designated as priority or restricted areas. As far as spatial planning itself is concerned, not all tools in the toolbox are taken into account, such as regional green belts and corridors which might benefit an ecological network. It is true, however, that such areas also play important parts in recreational terms thus conflicting with the biotope network. This is why they are not taken into account in this context.

Apart from beneficial effects, such ecological networks unfortunately also give rise to opportunities for less pleasing developments. It is expected for example that as a result of climate change, undesirable species brought in by humans will be able to further widen their distribution range. This problem will have to be addressed by good management of ecological networks in order to prevent any developments counteracting nature conservation objectives or at least to minimise their impacts.

Priority and restricted areas reserved for wildlife and landscape make valuable contributions to the large-scale biotope network. (Photograph:© ExQuisine / stock.adobe.com)

Interfaces

BD-R-2: Protected areas

Objectives

Assisting the adaptation of species to climate based shift of habitats by means of regulatory planning support for the purpose of safeguarding the priority areas reserved for nature conservation and for safeguarding an ecological network (DAS, ch. 3.2.14)

Safeguarding a functionally contiguous network of ecologically important open spaces thus facilitating migration across national borders (Handlungskonzept Klimawandel, MKRO 2013, ch. 3.7)

Safeguarding habitat corridors and functional spaces for the genetic exchange among populations in habitats worth protecting by means of spatial, regional and physical planning, incorporation of memoranda for further habitat corridors in spatial planning designs (Bundesprogramm Wiedervernetzung, ch. C.3.1, C.3.2)

Spatial planning for drinking water and groundwater conservation

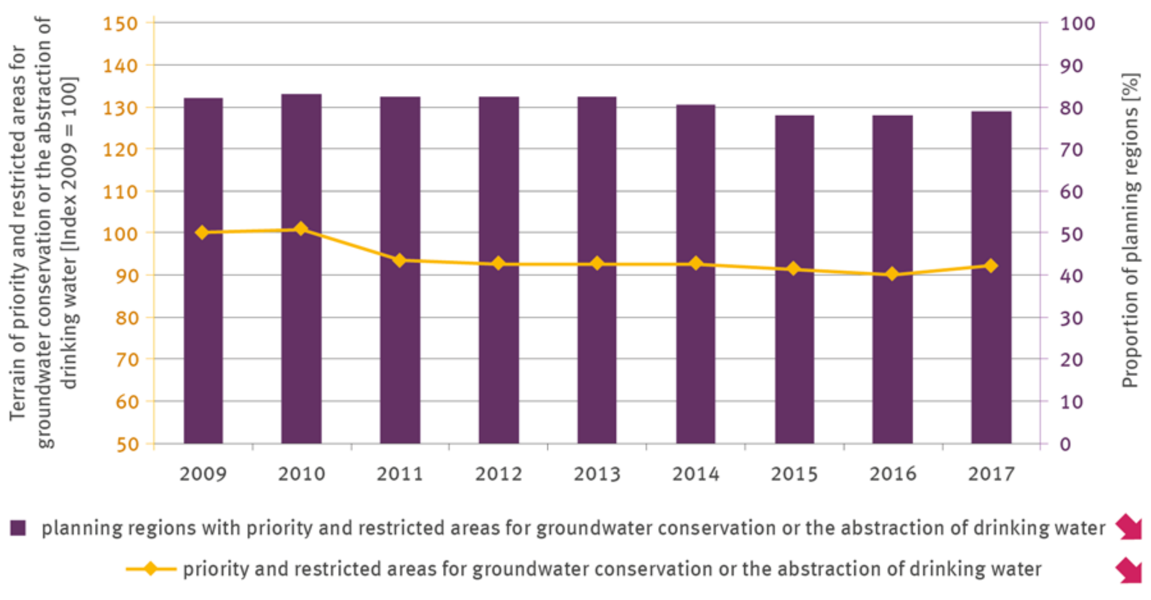
Although Germany is a water-rich country with, generally speaking, adequate availability of water, there are some regions in which there are localised areas with water shortages where usable groundwater resources are scarce and where in some seasons the demand for water cannot always be met from resources within the region. In those regions distribution systems are used to balance regional differences in the availability of water. Climate change may further worsen the currently already unfavourable climatic water regime in some regions of Germany. Changed precipitation and temperature conditions affect all processes occurring in the water regime thus influencing also the formation of groundwater recharge rates as well as the amount and quality of groundwater and surface waters used for the abstraction of drinking water. Increasing water shortages and more frequent droughts may give rise to regional conflicts in particular regarding the use of water resources near the surface.

Planning at state and regional level can designate priority and restricted areas for the conservation of drinking water and groundwater, thus safeguarding water resources by means of planning measures, moderating between diverging claims on land use and avoiding or mitigating conflicts. Just under 80% of planning regions avail themselves of this opportunity. The high proportion of planning regions which carry out designations demonstrates that spatial planning tools are not just used in planning regions affected by water shortages. In fact, the protection and safeguarding of water resources is of major importance also in water-rich areas, partly because their water resources are in part used for provisioning water-poor areas.

To what extent various area categories are implemented for the conservation of groundwater and drinking water in individual planning regions depends above all – apart from variations in planning practice – on the individual

RO-R-2: Priority and restricted areas for groundwater conservation or the abstraction of drinking water

In the process of redesigning individual regional plans over recent years, priority and restricted areas were in many cases either not renewed or designations were limited to a rather smaller spatial extent. Consequently, by 2009 the terrain of spatial planning areas dedicated to the conservation of drinking water and groundwater had declined.



Data source: BBSR (ROPLAMO – spatial planning monitor)

spatial character of regions, such as soil properties and geological baseline conditions, for instance whether the vegetation is near-natural and the intensity of its use. In 2017 an overall terrain of approximately 39,000 square kilometres in Germany was designated as priority or restricted areas for the conservation of drinking water and groundwater – the equivalent of more than 10 % of the total land of the Federal Republic. Even though the areal expansion does not provide any direct conclusions on whether areas are designated to the appropriate spatial extent or quality, this percentage does illustrate the great importance attached to the conservation of water resources in spatial planning terms.

As a rule, regional plans are redesigned or updated every ten to fifteen years. In this process, planning regions may update the specifications contained in plans, which may entail changes in areal designations. Furthermore, plans may on these occasions also be adapted to changes in law or jurisdiction.

Especially in dry regions of the Federal Republic, specifications on climate-related groundwater protection have already been designed for inclusion in the updating process of spatial planning regulations. Nevertheless, the terrain designated for the conservation of water resources has declined by approximately 3,700 square kilometres since 2009. The reason for this was that spatial planning areas intended for safeguarding the supply of drinking water or for the conservation of groundwater resources were not specified again in some of the newly designed regional plans or that their areal extent was reduced.

Spatial planning tools help to ensure the protective use of an area thus safeguarding drinking water and groundwater resources. (Photograph: © alexlukin / stock.adobe.com)

Interfaces

WW-I-1: Groundwater level
WW-R-1: Water use index

Objectives

Strengthening the safeguarding of water resources by spatial planning regulations and making increased use of planning tools for the adaptation of land use (DAS, ch. 3.2.14)

Intensified safeguarding of water resources, also and especially for the purpose of sustained, long-term safeguarding beyond current usage requirements (spare areas); support for the conservation or enhancement of the water regime of soils (increasing their water storage capacity, enhancing their infiltration capacity) in sensitive parts of groundwater catchment areas; provident governance in respect of water-based processes in areas particularly affected by drought (Handlungskonzept Klimawandel, MKRO 2013, ch. 3.5)

Safeguarding areas for inland flood protection

One potential consequence of climate change might be a change in the frequency and severity of flood events, for example when incidents of heavy rainfall in summer intensify or when precipitation in winter increases or when it more frequently falls as rain. In winter months soils saturated with rain can absorb only very little precipitation. Consequently, this precipitation is usually almost immediately added to run-off. Consequently, provident flood protection is an important measure for the adaptation to impacts of climate change.

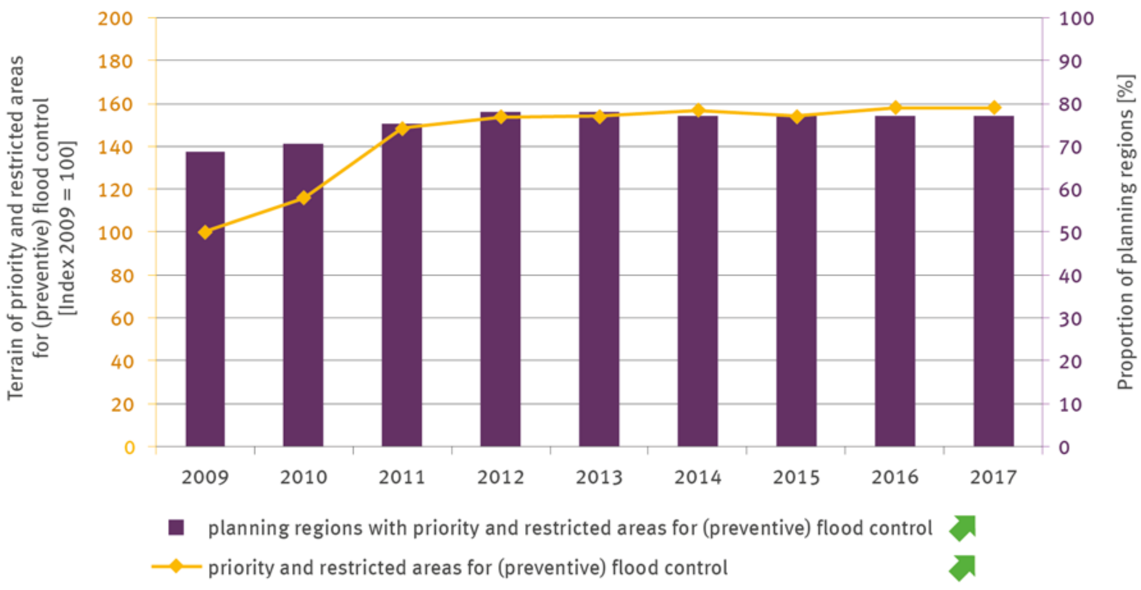
The designation of flood plains, as covered by binding regulations embedded in the nationwide WHG, is therefore a key component of preventive flood protection. It is the remit of competent authorities to designate flood plains within areas perceived to be at risk thus ensuring that they are available for flooding in case of a so-called 100-year flood event. Furthermore, areas such as flood polders and flood channels have to be included in this designation to serve as flood relief spillways.

However, over and above any legal regulations, it is the remit of spatial planning to use its own tools for contributing to preventive flood protection. An essential element of the planning toolbox available for this purpose is the use of spatial planning specifications on flood protection. These can be used to govern spatial utilisation in a way to make an area less vulnerable to flood risks which – judging by experience – are expected to increase as a result of climate change. Any areas at risk can be precluded from utilisation as settlement or infrastructure areas. Areas of importance for water retention in the landscape and for provident flood protection with a view to climate change can be safeguarded by means of imposing usage restrictions.

The most significant spatial planning tool for this purpose is the designation of priority areas for preventive flood protection. In areas covered by this category of designation, flood protection has priority. Types of spatial utilisation incompatible with this purpose are precluded. So far the practice of designating priority areas has been generally heterogeneous among planning regions.

RO-R-3: Priority and restricted areas for (preventive) flood control

In the period of 2009 to 2013, the terrain of priority and restricted areas for (preventive) flood protection underwent a distinct increase by approximately 4,000 square kilometres. By end of 2017, 88 of 114 regions had incorporated relevant specifications in their regional plans.



Data source: BBSR (ROPLAMO – spatial planning monitor)

However, usually it is based on the demarcation of legally recognised flood plains. In some cases, specifications are included in regional plans as memoranda, in others the designated priority areas are identical with specified flood plains, while in some other regions priority areas go beyond the demarcations of flood plains. In some cases, however, legal regulations expressly preclude priority designations by spatial planning authorities, as for instance in the 'Doppelsicherungsverbot' embedded in Bavaria's State Planning Act.

As stipulated in WHG regulations, the specification of flood plains had to be completed by 2013. As was to be expected, however, numerous planning regions have had to carry out a first-time or renewed designation of priority and restricted areas at a later date. By 2017, the terrain of priority and restricted areas comprised approximately 11,800 square kilometres in planning regions overall. Since 2009, 11 of 114 planning regions included new relevant designations in their regional plans, thus increasing the terrain of priority or restricted areas reserved for preventive flood protection by 4,330 square kilometres in Germany nationwide. The majority of new designations were carried out by 2013.

In the light of the impending adaptation to the impacts of climate change it seems sensible – where appropriate – to strengthen spatial planning designations for preventive flood protection by going beyond the legal specification of flood areas thus reinforcing the precautionary intention. In past years, various modelling projects of spatial planning examined relevant options. In the region of Oberes Elbtal-Osterzgebirge, for example, a new methodology was developed for designating priority and restricted areas for preventive flood protection. This methodology was subjected to legal scrutiny, including the demarcation of priority areas for preventive flood protection in terms of risk intensity (water depth and flow rate) during extreme flood events thus also including the extent of settlement. The outcomes are taken into account by the planning region in the current overall update of their regional plan and will be incorporated as implementation-oriented recommendations for action.

Overflowing permitted – priority and restricted areas for preventive flood protection can safeguard alluvial meadows and provide ample space for rivers.
(Photograph: © vladk213 / stock.adobe.com)

Interfaces

WW-I-3: Floodwater
RO-R-6: Settlement use in flood-risk areas

Objectives

Reinforced protection against increasing flood risks by means of passive safeguarding measures, especially in terms of keeping out development; safeguarding existing run-off and retention areas as well as provident planning for expanding such areas in case of 200-year flood events; substantial expansion of retention areas by 2020 (DAS, ch. 3.2.14)

Safeguarding existing flood plains as retention spaces; restoration of flood plains as retention spaces; risk provisioning in potential flood areas; enhancement of water retention in the catchment area of rivers; safeguarding potential locations for flood protection measures (Handlungskonzept Klimawandel, MKRO 2013, ch. 3.1)

Preventive inland flood protection, especially by means of safeguarding or restoring alluvial meadows, retention areas and flood relief spillways (ROG, § 2 (2) 6)

Conserving unsealed terrain to benefit local climate

In towns and greater conurbations with high-density settlements and a high degree of sealed surfaces, it is common to measure distinctly higher average temperatures and higher peak temperatures than in the periphery – this effect is termed 'urban heat island'. The intensity of heat island effects increases with increasing population density. In larger towns with approximately 100,000 inhabitants the temperature difference between town and periphery can amount up to 6 °C while for the megacity of Cologne a difference of 10 °C was measured at the end of a clear night. Depending on natural bio-climatic conditions (geographical location, altitude etc), summer months can give rise to increased heat stress compared to the periphery, and climate change may lead to a future increase in the occurrence of this phenomenon. Inhabitants may experience particular difficulties owing to the rather gradual cooling of urban spaces in the evening or at night, with high temperatures making a good night's rest impossible.

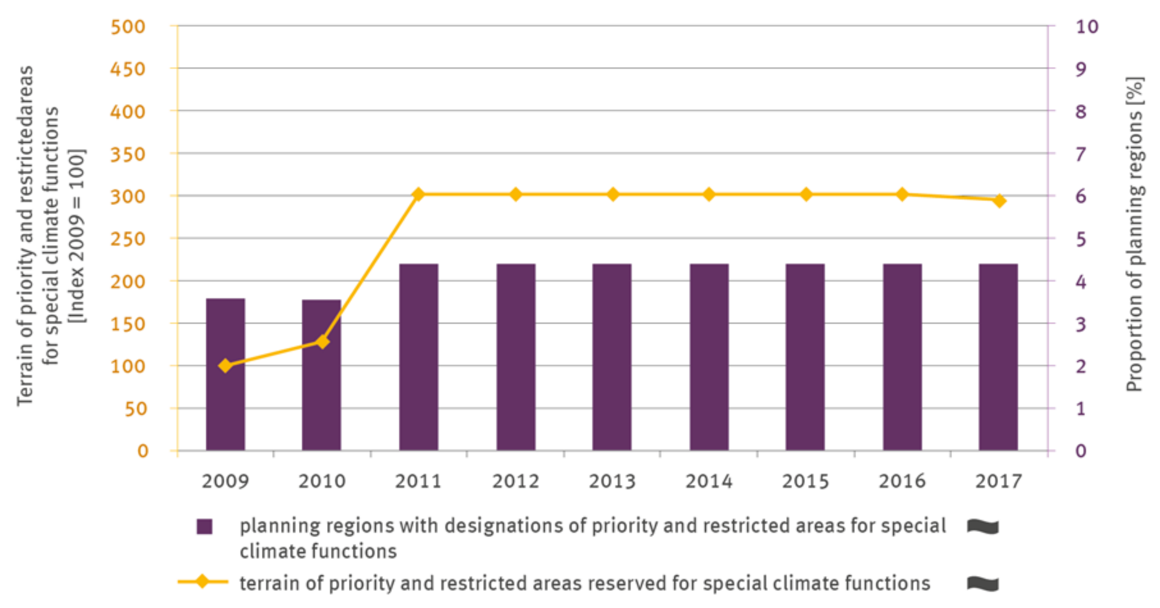
Regional planning is able to counteract this projected increase in bio-climatic stress situations by designating climatically important large-scale open areas as priority and restricted areas reserved for specific climate functions, and networking these areas where cool and fresh air accumulates with local green spaces, thus permitting the passage of fresh air into urban spaces. In this way regional planning is able to prevent any spatial usage which might counteract these objectives. Furthermore, planning can also designate areas where specific actions should be taken in view of local circumstances, in order to reduce bio-climatic stress.

It is true to say, however, that hitherto the designation of priority and restricted areas for facilitating specific climate functions has been carried out in very few regions. This is partly due to the fact that this planning category is still relatively new. Guide plans generated by state and regional planning authorities usually remain in existence over extended periods which means that innovations are only gradually incorporated into such plans.

In addition, regional planning also uses other spatial planning tools for the protection of open spaces, such as regional green belts for safeguarding climatically

RO-R-4: Priority and restricted areas for special climate functions

Priority and restricted areas for special climate functions are a fairly new tool used in spatial planning. This is why this area category has so far been applied in only five planning regions in Germany.



Data source: BBSR (ROPLAMO – spatial planning monitor)

important open spaces; alternatively, regional planning sometimes uses a symbolic approach to illustrate bio-climatically relevant 'air channels' without allocating tangible tasks to specific areas. Whatever tools are used and in what way they are applied, is also dependent on the designation practice prevailing in the federal state concerned. This is why there may not be an additional demand for designating specific areas.

In the planning regions of Hesse and Rhineland-Palatinate where priority and restricted areas for specific climate functions are designated, the two objectives mentioned above are achieved by means of practical implementation: the conservation of climatically important open spaces and the designation of bio-climatically exposed areas in major need of action. In Hesse regional plans have to fulfil the purpose of safeguarding areas sustainably which can serve as climate-balancing spaces or as air channels. In the regional plans for Middle Hesse and Southern Hesse areas are specified in detail where cool and fresh air accumulates and from where such air can be channelled elsewhere, in order to safeguard and – where necessary – restore such areas. These areas are to be kept clear of development and any other measures which might inhibit the formation or transport of fresh and cool air. Plans and measures which might impair the aeration of locations exposed to climatic stress or air quality stress are to be avoided in those areas. Their implementation is permitted only in cases where evidence can be produced that no substantial detrimental climatic impacts would ensue.

The second approach within the planning category as outlined above has been adopted in the regional plan for Middle Rhine-Westerwald and in the regional land use plan for Frankfurt/Rhine-Main. In this case, thermally stressed spaces and climatically vulnerable valley locations are designated as restricted areas, partly with the objective to enhance the prevailing climatic conditions as much as possible. To this end, it is intended to conserve or expand climate-balancing areas or to avoid housing development projects which would impede the free passage of fresh air.

Cool air can develop at night above meadows and vineyards like here in Stuttgart's periphery, finding its way eventually into the overheated inner city.
(Photograph: © Manuel Schönfeld / stock.adobe.com)

Interfaces

GE-I-1: Heat exposure
BAU-I-1: Heat stress in urban environments
BAU-I-2: Summer-related heat island effect

Objectives

Guarding against overheating in towns and greater conurbations in the summer months by means of planning green belts and fresh air channels, in the context of housing developments conserving open spaces where fresh and cool air can develop and conserving channels for the free passage of this air; avoiding excessive warming of buildings and recreational areas (DAS, ch. 3.2.14)

Safeguarding climate-relevant balancing spaces and air exchange channels as well as precluding counteractive types of usage by means of specifying suitable priority / restricted areas in regional plans, for example as priority / restricted areas for special climate functions or climate-ecological balancing spaces; safeguarding climate-balancing spaces by other specifications for open spaces; spatial governance of settlement or infrastructure development, for example by means of illustrating thermal stress areas (Handlungskonzept Klimawandel, MKRO 2013, ch. 3.4)

Provident new land use also contributes to adaptation

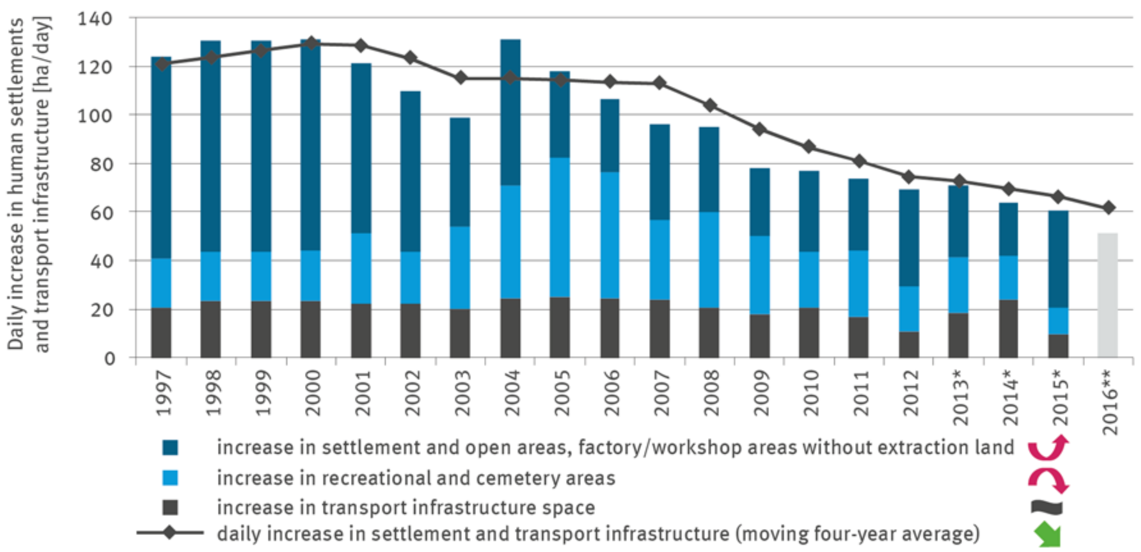
A terrain that has not been built on, is unfragmented and free from urban sprawl is a limited and desirable resource which is much in demand and the object of competition among agriculture, forestry, developers, transport infrastructure, nature conservation, the exploitation of raw materials and the generation of energy. The designation of priority and restricted areas is a tool used by spatial planning in order to guide any new land use and to moderate various claims on utilisation. Last not least the intention is to conserve or further enhance ecosystem services important to humans and nature.

In connection with changing climatic conditions, ecosystem services address the potential of unsealed surfaces to allow the infiltration of precipitation and also – at times of flooding – to provide temporary retention. Alluvial meadows free from housing developments provide space for rivers and take the pressure off downstream areas of the river basin at times of flooding. In bioclimatically stressed spaces, the passage of fresh and cool air to residential areas is paramount. On the periphery of conurbations, air can cool off faster in the summer months above meadows and arable land than in residential areas. Air channels such as parts of open valleys transport the cool air to neighbouring residential areas thus mitigating any thermal stress. As far as agriculture and forestry are concerned, and also in respect of the harvesting of renewable raw materials, it is above all relevant to protect fertile soil and productive land in a sustainable way for the future. Moreover, animals and plants depend on open spaces and networked, unfragmented habitats and landscape structures for their survival and reproduction. If habitat conditions change as a result of climate change, fauna and flora are in need of functioning biotope networks enabling them to adapt.

These potentials for use or change of use for agricultural or forestry purposes are maintained or relatively easily restored if the new type of land use is, for example, the generation of renewable energy or nature conservation, whereas these potentials would be permanently lost, if the new land use were to involve developing the terrain for settlement or transport infrastructure or if it were to involve any form of mining such as large-scale quarrying projects. Using tools from its toolbox, spatial planning

RO-R-5: Land used for human settlements and transport infrastructure

Based on the four-year average, the peak of land use for settlements and transport infrastructures occurred in 2000. Above all, there has been a slowdown in the growth in terms of settlement and open areas. It is true to say, however, that this growth has been increasing again over recent years. It must be borne in mind that the conversion processes required in terms of land registry in the 'newly' joined Länder have limited the informative value provided by land categories.



*2013 to 2015: data corrected due to changes in methodology in individual Länder;
**2016: owing to the regrouping of types of use, the StBA published only the value for the annual mean 2013 to 2016.

Data source: StBA (Sustainable development indicators) can reduce the amount of adverse effects from unsuitable types of land use; consequently this action can be seen as a general adaptation measure. At the same time, reducing any new land use is also one of the key sustainability objectives pursued by the Federal Government. The target is to reduce the daily new land use for the development of settlements and transport infrastructure by 2020 to 30 hectares, and by 2030 to less than 30 hectares (minus X). Since 2000 new land use has been declining. This can be attributed above all to a slowdown in growth regarding the development of settlement and open areas as well as factory or workshop areas with the exception of extraction land. This growth has diminished by half, and since 2005 it has been fluctuating between 30 and 40 hectares per day. At present, the level of activity in the building industry is rising again, especially in respect of space-saving multi-storey residential buildings, less so regarding the space-hungry construction of detached and semi-detached houses. Up until 2007, the increase in transport infrastructure remained largely consistent between 20 and 25 hectares per day, owing to the continued enhancement of the interurban roads network. Since 2008 this growth has slowed down: with approximately 11 hectares per day, 2012 reached the lowest level so far; however, in view of changes in the methodology underpinning spatial statistics, these statements are subject to major uncertainties. However, the strong increase in recreational and cemetery areas between 2003 and 2009, does not constitute an altogether real change in land use; in fact, this rise should be attributed to the conversion of official land registry methods, especially in the 'newly' joined Länder of the Federal Republic, which the survey is based on. In other words, the real change in land use therefore tended to be lower than indicated by spatial statistics.

To what extent the tools employed by spatial planning have contributed to the overall slow-down in new land use is hard to tell from looking at spatial statistics. Actually, the reasons for subdued growth in new land use for settlement and transport infrastructures over recent years are considered to be related to the development of demographics and the economy. However, the sustainability goal aspired to in the run-up to 2020 seems rather hard to achieve, even if current development trends continue and despite the temporarily major influx of immigrants. Any additional efforts required to achieve provident land use will have to take account of potential impacts from climate change. An intensified development of settlements in an inward direction, that is to say, by means of land recycling or retro-densification, must not increase any existing bio-climatic stresses.

Once soils are sealed by buildings, they are unable to provide ecosystem services which are important in times of climate change. (Photograph: © Superingo / stock.adobe.com)

Interfaces

BAU-I-1: Heat stress in urban environments
WW-I-3: Floodwater
RO-R-6: Settlement use in flood-risk areas

Objectives

Enhancing the infiltration potential of soils by reducing the amount of new land use and by supporting the renaturation and desealing of land (DAS, ch. 3.2.14)

Land use reduced to less than 30 hectares per day by 2030 (NHS 2016, Part C, II 11)[83]

Protective and provident handling of ground, reducing any additional use of areas for building purposes, giving priority to internal development (BauGB, § 1a (2))

Reducing any first-time utilisation of open spaces for settlement or transport infrastructure, in particular by means of quantified targets to reduce land use (ROG, § 2 (2) 6)

Non-renewable natural assets should be used in a provident and prudent manner. (BNatSchG, § 1 (3))

Avoiding settlements in terrain vulnerable to climate risks

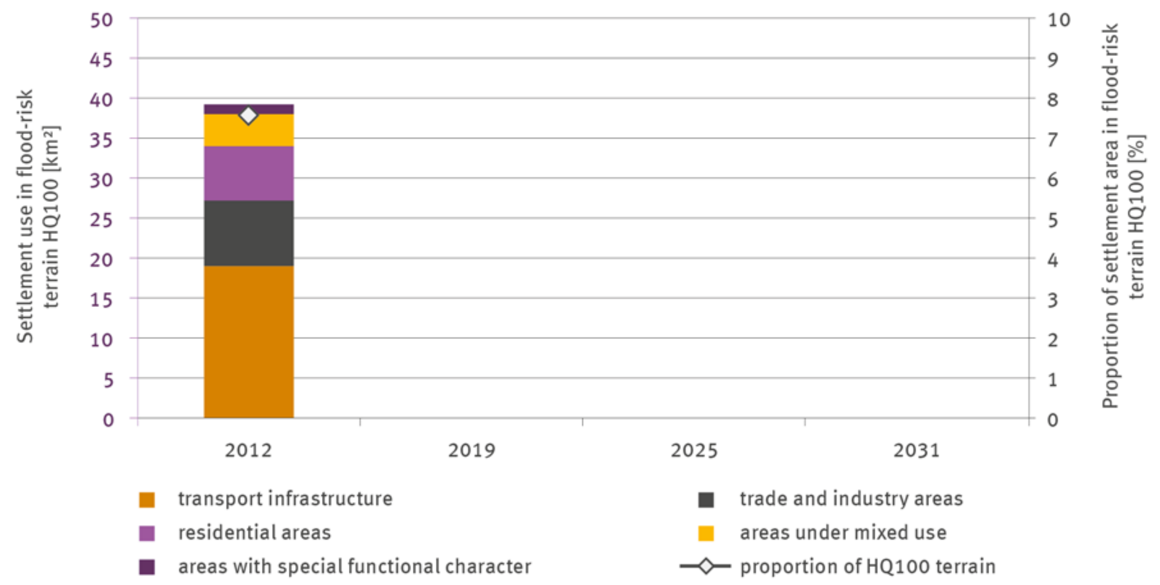
In connection with climate change, it is one of the essential tasks of spatial planning to make appropriate provision for potential risks. On one hand, spatial planning can help to steer the development of settlements deliberately into directions where risks associated with climate change either do not exist at all or exist only to a manageable degree. On the other hand, spatial planning can ensure that recognisably vulnerable areas are to be kept free, as far as possible, from settlement. Relevant risks include the movement of masses of materials such as rock falls, landslides or sinkholes as well as – in coastal areas and on islands – storm surges. Such hazards can increase regionally as a result of climate change, if in future extreme weather situations and weather patterns increase in both frequency and intensity.

It is also expected that climate change will bring about changes in precipitation regimes as well as hazards resulting from flooding events, as these may occur more frequently and also more violently. Besides, the occurrence of floods and associated damage potential will be influenced considerably also by past and current human activities. For example, in former times natural flood plains in many river valleys were eradicated by measures such as building dykes and river modification. Numerous watercourses were shortened thus increasing their flow rate; in the event of flooding the run-off from countless tributaries accumulates faster in a river bed. Nowadays floodwater waves are often steeper than in former times, and their duration is shorter. Therefore, there is an increased risk of damage from floodwater. Besides, valuable material assets were constructed in the shelter of dykes where the land was formerly available to rivers as flood plains. If the flood protection provided proves inadequate when these settlements or industrial estates are flooded, the damage caused can be considerable.

Nowadays, protection from flood events is covered by the German Water Resources Act in accordance with specifications contained in the FRMD. Furthermore, it is required in Germany in accordance with precautionary land use to stipulate binding specifications for flood plains on the basis of (statistically speaking) once-in-a-hundred-years flood events (HQ100); these specifications

RO-R-6: Settlement use in flood-risk areas – case study

Along the Bavarian part of the river Main, just under 8 % of the terrain that would be flooded in case of a once-in-a-hundred-year flood event, was in use for settlement purposes in 2012. Transport infrastructures take up almost half of those areas, but also trade and industry as well as housing take up a major part of the terrain in flood plains.



Data source: Bayerisches Landesamt für Umwelt (flood risk maps for the Main river basin) have to conform to specific protective rules. In such areas, both the specification of urban land use plans for new building locations in the outskirts, and the construction or extension of buildings, are prohibited or permitted only in exceptional cases. Since 2018, it is furthermore mandatory that flood formation areas be identified, and express permission is required for such areas where specific changes of land use such as conversion of grassland to arable land or conversion of alluvial woodland to another type of utilisation are proposed.

However, in the past many forms of construction such as transport infrastructures, industrial and trade buildings as well as residential buildings had already been implemented in numerous flood plains; and these are now at risk from flooding. The example of the evaluation of a flood risk management plan for the Main river basin shows that here just under 8% of the terrain – which would be flooded in case of a once-in-hundred-years flood event – was used for settlement. Transport infrastructures take up almost half of those areas, but also trade and industry as well as housing take up a major part of the terrain in flood plains. According to current legislation, these area percentages are not to be increased in future. Nevertheless, the pressure on these areas remains high, especially in river valleys which are already densely populated and offer very little leeway for development. This pressure must be resisted by provident spatial planning, regional and urban development.

Settlements along riversides are exposed to the risks of extreme flood events.
(Photograph: Konstanze Schönthaler / Bosch & Partner GmbH)

Interfaces

WW-I-3: Floodwater
BAU-R-5: Insurance density of extended natural hazard insurance for residential buildings
RO-R-5: Land used for human settlements and transport infrastructure

Objectives

Reinforced protection against increasing flood risks by means of passive safeguarding measures; safeguarding existing run-off and retention areas; substantial expansion of retention areas by 2020 while making extensive use of all available potentials
(DAS, ch. 3.2.14)

Maintaining the function of flood plains as retention areas; as far as possible – restoration of former flood plains suitable for use as retention areas (WHG, § 77)

Safeguarding existing flood plains as retention spaces; restoration of flood plains as retention spaces; risk provisioning in potential flood areas (Handlungskonzept Klimawandel, MKRO 2013, ch. 3.1)

Preventive inland flood protection, especially by means of safeguarding or restoring alluvial meadows, retention areas and flood relief spillways (ROG, § 2 (2) 6)

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Civil protection

Coping with heavy rain and storms but also flooding events or periods of hot weather is a core remit of civil protection. The impacts of climate change give rise to new challenges for disaster risk reduction and disaster management to which civil protection will have to be adapted. Most notably, challenges arise from the expected increase in frequency and intensity of extreme weather conditions, weather patterns and associated consequences.

Civil protection must be able to fulfil its tasks reliably even under changing circumstances. Part of this is the protection of the lives and health of citizens and the prevention of material damage in disaster events and major emergencies. Besides, it is part of civil protection's core objectives to safeguard the availability of services such as energy and water supply, transport and haulage as well as telecommunications and information technologies (KRITIS/critical infrastructures). In this context, prevention is often the best form of protection and this has to be provided by both, the competent authorities and private individuals.

In enhancing civil protection, organisations active in this area will increasingly have to adapt their material, personnel and infrastructure resources to extreme weather events and associated consequences. Furthermore, it may be necessary to adapt areas of responsibility such as training and further education, the co-ordination or organisation of operations or the optimisation of warning and communication channels. Last not least, the importance of informing the public and raising public awareness as well as practising behavioural responses in case of real-life emergencies cannot be underestimated, because numerous protective measures and types of assistance will have to be taken by individual citizens themselves.

Effects of climate change

Adaptations

Carrying on to exhaustion?

Since 2000, Germany has experienced a number of extreme flood events which all took the form of once-in-a-hundred-year-floods. Latterly, in early spring 2016, entire landscapes were under water in areas of the south and east of Germany. Rivers broke their banks flooding settlements with mud and flotsam; cellars were flooded, houses were damaged and some were even destroyed. In October 2017, hurricanes such as Xavier and Herwart also left major impacts on the country.

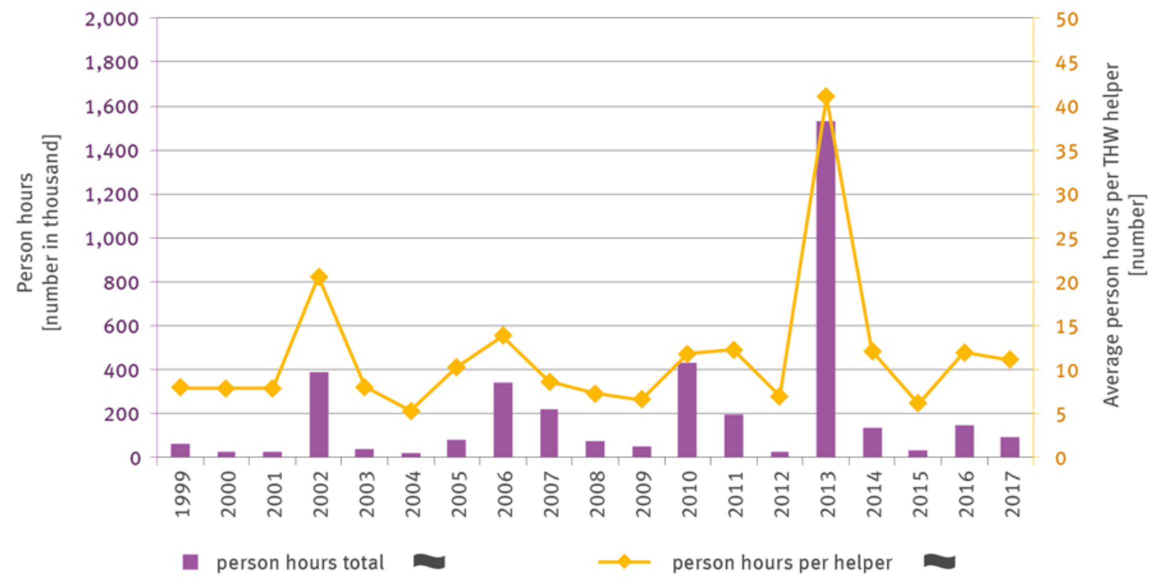
Such extreme events which, judging by projection outcomes, may increase in frequency and intensity as climatic conditions change, entailing massive increases in operational burdens for emergency personnel. After all, part of the essential remit is to provide technical assistance whenever extreme weather events cause emergency or disaster situations. For example, the emergency personnel secure dykes by means of sandbags or they install mobile flood protection walls in order to prevent flooding, they evacuate residents and they prevent the flooding of industrial installations or sewage treatment plants. After severe storms or hurricanes the emergency services remove windthrows from roads and rails making them passable again. Even after a relatively brief and localised heavy-rain event, emergency personnel are often busy for hours pumping out flooded cellars and living accommodation dry.

In many places the organisations active in the area of civil protection are signalling already now that the number of weather-related incidents is rising for which technical assistance is required. There are detailed and comparable data available on the number, duration and causes of operations carried out by the THW. Although so far no significant trends have been determined regarding long-term increased burdens on emergency services, the figures for recent years demonstrate the way in which individual extreme events – and especially the 'floods of the century' in various river basins – have characterised the operational regime.

The flooding events in catchment areas of Danube and Elbe in 2013 were particularly demanding in terms of operational effort. The total number of person hours in

BS-I-1: Person hours required for dealing with damage from weather-related incidents

In years with hurricanes, heavy rain or extreme flood events, there is increased demand on the operational burdens to be borne by THW helpers. The time series examined is strongly marked by extremely severe individual weather events. So far, it has not been possible to identify a significant trend.



Data source: THW (helper statistics)

that year amounted to 1.5 million. The reasons for this enormous burden can be found in the THW's partly preventive requirements, the consistently high demand for emergency personnel for the entire duration of operations from late May to mid-July and the spatial extent of the areas affected. Overall, there were nine Länder affected. The high number of person hours which accrued in 2002, 2006 and 2010 were mostly due to flooding events. The above-average person hours accrued in 2007 were predominantly due to the low-pressure system inflicted on Germany by hurricane Cyril in January of that year.

In May and June 2016, the impacts of heavy rain kept emergency services on their toes nationwide. From late May until early July, approximately 10,000 THW personnel – 7,700 of those THW's were voluntary helpers – worked day and night using boats, high-performance pumps, big emergency generators and lighting equipment. Simbach-am-Inn was assisted by the THW's biggest drinking water emergency operation in Germany ever. For 14 days the THW supplied the population with a total of 5.6 million litres of water. Another focal point was the restoration of road bridges and supply infrastructures which had been destroyed by streams and rivers turning into raging torrents.

The steadily high demand for emergency services continuing work week after week is a particularly great challenge for THW which relies predominantly on voluntary helpers for their personnel. For some helpers this involves release from their place of work, sometimes for weeks on end – a tricky situation in view of the current labour market. This results in a high turnover of emergency helpers which requires co-ordination and entails organisational problems.

Basically it has to be borne in mind that the THW's person hours give only limited clues as to the other organisations involved in civil protection because the THW operates only on demand. Besides, the figures are also dependent on the type of events occurring, as in specific cases, it is above all the THW with their specific material equipment which will be geared up for the task. For years with particularly extreme events it has to be expected that other organisations too will encounter distinct difficulties in view of weather-related operational burdens and problems resulting from their voluntary structure; apart from THW, these other organisations are the fire brigades, the German Red Cross, the Workers' Samaritan's Foundation, the German Lifeguard Association, the Malteser Hilfsdienst and the St. John Ambulance Brigade.

Major damage events make high demands even on well-trained emergency services.
(Photograph: © Sebastian / stock.adobe.com)

At present, options are being examined to see in which way the experiences of other emergency organisations can be incorporated usefully in DAS Monitoring as far as civil protection is concerned.

Interfaces

BS-R-4: Active disaster protection workers
BAU-I-5: Claims expenditure for property insurance
WW-I-3: Floodwater

Objectives

Adaptation of existing crisis management and emergency provisioning to current requirements and future developments such as climate change
(DAS, ch. 3.2.14)

Information and knowledge – building blocks for self-help

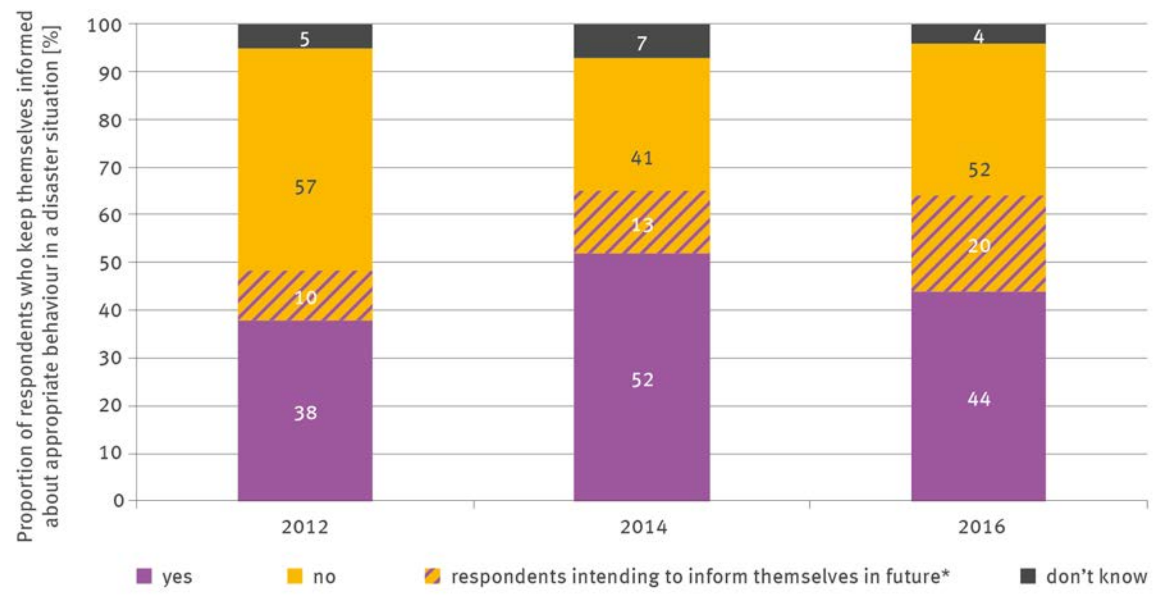
The population's ability to protect themselves is an important component of civil protection. The term self-protection encompasses the total of individual measures taken by the public, the authorities and/or businesses for the prevention, precautionary measures and self-help required for coping with events. By behaving appropriately in emergencies, citizens can protect their own safety and that of their fellow human beings at the same time helping to improve overall safety.

In case of an accident or emergency situation, emergency teams need time to reach a location and provide the necessary assistance. In case of an accident, it might just take minutes whereas in weather-related extreme events it can take considerably longer for rescue teams to arrive in sufficient numbers enabling them to assist everyone concerned. It can also happen that the extent of the emergency location is particularly widespread making it difficult to reach all individuals in need of assistance as fast as necessary. In order to protect life and limb and to protect material assets, it is therefore of particular importance for citizens to be able to help themselves in the first instance until the fire brigade, rescue service or emergency services arrive to provide assistance in a more organised way in events such as severe tempests, extraordinarily heavy falls of snow, flash floods or large-scale flooding

To this end, it is vital that appropriate assistance is provided by a person well acquainted with the potential impacts of damaging events before they actually occur. It therefore matters that as many people as possible are familiar with the potential risks and well informed regarding the appropriate behaviour in emergency situations. Technical progress in the processing and dissemination of geographic information over recent years has produced numerous sources available to citizens to inform themselves regarding risks that may exist either locally or regionally. For example, the internet provides information on flooding risks some of which is precisely focused on individual land parcels, or information on geological risks such as mass movements, landslides or risks of storm damage. The GDV offers its 'Kompass Naturgefahren' on the internet which provides online estimates for individual addresses on natural hazards such as flooding, storm and hailstorm, lightning and

BS-R-1: Information on how to act in a disaster situation

In 2016, 44 percent of respondents to the environmental awareness survey stated that they had informed themselves on the appropriate behaviour in disaster situations, while another 20 percent stated that they intended to do so in future. Slightly more than half of respondents do not think that this is necessary.



* partial amount of 'no'

Data source: BMUB & UBA (Umweltbewusstsein in Deutschland)

overvoltages. For the time being, however, such data are not yet available contiguously nationwide.

On the basis of their awareness of risks which might exist regarding the area where they live or work, citizens can obtain information on the appropriate behaviour in emergency situations. On one hand, it is important to develop and maintain general skills in courses such as First Aid. On the other, information material is made available by authorities. At Federal Government level, the BBK provides information on appropriate behaviour in emergencies, for example by means of leaflets and through its website. Besides, citizens can subscribe to the Federal Government's warnings app NINA (Emergency Information and News App) to receive warnings in respect of civil protection or storm warnings issued by the DWD which also provides flood information via its transnational Flood Portal for both individually selectable locations and for their own location. In addition, there are information services provided by individual Länder and in some cases by competent municipal authorities.

The proportion of respondents who in the representative environmental awareness survey[I] stated to have familiarised themselves with the appropriate behaviour in case of emergencies has risen slightly. While in 2012 the figure was 38 %, this value had risen to 52 % in 2014, with 44 % of all respondents in 2016 stating that they had obtained the relevant information.

Also the proportion of respondents who intend to obtain information in future has increased from 10 % in 2012 to 20 % in 2016. Although these figures do not reveal the degree of intensity in which the respondents looked into the range of risks and possible behavioural responses, they do indicate that more than half of respondents appreciate the need for such information. Besides, it should be borne in mind when interpreting these figures that not all citizens are exposed equally to all weather-related natural hazards. For example, storm surges or flooding occurs along coastlines and in river basins whereas other areas are not or distinctly less frequently and less severely affected by such events. Even though the overall demand for information varies, widespread knowledge of fundamental rules of behaviour in emergencies would be desirable in view of the (in some cases) considerable spatial extent of areas at risk (for example from heat); another important point is that the event (such as heavy rain) might occur practically anywhere; last not least, the high mobility of German citizens must be taken into account.

I The representative population survey (of German-speaking residents aged 14 or more years) entitled Environmental Awareness and Behaviour in Germany (Umweltbewusstsein und -verhalten in Deutschland) has been carried out every two years since 2000 on behalf of the BMU and the UBA. Since 2012, additional questions have been asked in the survey, intended to supply data for DAS monitoring indicators; from 2016 onwards, these questions are asked every four years in the environmental awareness surveys.

The knowledge and updating of general skills such as First Aid are part of precautionary measures to be taken at a personal level. (Photograph: rh2010 / stock.adobe.com)

Interfaces

BS-R-2: Precautionary measures for protection of the public
FiW-I-2: Incidence of storms and floods
HUE-2: Usage of warning and information services

Objectives

Further enhancement of the dissemination of risk communication among citizens; providing support for precautionary measures; making improvements in respect of real-time, clear and effective warnings and information communicated to the public in respect of civic health protection. (DAS, ch. 3.2.14)

Reducing, as far as possible, the consequences of severe disruptions and failures of critical infrastructures by making sure (...) that people directly affected by a disaster event possess an effective capacity for self-help (KRITIS-Strategie, ch. 5)

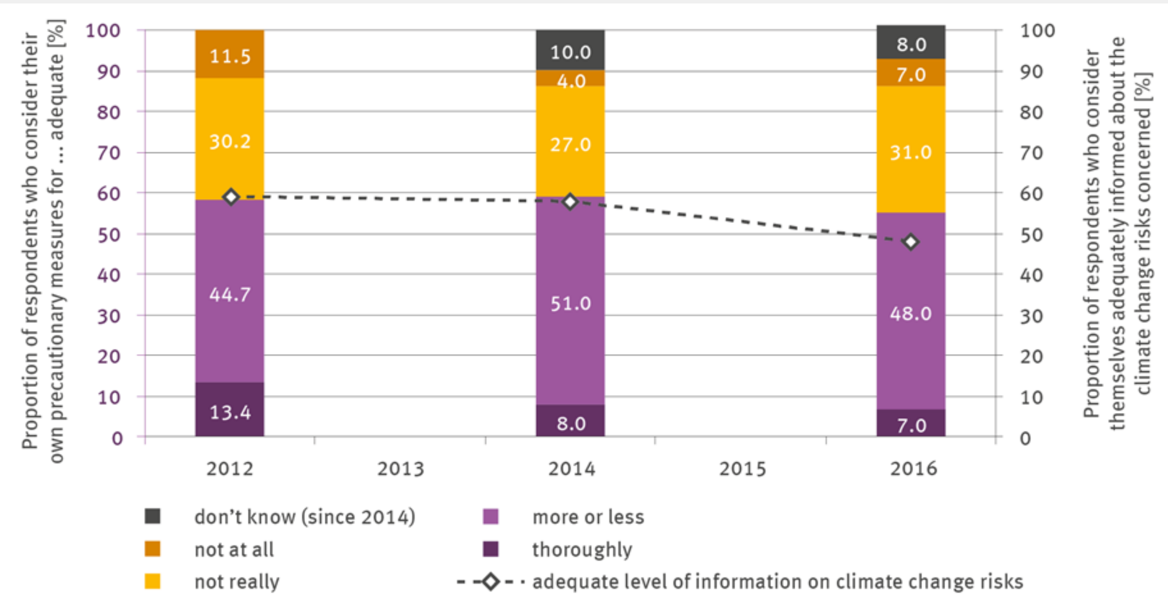
Personal provision for emergency situations

In order to safeguard personal protection, it is not just important to be able to help oneself and others quickly and efficiently. Citizens can also take various appropriate measures in their own personal environment to protect themselves from the impacts of weather-related situations such as periods of hot weather, storms or heavy rain thus preventing worse outcomes. To this end it is essential that citizens know themselves adequately informed about the risks associated with climate change. Some of the behavioural responses adapted to extreme weather are more or less part of automatic everyday routines. In that context it is, for example, sensible to avoid physical exertions in extreme heat, to wear the right clothing for certain temperatures whether at home or at work, to drink plenty of liquids on hot days and to avoid unnecessary long car journeys when weather patterns point towards risky conditions.

While such measures appear obvious, the same cannot be said of provisions required for emergency situations. In Germany, the supply of basic goods and services such as groceries, water, electricity and telecommunications is known to function at a very high level. As a rule, citizens can trust in the reliable functioning of fundamental logistics and infrastructures. But here is the other side of the coin: In view of the fact that negative experiences regarding supply and provisioning are rare in Germany, the population is in general less well prepared for exceptional circumstances. Emergency reserves of water, groceries, candles or batteries – held routinely only a few decades ago – are nowadays held by only comparatively few households. However, just by stocking some of these largely basic supplies, citizens can play their part in ensuring that extreme situations do not entail any disastrous outcomes for themselves. Furthermore, houseowners can take structural precautions to protect their homes from weather-related risks such as flooding and flash floods, storm, hail or just heat. The BBK informs houseowners not only by means of relevant information leaflets but also by means of videos on a dedicated video YouTube channel (https://m.youtube.com/user/bbk), in order to reach as many members of the public as possible.

BS-R-2: Precautionary measures for protection of the public

Although in 2016 approximately half of the majority of respondents (48 %) still felt adequately informed about the relevant impacts of climate change, this proportion has declined since 2012. The perception to have made adequate provision for personal protection was common to more than half of all respondents in all surveys.



Data source: BMUB & UBA (Umweltbewusstsein in Deutschland)

A major role in civil protection is played by the precautionary measures taken by citizens in various respects. A person who has taken precautionary measures requires less assistance and can possibly take the pressure off emergency services by providing assistance themselves.

Comparing the outcomes of environmental awareness surveys[I] conducted in 2012, 2014 and 2016 it becomes clear that the proportion of respondents who inform themselves adequately on impacts of climate change relevant to them personally, has been declining. Compared to 59 % in 2012, the value of 48 % determined in 2016 has decreased by more than 10 %. Examining the question whether respondents are making adequate provisions for themselves, all surveys show that a little more than half of the respondents feel that they are making adequate provisions. On the other hand, the outcomes indicate that more than half the respondents consider their information level as inadequate while approximately 40 % of respondents consider their own provisions as inadequate. When interpreting the outcomes, the following limitation should be borne in mind: the statements are based on a subjective understanding of risk information and provisioning which makes it impossible to estimate whether respondents are indeed taking the necessary precautions for emergency situations.

Being self-sustaining in emergencies means keeping stocks – not just of groceries, but also of drinking water, medication, batteries, candles and many other things.
(Photograph: Konstanze Schönthaler / Bosch & Partner GmbH)

Interfaces

BS-R-1: Information on how to act in a disaster situation

Objectives

Reducing, as far as possible, the consequences of severe disruptions and failures of critical infrastructures by achieving (...) an effective capacity for self-help among people directly affected by a disaster event (KRITIS-Strategie, ch. 5)

I see footnote p. 237

Exercises – training for a real-life emergency

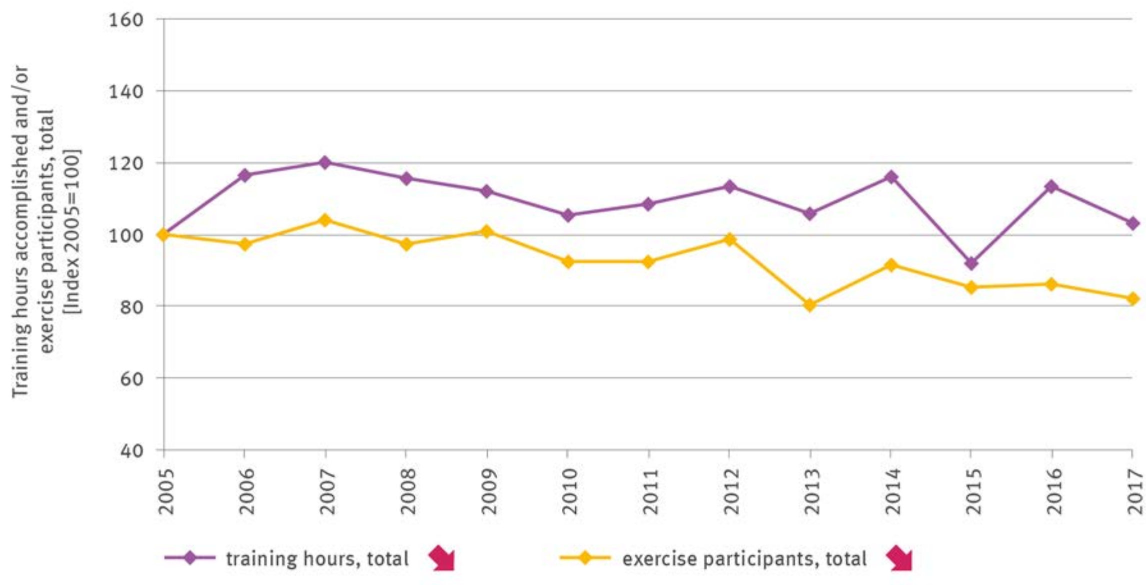
By means of regular training exercises the emergency services safeguard the foundation for appropriate action in extreme situations; it is also the basis of targeted crisis management. Regular training enables the emergency services to act appropriately, both in respect of organising and co-ordinating operations and also in providing assistance on site. There is no specific climate-related aspect required for these exercises as far as preparing for the impacts of climate change is concerned, because the potential events arising will not differ much from the way they are occurring now. Coping with heavy rainfall and storms but also flooding events or periods of hot weather is part of the core remit of civil protection. New challenges may arise, above all, from increases in frequency and intensity of such events in future and also increasingly from a potential overlap as to when they occur.

Basically, training exercises for civil protection can be carried out in two different ways: either as a full-scale exercise within a real training scenario or as a (simulated) command post exercise. The purpose of the latter is to examine the communication structures and to prepare the authorities responsible for emergency services for a real emergency. This is because after training or genuine emergencies it has often emerged that there is room for improvement in civil protection, especially in terms of inter-organisational communication and co-ordination. For this reason, training exercises in civil protection are usually structured in a way as to involve units from various regions and – where appropriate – with different types of specialisation including their material equipment, thus allowing them to train jointly.

In this process, the frequency of, and participation in, exercises are subject to various influencing factors. This can mean on occasion that an exercise is slightly reduced in scale without affecting the efficacy of service personnel. For example, in years with increased frequency of emergency situations, the number of participants and hours trained may be diminished because the emergency personnel lack the time to participate or they need to be allowed the necessary time to rest. Any deficiency in routine responses acquired in training exercises will then be offset by experience gained in real-life emergencies.

BS-R-3: Training exercises

On the whole, the THW is able to carry out the necessary amount of training exercises adequately, both in terms of time and personnel, even in years when extreme events have to be dealt with. In 2013 the heavy operational burden caused by early-summer flooding resulted in a relatively low participation in training exercises.



Data source: THW (training statistics)

Increasingly, one obstacle to participation in exercises is a lack of willingness on the part of employers to release the THW's or other organisations' voluntary helpers from their paid work for the purpose of participating in training exercises. In years with high person hours, this can be one of the reasons why non-participation in training exercises is granted, thus making it unnecessary for helpers to request yet more release from their paid occupation.

Since 2005 there has been a significant decline in the number of participants in training exercises. During the years 2005–2012 approximately 19,500 full-time and voluntary personnel took part in the THW's exercises. In 2013, the number of participants was clearly below average, amounting to some 16,000 individuals. This was due to major operational efforts required for dealing with early-summer flooding in the catchment areas of Danube and Elbe. Between 2013 and 2017, on average just short of 17,000 helpers participated. The number of training hours carried out fluctuated in the period in question between approximately 308,000 and 400,000 hours while the mean value of training hours carried out was slightly above 365,000. The lowest number of training hours – slightly above 308,000 hours – occurred in 2015. This was caused by greater involvement of THW in the co-ordination and implementation of finding accommodation for refugees in Germany.

There are indeed other organisations which take on tasks in connection with civil protection; they too participate in training exercises thus preparing themselves for coping with the challenges of weather-related extreme events. However, the THW's figures do not permit any conclusions regarding the training regimes of other organisations

To make sure that helpers are ready to cope with all eventualities, they regularly train for a variety of scenarios. (Photograph: © Jörg Hüttenhölscher / stock.adobe.com)

Interfaces

BS-I-1: Person hours required for dealing with damage from weather-related incidents

Objectives

Adaptation of existing crisis management and emergency prevention to current requirements and future developments such as climate change (DAS, ch. 3.2.14)

Are we running out of human resources?

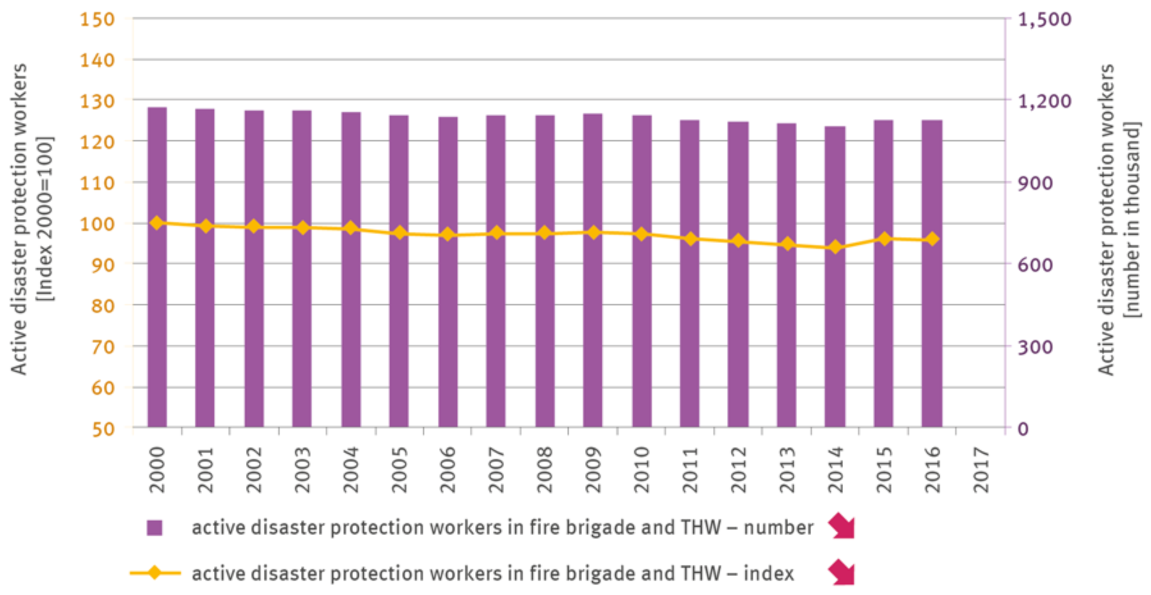
As far as civil protection in Germany is concerned, volunteers are our core strength. Approximately 1.7 million voluntary helpers get involved in various emergency organisations. Approximately 99 % of THW's helpers are working on a voluntary basis. Approximately 95 % of members of fire brigades in Germany are organised in volunteer fire brigades. In that light, helpers involved in civil protection have asserted time and again that unless enough members of the public are willing to take on these voluntary roles, the capacity of units to carry out their tasks will be seriously jeopardised. The same is true for the further enhancement of civil protection in view of climate change; the minimum requirement for this is a stable staff of full-time and voluntary helpers. This is not just because the expected changes in terms of climatic conditions are likely to require more frequent and more extensive operations resulting in greater burdens, but also because the availability of volunteers may be restricted as a result of health impacts from potential heat waves.

Looking at the development from 2000 until 2016, it is clear that there has been a significant decline in active members of the emergency services, both in respect of THW and the fire brigades. During that period, their number decreased by approximately 50,000 from 1.17 million to 1.12 million active members. The declining trend is particularly striking with regard to the negative development in respect of volunteer fire brigades. While professional fire brigades as well as factory or company fire crews can boast increasing or at least stable membership figures, volunteer fire brigades now have approximately 74,000 fewer volunteers than just ten years previously. In 2016 more than 250,000 young people got involved in volunteer youth fire brigades.

The number of active helpers involved in THW is many times lower compared to fire brigades. This is why increases in the number of THW helpers only have a minor influence on the overall development of the number of active helpers. The mean number of active THW helpers for 2000-2014 was approximately 41,000 individuals; in 2015 this number increased to 66,000 active THW helpers, stabilising at this level for 2016 and 2017. In the THW the number of female helpers

BS-R-4: Active disaster protection workers

The number of emergency helpers declined between 2000 and 2016, above all owing to a decline in the number of members of fire brigades. The increasing involvement of female volunteers – which has gained in importance also with a view to the suspension of compulsory military service – is not sufficient to offset the decline in the number of male volunteers.



Data source: THW (helper statistics), Deutscher Feuerwehrverband e.V. (fire brigade statistics) has increased steadily since 1999 by almost 7,000. While in 1999 their proportion was just under 4 %, the proportion of active female THW members had risen to 13.5 % by 2017. The membership numbers of THW Youth (-Jugend) have been stable for the past few years at a high level.

The decline in membership numbers among volunteer fire brigades is due to various developments. The suspension of compulsory military service since 2011 had a major influence on the recruitment of helpers in the age group of 20 to 25 year olds. In order to safeguard a viable number of emergency helpers, the THW requires approximately 5,200 new helpers per year. Up until 2011, it was possible to recruit annually approximately 2,500 individuals owing to the suspension of compulsory military service.

Besides, the impacts of demographic change on civil protection also need to be taken into account. Changes in the age pyramid have led to shrinkages in the pool of potential helpers just as much as the increasing concentration of people living in towns and cities. Recruitment bottlenecks can occur above all in sparsely populated rural areas with a comparatively older population, compared to a higher willingness prevailing among inhabitants of towns and cities to get involved in volunteer services. In this respect, various studies take a very critical view of the future, raising the question in what way the existing structures are to be taken forward in order to ensure their reliable functioning.

In order to maintain the voluntary structures of civil protection and a sufficient number of helpers, the organisations active in the area of civil protection want to make greater efforts to involve people with migration backgrounds or even senior citizens as helpers in accordance with their individual capacity. In recent years it was at least possible to increase the proportion of female helpers in organisations which are predominantly technically oriented. In 2000 the proportion amounted to 5.7 %; by 2016 the proportion of female volunteers had risen to 9.2 %. In youth fire brigades, the proportion of young women also increased gradually from 2000 until 2016 from 22 % to 27 %. In fire brigades there are nowadays 30,000 more women active than in 2000.

Furthermore, social and technical developments also open up new options. For example, during the flood events of 2013 and 2016 assistance was organised quickly and unbureaucratically via social networks in many of the areas affected. This seems to indicate that it might be possible for civil protection to tap into the continued willingness of individuals to get involved and provide assistance, even though the way this is done relies less on fixed structures than in former times.

The training of young volunteers is essential in order to be equipped for a potential future increase in the challenges and burdens of operations.
(Photograph: © Kzenon / stock.adobe.com)

Interfaces

BS-I-1: Person hours required for dealing with damage from weather-related incidents

Objectives

Adaptation of effective existing crisis management and emergency prevention to current requirements and future developments such as climate change (DAS, ch. 3.2.14)

Cross-sectional activities carried out at Federal level

The adaptation to the impacts of climate change is a challenge which individuals, authorities and organisations have to face at nearly all levels of social, political and economic life. The impacts of climate change and any activities already initiated in respect of DAS Action Areas have been illustrated and explained in the chapters above. Apart from informative and planning measures, these chapters also covered tangible operational activities and how they were financed. These explanations make it clear that the adaptation process is the remit of a great variety of authorities and individuals involved at governmental and non-governmental level. Dependent on the relevant action area, the Federal Government is responsible for various tasks and options available for guiding and supporting the adaptation process and developments within the federal system.

The Federal Government's 2011 Adaptation Action Plan (APA I) and the 2015 Adaptation Action Plan (APA II) both submitted an overview of the specific tasks involved in the adaptation process. APA I contained a breakdown of the activities required in the three national cross-sectional strategic pillars. Accordingly, one major responsibility of Federal Government is to communicate the existing knowledge regarding climate change and the adaptation process required, to inform citizens and other important stakeholders thus enabling them to respond in a targeted manner. Other options for action by Federal Government arise from nationwide frameworks such as legal regulations, standards or the enhancement of support programmes. In some respects Federal Government can also set examples by implementing adaptation measures within the realm of its own real estate. This is true for example in respect of federal buildings and infrastructures or the federal forest. Relevant activities have already been discussed above in connection with action areas. Supplementary to the three national pillars there is an additional pillar for international projects and activities undertaken by the Federal Government in respect of its international responsibilities. In this respect, relevant policies are in many cases 'bundled' under the Adaptation Framework as part of the UN's Framework Convention on Climate Change. The monitoring indicators regarding cross-sectional activities provide information on cross-sectional activities categorised under the four strategic pillars.

Adaptations

Will we get to grips with climate change?

The availability of and access to fairly robust projections of future climate change and associated impacts are essential prerequisites for adequate political, administrative, operational and private decision-making and appropriate actions.

Federal Government considers it as one of its key responsibilities to ensure such wide-ranging information is easily accessible, to clearly outline the challenges concerned and to highlight the decision-making assistance available. To this end, Federal Government created the German Climate Preparedness Portal. By visiting the website www.klivoportal.de, authorities, companies and civilians can home in on approved support offerings which provide targeted advice on adapting to climate change, as well as implementation support. Whether and to what extent the information provided is ultimately taken on board by relevant members of the public, motivating them to take rational and targeted action, is largely dependent on how they view the issues concerned. To achieve widespread acceptance of the concept and implementation of adaptation measures in Germany nationwide, depends on a broad consensus among the German public recognising that climate change is a challenge that should be taken seriously.

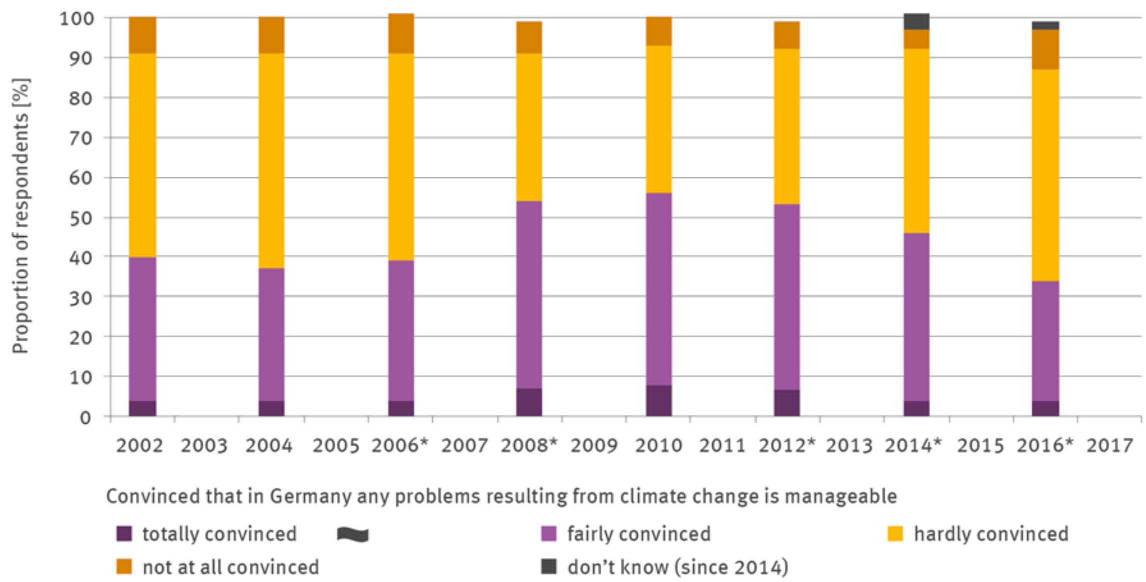
To know the public's perception of climate change and its impacts on society is an important basis for the Federal Government in shaping its information policy accordingly and in targeting its funding activities in a meaningful way.

The social appraisal of these issues is the outcome of numerous factors often interacting in complex ways. Crucial influencing factors are, for example, an individual's personal perception, their understanding of causes, consequences and possibilities of action, their trust in the Government's capacity for action as well as the individual's own scope for action based on their private and professional life.

A representative public survey carried out every two years on behalf of the UBA, entitled Environmental Awareness in Germany (Umweltbewusstsein in

HUE-1: Manageability of climate change impacts

Since 2010 the proportion of citizens stating as a result of a representative public survey that the impacts of climate change are manageable in Germany has declined. In 2016, 63 % of respondents were little or not at all convinced.



* rounding error due to missing decimal places

Data source: BMUB & UBA (Umweltbewusstsein in Deutschland)

Deutschland)[I] asks respondents several questions which provide clues as to the perception of respondents regarding the impacts of climate change. Since 2002 the questionnaire integral to this study also asks respondents to what extent they are convinced that Germany is capable of managing the problems arising from climate change. The outcomes of this question are illustrated in the accompanying chart.

It is not yet possible to discern a trend for past years. However, it is possible to state that up until 2006 the majority of respondents were little or not at all convinced that it would be possible to manage the impacts of climate change. In the period 2008 to 2012 the majority status has shifted and the appraisals turned out more optimistic than before. For example, in 2012 at least 53.1 % of respondents was convinced that the impacts of climate change would be manageable in Germany. The outcomes for 2014 and 2016 indicate increased scepticism. In 2014 slightly more than half of respondents were little or not at all convinced that in Germany the problems resulting from climate change are manageable. In 2016 this proportion amounted to nearly two thirds.

Can we still get to grips with climate change? There is notable scepticism. (Photograph: © Vlad Chorniy / stock.adobe.com)

I The representative population survey (of German-speaking residents aged 14 or more years) entitled Environmental Awareness and Behaviour in Germany (Umweltbewusstsein und -verhalten in Deutschland) has been carried out every two years since 2000 on behalf of the BMU and the UBA. Since 2012, additional questions have been asked in the survey, intended to supply data for DAS monitoring indicators; from 2016 onwards, these questions are asked every four years in the environmental awareness surveys.

Interfaces

FiW-I-2: Incidence of storms and floods
BS-R-2: Precautionary measures for protection of the public

Objectives

Enhancing the knowledge base thus augmenting the ability to highlight and communicate both chances and risks and to signpost opportunities for action (DAS, ch. 3.2.4)

Informing the public – an important task at Federal level

Warning and information systems are key tools used by Federal Government for informing the public of basic risks and imminent critical events. It is in the interest of Federal Government to ensure that these systems are used by the public as much as possible and to make them better known.

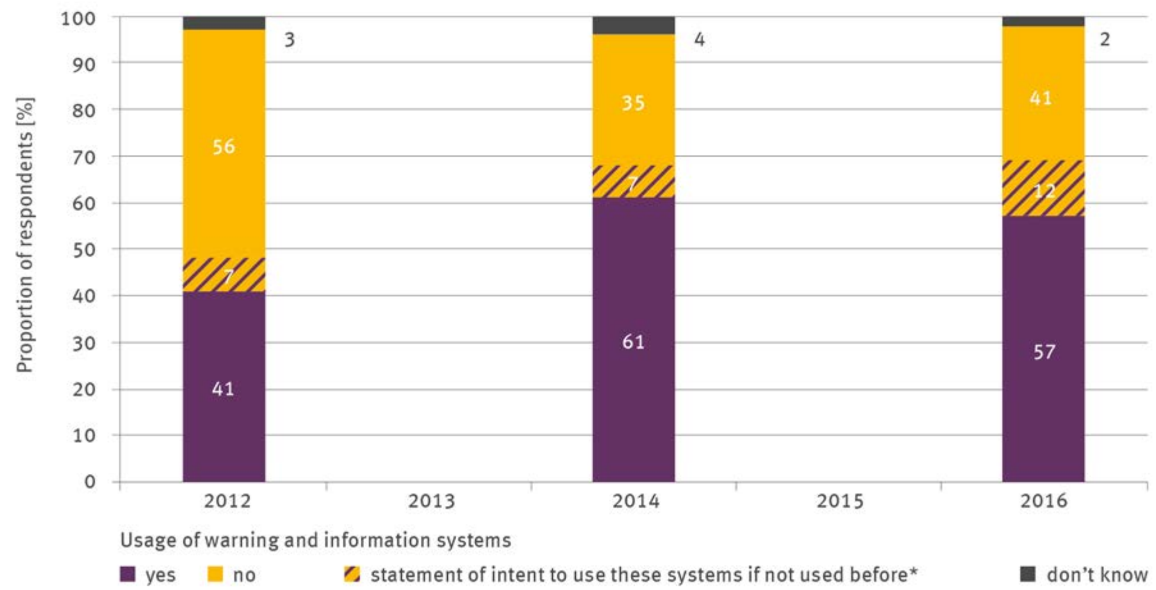
There are various warning and information systems available at Federal level in connection with climate-related changes in terms of risks and stress situations. The heat warning service was introduced by DWD in 2005. When defined threshold values threaten, this service issues heat warnings at Federal and Länder level for the current and the subsequent day. The general public can check for warnings on the internet. Furthermore, the DWD uses this portal to issue warnings for other major and extreme weather events such as storms, heavy rain or thunderstorms. For enhanced information for allergy sufferers, the DWD jointly with the PID publishes a pollen exposure risk index. During the season when pollen is airborne, this index provides information on the intensity of exposure to the eight allergologically most important types of pollen for the current and the subsequent day.

Besides, citizens can subscribe to the Federal Government's warnings app NINA (Emergency Information and News App) offered by the BBK to receive warnings in respect of civil protection or storm warnings issued by the DWD which also provides flood information via its transnational Flood Portal for both individually selectable locations and for their own location.

Less directly associated with climate change are health risks caused by ozone and UV radiation. As climate change progresses, certain weather regimes may emerge more frequently, increasing the formation of ground-level ozone. In a global context there are also ongoing discussions about impacts on the stratospheric ozone layer which might impact on the intensity of UV radiation in our own latitudes. Prognoses on ground-level ozone are issued via the UBA's internet offerings. The Federal Office for Radiation Protection (BfS), in co-operation with the UBA, uses the Germany-wide UV monitoring network to

HUE-2: Usage of warning and information services

Warning and information services operated at Federal and Länder level are used by more than half of the population.



* partial amount of 'No'

Data source: BMUB & UBA (Umweltbewusstsein in Deutschland)

generate information on UV radiation on a daily basis. UV warnings are also issued by the DWD.

Particular attention is paid to the flood warning or information services which have been operated for many years by the Federal Waterways and Shipping Administration which publishes current water level data for Federal Waterways. The same can be said of the Hochwasserportal (floodwater portal) operated jointly by the Länder. This portal issues data on flood warnings on a daily basis for any water bodies that are part of their remit. A smaller target audience subscribes to the Sturmflutwarndienst (storm surge warning service) operated by BSH, which communicates water levels indicated at gauges on the North Sea and Baltic Sea coasts.

Other extant warning and information services focusing on events which can be associated with climate change are of particular interest to specific professional groups, companies or administrations. These include the Länder's phytosanitary services which forecast the occurrence of pest organisms and recommend integrated pest control measure. Likewise, information services forecasting low water levels are available.

Since 2012, the representative population survey 'Environmental Awareness in Germany' (Umweltbewusstsein in Deutschland)[I] has also contained questions regarding the usage of warning and information services. The survey refers to examples such as the pollen information service, the heat warning services and the flood warning or information services. In the 2012 survey, 41 % of all respondents stated that they make use of warning and information services. The outcomes of subsequent surveys indicate an increase in usage. In 2014, 61 % and in 2016, 57 % of respondents stated that they use warning services. The proportion of respondents who intend to use these services in future amounted to 7 % in 2014 and 12 % in 2016 respectively. The increased use of smartphones facilitates the use of warning services as it is easy to consult these services spontaneously while travelling. The offerings of relevant apps have also increased, as demonstrated by the example of the enhancement of the pollen information services provided by PID.

These and other information services related to climate impacts and the prevention of damage arising from climate change are offered in bundled form by the German Climate Preparedness Portal available at www.klivoportal.de.

I see footnote p. 247

Many warning and information services are accessible en-route by using a mobile telephone with internet connection. (Photograph: Konstanze Schönthaler / Bosch & Partner)

Interfaces

GE-R-1: Heat warning service
GE-R-2: Successes of the heat warning system
GE-R-3: Information zu Pollen

Objectives

Efficient early warning systems reduce the risks of health impacts. (DAS, ch. 3.2.1)

Examining whether climate-related changes necessitate the adaptation of forecasting and warning services in maritime shipping (DAS, ch. 3.2.11)

Promotion of research and development regarding climate change impacts and adaptation

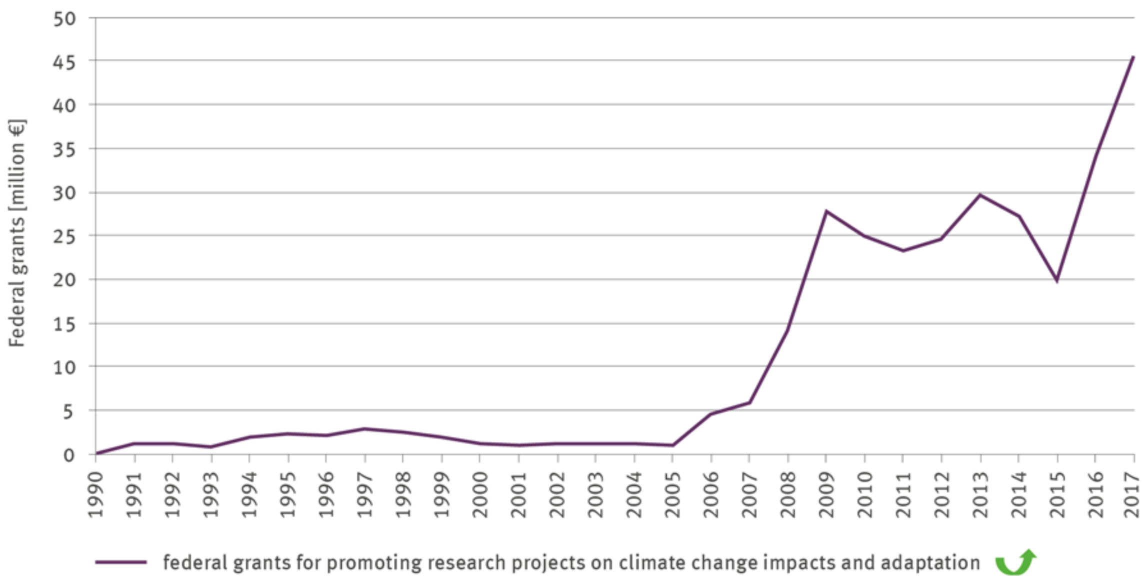
Already now, many decisions affecting the long term have to consider and take into account any potential impacts from climate change and future climatic conditions. Planning and projects financed from the public purse, for example infrastructure projects such as the expansion of extant or the construction of new roads and railway lines or the enhancement of inland waterways for the shipping industry, the construction of new power lines, flood protection measures, the assigning of building sites for municipal developments, or the construction of public buildings – any of these have to be built resilient enough to cope with the impacts of future climatic changes. Likewise, companies are keen to make appropriate location choices for their developments and to make their long-term investments such as the construction of new buildings or works robust enough to withstand the impacts of climatic change. Last not least, private individuals who, possibly with a view to their health or in their capacity as owners, want to ensure that they make the right decisions.

An essential basis for decision-making is, on one hand, a well-informed vision of the future, combining a fairly reliable appraisal of future climatic changes and a solid grasp of existing vulnerabilities and the potential impacts of climate change. On the other, robust and flexible strategic, technical and also practical solutions are required – able to cope with the continuing uncertainties regarding a wide range of potential climatic changes. It is therefore an important aspiration at Federal level to make every effort regarding the expansion of the knowledge base required for adaptation processes or measures and to pursue a methodical approach in promoting relevant research activities.

Many Federal research funding activities on issues of climate change and adaptation are bundled within the framework programme FONA (Research for sustainable development) financed by the BMBF. Besides, there are other programmes sponsored by Federal departments

HUE-3: Federal grants for promoting research projects on climate change impacts and adaptation

Several Federal departments promote research on the theme of climate change impacts and adaptation by means of grants for time-limited projects. There has been a distinct increase in the volume of such grants since 2006. However, the figures reflect only part of the research grants provided at Federal level. By the same token, any contract research commissioned by Federal ministries is not included.



Data source: BMBF (Förderkatalog – catalog of federal project funding – own analysis) which study adaptation issues and are involved in piloting adaptation measures. In this context, special attention is drawn to the BMU's focus area 'Adaptation to the impacts of climate change' which is part of the departmental research plan. In the run-up to 2015, the BMVI (Federal Ministry of Transport and Digital Infrastructure) has brought together the greater part of its own research activities for adaptation under the auspices of KLIWAS (impacts of climate change on waterways and shipping – development of adaptation options). Since 2016, the BMVI has been developing a network of experts with seven departmental research institutes and competent authorities working on innovation in the fields of adaptation to climate change, protection of the environment and risk management.

In many cases, as for example in respect of the BMU's departmental research plan, time-limited research and development projects are awarded in a competitive approach (commissioned research). In addition, Federal Government provides funding by way of earmarked grants for the promotion of projects associated with funding programmes and/or specialised programmes. With regard to projects in the field of climate change impacts and associated risks as well as adaptation, the BMBF for example promotes major joint projects such as 'climate resilience thanks to measures taken in towns and regions' (within the FONA flagship initiative 'town of the future') and RegIKlim (regional information on taking action to prepare for climate change).

To date there has been no cross-sectional compilation of all promotional activities relating to the adaptation to climate change; neither has there been an overview published of the funding disbursed for those purposes. Only the grants contributed by BMBF, BMU, BMVI and BMEL (Federal Ministry of Food and Agriculture) as well as the BMWi (Federal Ministry for Economic Affairs and Energy) are listed centrally in the promotions catalogue published by BMBF, thus permitting evaluation in respect of the themes of climate change impacts and adaptation. Looking at the grants awarded for projects covering these focal areas, it becomes clear that the promotion of research activities regarding this theme has increased since 2006. In those days the BMBF created the promotional focal point 'Klimazwei – Research for Climate Protection and Protection from Climate Impacts' endowed with a funding volume of approximately 35 million Euros to cover the period 2006-2009. Beginning in 2008, the BMBF awarded the KLIMZUG programme (making climate change sustainable in regions) a total of more than 80 million Euros for projects conducted as part of seven regional joint projects. BMBF measures made the greatest contribution to the funding-based financing of research and development in respect of climate change impacts and adaptation, while other relevant funding was contributed by BMEL and BMU. However, the promotions catalogue does not cover any commissioned research. The figures therefore reflect only part of the funding provided for research and development for the adaptation to climate change.

Research remains an important basis for sound planning and acting. (Photograph: © tinyakov / stock.adobe.com)

Any relevant activities such as those conducted by BMG (Federal Ministry of Health) whose planned activities are outlined within the framework plan for departmental research or any relevant parts of the BMU's departmental research plan are currently not reflected in the indicator. Likewise, any measures which indirectly impact on adaptation, are not covered by the time series. The data do not permit any evaluative statements in respect of quantity or quality of Federal grants.

Interfaces

HUE-4: Adaptation to climate change at municipal authority level

Objectives

Expanding and enhancing the scientific foundations for the adaptation process by means of research activities at Federal level (DAS, ch. 5.2)

Municipalities are important stakeholders

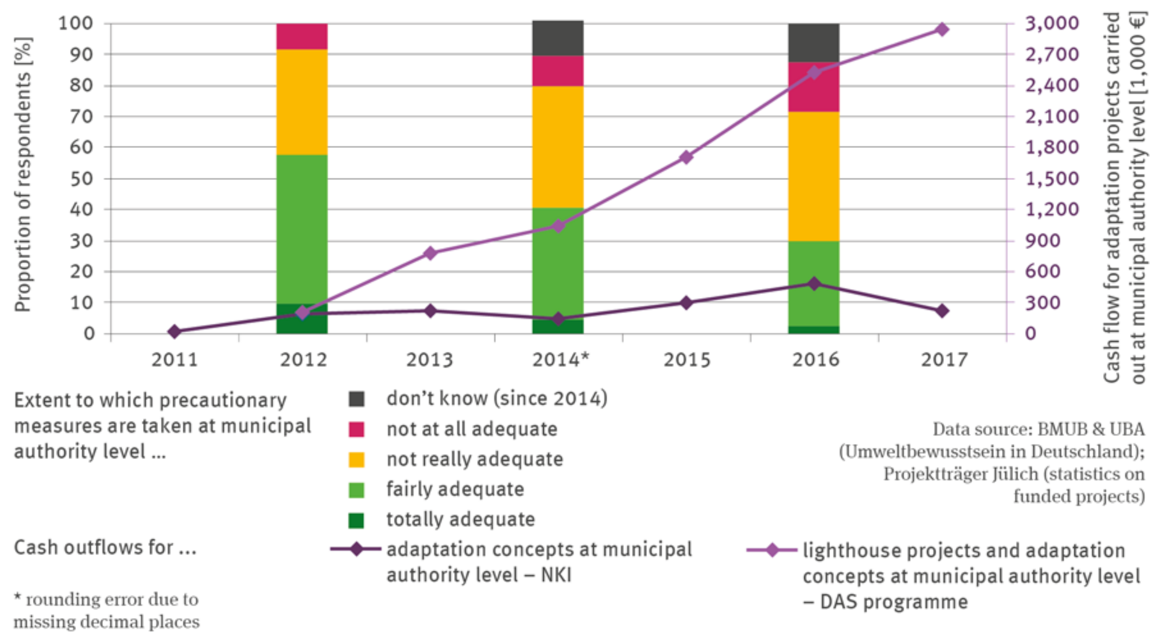
Municipalities are key players in the adaptation to climate change, as many impacts of climate change materialise at the local level. Accordingly, measures have to be developed and implemented in co-operation with municipalities. Some of these are for example measures in connection with urban greening and settlement developments as well as the adaptation of urban infrastructure or precautionary measures in the building sector. However, the adaptation to climate change as a municipal task is a relatively new and not yet well recognised action area in Germany. Federal Government therefore attaches great importance to supporting municipalities in the adaptation process.

It is currently not possible to present a general overview of the way in which Federal Government provides assistance to municipalities in these tasks. However, the award of funding in connection with two major municipal promotional programmes reflects at least part of the Federal Government's commitment. Within the framework of the Nationale Klimaschutzinitiative (NKI/ National Climate Initiative – NCI) Federal Government has, since 2011, assisted the generation of municipal adaptation concepts. Within the framework of the municipality guideline, municipalities or municipal associations were able to apply for funding for the generation of municipal adaptation concepts; while for the implementation of their adaptation concept they were able to apply for the assistance of an adaptation manager.

The concepts are used by municipalities as strategic planning and decision-making tools, they help to identify the demand for adaptation, make statements on the participation of relevant players, and indicate options for action at a local level. Between 2011 and 2017 a total of 39 towns and districts received funding awards amounting to just short of 1.6 million Euros for generating adaptation concepts. During the same period, the implementation of two partial adaptation concept themes were supported. The total outflow of funds within the framework of the municipality guideline in the period 2012 to 2017 amounted to approximately 359 million Euros. The proportion of funding benefiting adaptation concepts is rather negligible. One reason for this is that NKI cannot be used to take any investment-related and thus expensive adaptation measures. Since the

HUE-4: Adaptation to climate change at municipal authority level

Federal Government has supported municipalities, towns and districts, for example via the NKI (2011-2018) and the DAS programme for the generation of concepts and the implementation of measures ensuring good adaptation. The funding awarded by those programmes has increased. By contrast, the proportion of survey respondents giving a favourable answer to the question whether their municipal authorities were sufficiently engaged in adaptation had clearly declined.



Data source: BMUB & UBA (Umweltbewusstsein in Deutschland); Projektträger Jülich (statistics on funded projects)

* rounding error due to missing decimal places

beginning of 2019, funding opportunities have again been restricted solely to activities relating to climate protection.

Since 2012, measures for the adaptation to climate change are also supported within the framework of the DAS programme entitled ‘Promotion of Measures for Adaptation to Impacts of Climate Change’ operated by the BMU. This promotion is intended to strengthen the adaptability, especially at the local and regional level, by means of initiatives for awareness-raising, dialogue and participation as well as networking and the co-operation of regional or local stakeholders. Municipal initiatives relating to adaptation are assisted in particular with regard to two of three focal areas of the programme. On one hand, Federal Government creates stimuli for companies to generate adaptation concepts; this approach explicitly includes companies with municipal responsibilities. However, the promotion of adaptation concepts is an opportunity which municipal companies have not been taking up. So far not one municipal company has generated an adaptation concept. On the other hand, it is essential to promote municipal flagship projects and inter-municipal or regional joint ventures with the objective to develop partnerships, generate adaptation concepts and to implement these as pilot projects. In the period 2012 to 2017, the Federal Government awarded funds totalling just short of 9.2 million Euros for municipal flagship projects. This promotional tool has been financed for more than six years and, going forward, its financial base is to be increased gradually.

The two programmes do not convey a comprehensive picture of investments in municipalities’ adaptation concepts and processes, because municipalities had many other opportunities to obtain finance. These include promotional programmes such as KLIMZUG (see above) and KlimaMORO (pilot project ’spatial development strategies and climate change’) which are focused on research activities and have meanwhile terminated. EU funding for structural projects is another opportunity to obtain funding for municipal adaptation projects. As far as operational implementation measures in connection with promotional programmes are concerned, the management of climate change impacts is just an ancillary objective which – although influencing the design of the measures concerned – is not usually an element of calculation which can be extricated from the total amount of funding. In addition, there are various Länder programmes or Länder promotions. At the municipal level it is of particular importance to ensure the inclusion of citizens in discussions on what can be considered as good adaptation and on the actual implementation of measures. A prerequisite of civic engagement in this process is that the municipalities concerned take a pro-active approach, for instance by giving citizens a platform for discussion and participation and by setting an example in providing good implementation projects for adaptation purposes.

Municipalities require support and assistance in planning and implementing adaptation measures.
(Photograph: © coastoak / stock.adobe.com)

Since 2012, the representative survey ‘Environmental Awareness in Germany’ (Umweltbewusstsein in Deutschland)[I] citizens have been asked to state whether they consider that the authorities in the urban or municipal environment they inhabit have addressed the adaptation theme sufficiently and whether, in their opinion, the authorities are taking adequate precautionary measures. While in 2012, 58 % (the majority) of respondents answered this favourably, by 2014 this proportion had diminished to 41 %, and by 2016, the proportion had declined to only 30 % which is just a third of respondents.

I see footnote p. 247

Interfaces

HUE-3: Federal grants for promoting research projects on climate change impacts and adaptation

Objectives

In view of the fact that in most cases, adaptation has to be carried out at regional or local level, decisions have to be made at municipal or district levels.
(DAS, ch. 5.2)

The need for adaptation is a global challenge

In view of the global dimension of climate change and associated impacts, Germany has for years campaigned for wide-ranging international co-operation on adaptation efforts. The goal is to achieve joint generation of the European framework conditions for adaptation in developing countries with emerging economies and in European co-operative research projects. As far as the wider international environment is concerned, German activities take their cue from international processes and partnerships including the IPCC.

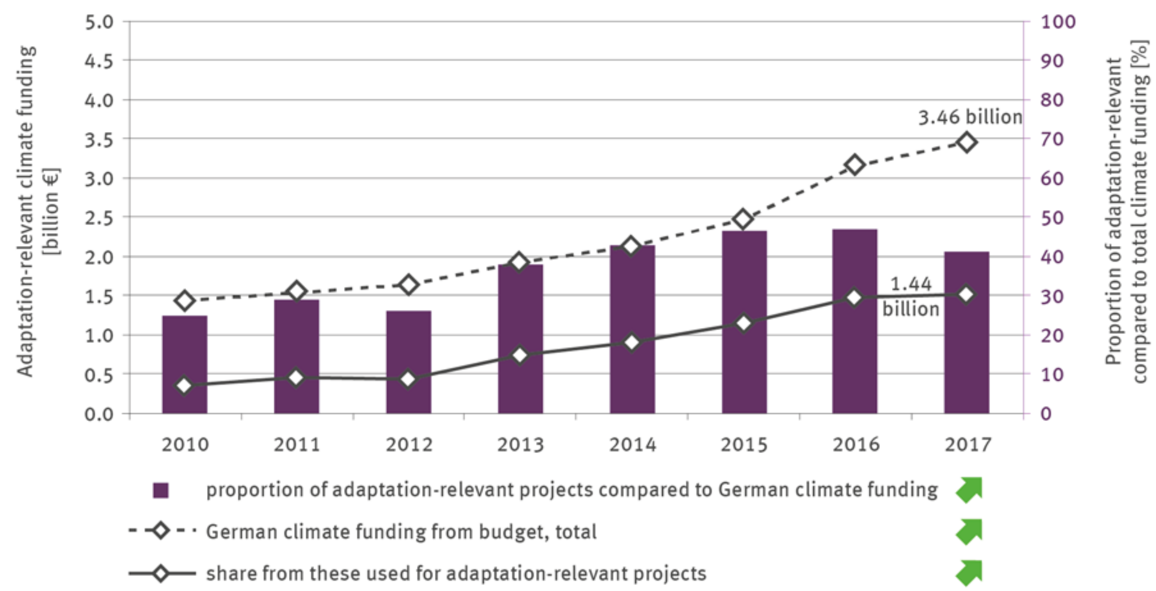
Developing countries are particularly affected by the adverse effects of climate change. Impacts have already materialised in terms of pronounced weather extremes and, for example, the deterioration of agricultural cultivation regimes. Owing to their economic and political circumstances, some of the countries affected suffer from having inadequate adaptation capacities. Providing support for developing countries in solidarity is a must, not least because – compared to industrialised countries and emerging economies – they are responsible for only a small proportion of greenhouse gas emissions which impact on the global climate.

Germany provides assistance with adaptation measures in developing countries within the framework of co-operation at a development- and climate-political level. In that light, Germany assists with designing and implementing national adaptation plans (NAPs) and adaptation objectives as embedded in the Nationally Determined Contributions (NDCs) under the international climate agreement signed in Paris. This assistance is provided, for example, via NDC partnerships. Between 80 and 90 % of the German contribution to international climate funding is made available by the Federal Ministry for Economic Cooperation and Development (BMZ). Further funding is made available by BMU predominantly within the framework of the International Climate Initiative (IKI). Other ministries contribute to projects by way of research partnerships. For her endeavour to balance the country's national contributions, Germany takes her cue from the model of balancing mitigation and adaptation within the framework of international climate finance as laid down in the Paris Climate Agreement.

At the 2009 World Climate Conference in Copenhagen the industrialised countries gave an undertaking to mobilise, from

HUE-5: International finance for climate adaptation (from budget resources)

In recent years, there has been a distinct increase in the endeavour to support adaptation in an international context. The proportion of adaptation-relevant funding compared to the overall international climate funding has increased from just short of 25 % in 2010 to 41.4 % in 2017. The demand for adaptation funding will further increase in future.



Data source: BMZ (reporting according to EU-MMR-regulations)

2020 onwards, funds in the amount of USD 100 billion from a variety of sources. At the 2015 World Climate Conference in Paris this commitment was reviewed and the target year was deferred 2025. A differentiation is made between financial contributions to multilateral programmes and bilateral development co-operation. As far as multilateral funding is concerned, several states contribute to international funds held in multilateral development banks (MDBs) and international organisations. In 2002 the Least Developed Countries Fund was created with a focus on adaptation. The Green Climate Fund (GCF) has been in operation since 2014; it endeavours to allocate funding in a 50:50 split between mitigation and adaptation. With 54 % of GCF funds awarded for adaptation, the GCF has exceeded its objective. In this way, it has been possible to improve the adaptability of approximately 310 million human beings. Germany contributed 750 million Euros towards the first replenishment of funds (pledged to contribute 1 billion USD). In the next replenishment phase, Germany is to contribute a further 1.5 billion Euros (approximately 1.69 billion USD). In 2008 the adaptation fund was created as part of the Kyoto Protocol. This fund will now also implement tasks arising from the Paris Climate Agreement. At the 2018 Climate Conference in Katowice, the BMU made a commitment to contribute 70 million Euros. Within the framework of bilateral funding for projects and programmes, Germany makes contributions to specific projects promoting carbon-poor and climate-resilient economic growth. Projects are implemented predominantly by a banking group consisting of Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) Ltd. and the KfW but also by private, civil-society and church sources of finance as well as political foundations in developing countries.

Apart from projects whose key objective is the adaptation to climate change, there are some projects on development co-operation which include a cross-sectional reference to climate change. For example, numerous projects are concerned with the objectives of fighting poverty, safeguarding food security and diversification of a country's economic structure; these projects also address the adaptation to climate change. Linking sustainable development with adaptation to climate change enhances the effectiveness of public funds. However, it is a crucial prerequisite for approving an adaptation project for international climate funding that the adaptation objectives are phrased distinctly and explicitly and that specific measures are implemented in a way as to reduce the vulnerability of human or natural systems to impacts or risks of climate change, thus increasing their climate resilience. This includes measures addressing information, awareness-raising in legal, planning and programming respects, as well as implementation measures such as the conversion to water-saving irrigation systems, the cultivation of drought-resistant crops, the introduction of sustainable practices in fisheries or measures concerned with malaria control.

Developing countries are particularly affected by extreme events and in many cases have more limited adaptation capacities. (Photograph: © africa / stock.adobe.com)

The sum total contributed by Germany towards international funding for climate protection in terms of mitigation, adaptation, forest and biodiversity measures from budgetary funds has increased from 471 million Euros in 2005 to 3.46 billion Euros in 2017. Since 2010 Germany has kept separate records of the proportion spent on international climate funding; it is therefore possible to state that this proportion has more than quadrupled from 355 million Euros in 2010 to 1.44 billion Euros in 2017. Likewise, the proportion of adaptation funding compared to overall international climate funding has increased; in 2017 it already amounted to – with 41.4 % – just short of half the overall funding. These contributions included projects with adaptation effects in the field of forest protection and conservation of biodiversity. Leaving those two elements aside, it is clear to see that already in 2017, Germany's international contributions towards adaptation funding amounted to 1.21 billion Euros.

Objectives

Assisting particularly vulnerable developing countries in the adaptation to adverse impacts of climate change (DAS, ch. 4)

Providing appropriate, calculable and sustainable sources of finance [...] for the support of adaptation measures in developing countries (Copenhagen Accord 2009)

Appendix

Authorship

Institution	Authors
Lead agency	
Umweltbundesamt (UBA), Koordinierungsstelle für das Monitoring zur DAS	FG I 1.6 KomPass: Dr. Petra van Rüth, Gabriele Schönwiese
Further development of indicators for the action areas: Building Industry; Water Regime, Water Management, Coastal and Marine Protection; Transport and Transport Infrastructure	
Bosch & Partner GmbH	Konstanze Schönthaler, Stefan von Andrian-Werburg, Mareike Buth
Statistical analyses of the indicators	
Ludwig-Maximilian-Universität München	Fakultät für Mathematik, Informatik und Statistik, Institut für Statistik, Statistisches Beratungslabor: Prof. Dr. Helmut Küchenhoff, Jonas Hagenberg, Sevag Kevork
Development of Germany's climate – data and text	
Deutscher Wetterdienst (DWD)	Referat KU 21 Nationale Klimaüberwachung: Dr. Florian Imbery, Karsten Friedrich
	Referat KU 42 Niederschlagsüberwachung: Dr. Andreas Becker
	Referat KU 41 Hydrometeorologische Beratungsleistungen: Dr. Thomas Deutschländer
	Referat KU 31 Agrarmeteorologische Fachleitung und Beratung: Dr. Christina Koppe, Elisabeth Krauthan

Contributions

The list below contains the names of all individuals who made tangible contributions to the further enhancement and updating of the indicators and/or the preparation of texts for the 2019 DAS Monitoring Report. The individuals are listed in accordance with the institutions they were employed by at the time they contributed to this process. Any individuals who assisted in the preliminary stage of preparations for the 2015 DAS Monitoring Report in developing indicators or generating text are not named in this list. Those contributors are named in the Appendix to the 2015 DAS Monitoring Report.

Institution	Authors
Indicators for the action area Biodiversity	
The work was carried out within the scope of the BfN projects 'Indicator system to illustrate direct and indirect impacts of climate change on biodiversity' (Indikatorensystem zur Darstellung direkter und indirekter Auswirkungen des Klimawandels auf die biologische Vielfalt) (FKZ 3511 82 0400) and 'Enhancement of indicators on the impacts of climate change on biodiversity' (Weiterentwicklung von Indikatoren zu Auswirkungen des Klimawandels auf die biologische Vielfalt) (FKZ 3517811000)	
Bundesamt für Naturschutz (BfN)	Fachgebiet II 1.3 Monitoring: Dr. Elisa Braeckevelt, Dr. Ulrich Sukopp
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Hochschule für Technik und Wirtschaft Dresden	Fakultät Landbau / Landespflege, Professur Tierökologie / Angewandter Umweltschutz: Prof. Dr. Frank Dziock, Silvia Dziock
Universität Stuttgart	Fakultät Bau- und Umweltingenieurwissenschaften, Institut für Raumordnung und Entwicklungsplanung: Dr. Livia Schäffler, Prof. Dr. Stefan Siedentop (auch ILS Dortmund), Stefan Fina
Dachverband Deutscher Avifaunisten e. V.	Dr. Christoph Sudfeldt, Sven Trautmann
PAN Planungsbüro für Angewandten Naturschutz GmbH	Werner Ackermann

Institution	Persons involved
Federal ministries	
Bundesministerium für Umwelt, Naturschutz, und nukleare Sicherheit (BMU)	Referat WR I 1 Allgemeine, grundsätzliche sowie internationale und europäische Angelegenheiten der Wasserwirtschaft: Silke Jung, Susanne Hempen, Susanne Huckele
Bundesministerium für Ernährung und Landwirtschaft (BMEL)	Referat 521 Nachhaltigkeit und Klimaschutz, Klimafolgen
Bundesministerium für Gesundheit (BMG)	Referat 422 Grundsatzfragen der Prävention, Eigenverantwortung, Selbsthilfe, Umweltbezogener Gesundheitsschutz: Karin Höppner
Bundesministerium für Verkehr und digitale Infrastruktur (BMVI)	Referat G22 Alternative Kraftstoffe und Antriebe, Infrastruktur, Energie: Lena Fiebig Referat G21 Energie und Klimaschutz: Sascha Faradsch, Kai Nowak
Bundesministerium für Wirtschaft und Energie (BMWi)	Referat IVC2 Klimaschutz, Emissionshandel, Internationale Umweltschutzpolitik: Jana Zimmermann
Bundesministerium für Wirtschaftliche Zusammenarbeit und Entwicklung (BMZ)	Referat 420 Klimapolitik: Christoph von Stechow Referat 421 Klimafinanzierung: Katharina Stepping Referat 422 Klimainitiativen: Ingrid Barth
Bundesministerium der Finanzen (BMF)	Referat I B 3 Energie, Umwelt, Telekommunikation, Post, Verbraucher und Nachhaltigkeit: Kerstin Lindner
Higher federal authorities	
Umweltbundesamt (UBA)	Fachgebiet I 1.6 KomPass Klimafolgen und Anpassung: Petra Mahrenholz, Dr. Thomas Abeling, Birgit Börner, Dr. Achim Daschkeit, Gabriele Schönwiese, Clemens Hasse, Dr. Inke Schauser, Kirsten Sander, Andreas Vetter Fachgebiet I 1.2 Internationale Umweltschutz- und Nachhaltigkeitsstrategien, Politik- und Wissenstransfer: Hans-Joachim Hermann, Ulrike Wachotsch Fachgebiet I 1.4 Wirtschafts- und sozialwissenschaftliche Umweltfragen, nachhaltiger Konsum: Dr. Angelika Gellrich Fachgebiet I 2.1 Umwelt und Verkehr: Petra Röthke-Habeck Fachgebiet I 2.5 Nachhaltige Raumentwicklung, Umweltprüfungen: Gertrude Penn-Bressel, Christoph Rau Fachgebiet II 1.5 Umweltmedizin und gesundheitliche Bewertung: Dr. Conny Höflich, Dr. Hans-Guido Mücke Fachgebiet II 2.1 Übergreifende Angelegenheiten Wasser und Boden: Corinna Baumgarten, Manuela Helmecke, Cindy Mathan Fachgebiet II 2.7 Bodenzustand, Bodenmonitoring: Dr. Frank Glante, Dr. Marc Marx, Jeanette Mathews, Kirstin Marx Fachgebiet II 2.9 Landwirtschaft: Dr. Knut Ehlers, Frederike Balzer, Lea Köhler Abteilung II.3 Trinkwasser- und Badebeckenwasserhygiene: Dr. Ingrid Chorus Fachgebiet II 3.3 Trinkwasserressourcen und Wasseraufbereitung: Dr. Jutta Fastner Fachgebiet IV 1.3 Pflanzenschutzmittel: Steffen Matezki, Konstantin Kuppe Fachgebiet IV 1.4 Gesundheitsschädlinge und ihre Bekämpfung: Dr. Carola Kuhn, Dr. Erik Schmolz Abteilung V 1 Klimaschutz und Energie: Michael Marty Fachgebiet V 1.3 Erneuerbare Energien: Carla Vollmer Fachgebiet V 1.4 Energieeffizienz: Jens Schuberth Fachgebiet V 1.5 Energieversorgung und -daten: Jeanette Pabst, Fabian Sandau

Institution	Persons involved
Bundesamt für Naturschutz (BfN)	Fachgebiet II 2.1 Biotopschutz, Biotopmanagement und Nationales Naturerbe: Stefanie Heinze
Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK)	Referat II.3 Grundsatzangelegenheiten Kritische Infrastrukturen: Susanne Krings, Christina Nikogosian
Bundesamt für Seeschifffahrt und Hydrographie (BSH)	Referat M2 Meeresphysik und Klima: Peter Löwe
Bundesanstalt für Gewässerkunde (BfG)	Referat M1 Hydrometrie und Gewässerkundliche Begutachtung: Dr. Hartmut Hein, Silke Rademacher Referat M2 Wasserhaushalt, Vorhersagen und Prognosen: Peter Krahe, Dr. Enno Nilson
Bundesanstalt für Immobilienaufgaben (BImA)	Zentrale – Sparte Facility Management, Fachgebiet 32: Thomas Boos, Oliver Schmidt; Fachgebiet 52: Elena Buscow-Ferber Zentrale – Sparte Bundesforst, Abteilung Naturschutz: Lothar Schmid
Bundesanstalt für Landwirtschaft und Ernährung (BLE)	Referat 321 Informations- und Koordinationszentrum für Biologische Vielfalt: Michaela Haverkamp Referat 324 Wald und Holz: Michaela Lachmann
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Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR)	Referat I 1 Raumentwicklung: Dr. Brigitte Zaspel-Heisters, Claudia Benz
Bundesnetzagentur (BNetzA)	Referat 603 Marktbeobachtung, Monitoring Energie: Maximilian Plugge Referat 606 Zugang zu Elektrizitätsverteilnetzen, technische Grundsatzfragen, Versorgungsqualität, Dominik Oleff, Carolin Wagner
Bundessortenamt (BSA)	Referat 203 Wertprüfung Mais, Gräser, Klee: Volker Klemm Referat P2 Kommunikation, Biopatent-Monitoring, Qualitätsmanagement: Nora-Sophie Quett
Deutscher Wetterdienst (DWD)	Referat KU 21 Nationale Klimaüberwachung: Dr. Florian Imbery, Silke Brinkmann Referat KU 42 Regionale Niederschlagsüberwachung: Dr. Tanja Winterrath Referat KU 41 Hydrometeorologische Beratungsleistungen: Dr. Uwe Böhm Zentrum für Medizin-Meteorologische Forschung KU 13: Dr. Stefan Muthers, Angelika Grätz Zentrum für Agrarmeteorologische Forschung KU 32: Dr. Mathias Herbst, Dr. Cathleen Frühauf Zentrales Klimabüro KU 11: Petra Fuchs, Dr. Meinolf Koßmann Regionales Klimabüro Essen KU 1 EM: Guido Halbig
FriedrichLoefflerInstitut (FLI)	Institut für Infektionsmedizin: PD Dr. Helge Kampen
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Julius Kühn-Institut (JKI)	Institut für Strategien und Folgenabschätzung im Pflanzenschutz: Sandra Krengel
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Institution	Persons involved
Statistisches Bundesamt (StBA)	Referat G 204 Materialfluss, Energie und Wasserrechnungen: Helmut Mayer, Linda Strelau, Christine Flachmann Gruppe VII-A Land- und Forstwirtschaft, Fischerei: Hamide Erfidan Referat G202 Nachhaltigkeitsindikatoren und Statistiken der Wasserwirtschaft: Franz-Josef Kolvenbach, Dr. Simon Felgendreher Verkehrszweigübergreifende Aufgaben, Personenverkehr, Verkehrsunfälle: Gerhard Kraski
Thünen-Institute (TI)	Institut für Agrarrelevante Klimaforschung: Dr. Andreas Gensior Institut für Seefischerei: Dr. Anne Sell Institut für Ostseefischerei: Dr. Christopher Zimmermann Institut für Waldökosysteme: Prof. Dr. Andreas Bolte, Erik Grüneberg, Franz Kroiher, Dr. Heino Polley, Dr. Thomas Riedel, Dr. Joachim Rock, Dr. Tanja Sanders, Dr. Walter Seidling, Dr. Nicole Wellbrock
Ministries of the federal states	
Hessisches Ministerium für Umwelt, Klimaschutz, Landwirtschaft und Verbraucherschutz	Referat III 2 Finanzierung, fachbezogene Verwaltung, Hochwasserschutz, Hydrologie, Badegewässer: Matthias Löw
Ministerium für Umwelt, Energie, Ernährung und Forsten Rheinland-Pfalz	Referat 37 Hochwasserschutz, Hydrologie und Wasserbau: Andreas Christ
Ministerium für Energiewende, Landwirtschaft, Umwelt, Natur und Digitali-sierung des Landes Schleswig-Holstein	Referat 45 Küstenschutz, Hochwasserschutz, Häfen: Frank Krüger
Ministerium für Landwirtschaft und Umwelt Mecklenburg-Vorpommern	Referat 440 Boden- und Grundwasserschutz, Altlastenfreistellung: Dr. Christine Reuther
Specialist authorities of the federal states	
Bayerisches Landesamt für Umwelt (LfU)	Referat 84 Qualität der Seen, Dienststelle Wielenbach: Martina Sendl
Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Württemberg (LUBW)	Thomas Gudera Institut für Seenforschung (ISF): Bernd Wahl
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Institution	Persons involved
LAWA AK Climate Indicators	
(Expert working group on the further development of indicators for the action area Water Regime, Water Management, Coastal and Marine Protection)	
Bundesanstalt für Gewässerkunde (BfG)	Referat M2: Wasserhaushalt, Vorhersagen und Prognosen: Peter Krahe
Umweltbundesamt (UBA)	FG I 1.6 KomPass: Dr. Petra van Rüth FG II 2.1 Übergreifende Angelegenheiten Wasser und Boden: Corinna Baumgarten
Senatsverwaltung für Umwelt, Verkehr und Klimaschutz Berlin (SenUVK Berlin)	Referat II B Wasserrecht, Wasserwirtschaft und Geologie, Fachbereich B II B 24 Wasserwirtschaft, Wasserrahmenrichtlinie, Hochwasserschutz: Antje Köhler
Ministerium für Ländliche Entwicklung, Umwelt und Landwirtschaft Brandenburg (MLUL)	Referat 22 Oberflächenwasser, Siedlungswasserwirtschaft: Sandra Berdermann
Hessisches Landesamt für Naturschutz, Umwelt und Geologie (HLNUG)	Dezernat W3 Hydrologie, Hochwasserschutz: Dr. Gerhard Brahmer Dezernat W4 Hydrogeologie, Grundwasser: Dr. Georg Berthold
Ministerium für Landwirtschaft und Umwelt Mecklenburg-Vorpommern	Referat 420 Gewässerkunde, Seenprogramm, Klimawandel: Eckhard Kohlhas
Ministerium für Umwelt, Landwirtschaft, Natur- und Verbraucherschutz NRW (MULNV)	Referat IV-5 Oberflächengewässer- und Grundwasserbeschaffenheit, Wasserversorgung: Christoph Rapp Referat IV-6 Flussgebietsmanagement, Gewässerökologie, Hochwasserschutz: Sabine Brinkmann
Niedersächsisches Ministerium für Umwelt, Energie, Bauen und Klimaschutz (MUEBK)	Referat 23 Grundwasser, Wasserversorgung, Fachplanungs- und Datenmanagement, Gewässerkundlicher Landesdienst: Dr. Astrid Krüger, Ulrike Lipkow, Ute Brase
Landesamt für Umwelt Rheinland-Pfalz (LfU)	Abt. 5 Gewässerschutz: Dr. Wolfgang Frey
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Ministerium für Umwelt, Landwirtschaft und Energie Sachsen-Anhalt	Referat Boden- und Gewässerschutz, Altlasten, Wasserrahmenrichtlinie, Geschäftsstelle LAWA-AO Ständiger Ausschuss „Oberirdische Gewässer und Küstengewässer“ der Bund/Länder-Arbeitsgemeinschaft Wasser: Susan Zimmermann
Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Württemberg (LUBW)	Dr. Gabriel Fink
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Universities and other scientific institutions	
Charité – Universitätsmedizin	Allergie-Zentrum: Prof. Dr. Karl-Christian Bergmann
Forschungszentrum Jülich GmbH / Projektträger Jülich (PtJ)	UMW 3 Nachhaltigkeit und Klima: Franziska Eichler, Heide Stephani-Pessel, Stefanie Porschel
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Non-governmental institutions	
Deutscher Feuerwehrverband e. V. (DFV)	Carsten-Michael Pix
Deutscher Verein des Gas- und Wasserfaches e. V. (DVGW)	Berthold Niehues
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Ingenieurbüro Prof. Dr. Hauser GmbH	Dr.-Ing. Stephan Schlitzberger

Institution	Persons involved
KfW Bankengruppe	Geschäftsbereich Mittelstandsbank & Private Kunden: Lars Rahn
Kommunale Aktionsgemeinschaft zur Bekämpfung der Schnakenplage KABS e. V.	Dr. habil. Norbert Becker, Artur Jöst
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Verband Deutscher Seilbahnen und Schlepplifte e. V. (VDS)	Birgit Priesnitz, ThuHà Prügelhof
VGB PowerTech e. V.	Power Plant Technologies: Stefan Prost

Sources

Endnotes

Human health

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Abbreviations

AdSVIS Adaptation of road transport infrastructure to climate change (Adaptation der Straßenverkehrsinfrastruktur an den Klimawandel)

AG / AK Working Group (Arbeitsgruppe /Arbeitskreis)

Ah Annual run-off volume

ALKIS Authoritative Real Estate Cadastre Information System (Amtliches Liegenschaftskatasterinformationssystem)

APA Adaptation Action Plan of the German Strategy for Adaptation to Climate Change (Aktionsplan Anpassung)

BBK Federal Office of Civil Protection and Disaster Assistance (Bundesamt für Bevölkerungsschutz und Katastrophenhilfe)

BBodSchG Federal Soil Protection Act (Bundes-Bodenschutzgesetz)

BBSR Federal Institute for Research on Building, Urban Affairs and Spatial Development (Bundesinstitut für Bau-, Stadt- und Raumforschung)

BDF Soil Monitoring Sites (Boden-Dauerbeobachtungsflächen)

BEKORS Calculation of operating costs of highway maintenance (Betriebskostenrechnung im Straßenbetriebsdienst)

BfG Federal Institute of Hydrology (Bundesanstalt für Gewässerkunde)

BfN Federal Agency for Nature Conservation (Bundesamt für Naturschutz)

BImA Institute for Federal Real Estate (Bundesanstalt für Immobilienaufgaben)

BMBF Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung)

BMEL Federal Ministry of Food and Agriculture (Bundesministerium für Ernährung und Landwirtschaft)

BMELV Federal Ministry of Food, Agriculture and Consumer Protection (Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz; since 1014: BMEL)

BMG Federal Ministry of Health (Bundesministerium für Gesundheit)

BMUB Federal Ministry for the Environment, Nature Conservation, Construction and Nuclear Safety (Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit; since 2018: BMU)

BMU Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Bundesministeriums für Umwelt, Naturschutz und nukleare Sicherheit)

BMVI Federal Ministry of Transport and Digital Infrastructure (Bundesministerium für Verkehr und digitale Infrastruktur)

BMWi Federal Ministry for Economic Affairs and Energy (Bundesministerium für Wirtschaft und Energie)

BMZ Federal Ministry for Economic Cooperation and Development (Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung)

BNetzA Federal Network Agency (Bundesnetzagentur)

BSA Federal Plant Variety Office (Bundessortenamt)

BSH Federal Maritime and Hydrographic Agency (Bundesamt für Seeschifffahrt und Hydrographie)

BWI National Forest Inventory (Bundeswaldinventur)

BZE Soil inventory (Bodenzustandserhebung)

BZE-LW Agricultural soil inventory (Bodenzustandserhebung Landwirtschaft)

CCM Corn-Cob Mix

DAS German Strategy for Adaptation to Climate Change (Deutsche Anpassungsstrategie an den Klimawandel)

DWD German Meteorological Service (Deutscher Wetterdienst)

EAFRD European Agricultural Fund for Rural Development

eEV extended natural hazard insurance for residential buildings (erweiterte Elementarschadenversicherung)

EPS Protein plant strategy (Eiweißpflanzenstrategie)

EU European Union (Europäische Union)

FFH Habitats Directive (Fauna-Flora-Habitat)

FGRDEU National Inventory of Forest Genetic Resources (Nationales Inventar forstgenetischer Ressourcen)

FoVG Forest Reproductive Material Act (Forstvermehrungsgutgesetz)

FRMD European Flood Risk Management Directive

GCF Green Climate Fund

GDV German Insurance Association (Gesamtverband der Deutschen Versicherungswirtschaft e. V.)

GIZ Society for International Cooperation (Gesellschaft für internationale Zusammenarbeit)

GMST Global Mean Surface Temperature

GSBTS German Small-scale Bottom Trawl Survey
GW Gigawatt
HQ100 Flood run-off with a mean probability of occurring once in 100 years (100-year flood)
HQ Flood run-off
HThw Highest tidal highwater level
HW Highest water level
IASCP Joint Task 'Improvement of Agrarian Structures and Coastal Protection'
IKI International Climate Initiative (Internationale Klimaschutzinitiatie)
IKZM National strategy for integrated costal zone management (Nationale Strategie für ein integriertes Küstenzonenmanagement)
IMAA Interministerial Working Group on Adaptation to Climate Change (Interministerielle Arbeitsgruppe Anpassung an den Klimawandel)
IPCC Intergovernmental Panel on Climate Change
KRITIS Critical infrastructure (Kritische Infrastrukturen)
LAWA German Working Group on water issues of the Federal States and the Federal Government (Bund/Länder-Arbeitsgemeinschaft Wasser)
MDB Multilateral Development Bank
MHQ Mean floodwater run-off
MKRO Ministerial conference on spatial planning (Ministerkonferenz für Raumordnung)
MNQ Medium low-water run-off
MQ Mean water run-off
MThw Medium tidal high-water level
MTmw Medium tidal mid-water level
MTnw Medium tidal low-water level
MW Medium water level
NAP National Action Plan on Sustainable Use of Plant Protection Products
NAP National Adaptation Plan
NASA National Aeronautics and Space Administration
NBS National Biodiversity Strategy (Nationale Strategie zur biologischen Vielfalt)
NDC Nationally Determined Contributions
nFK Usable field capacity (Nutzbare Feldkapazität)
NHS National Sustainable Development Strategy (Nationale Nachhaltigkeitsstrategie)
NKI National Climate Initiative – NCI (Nationale Klimaschutzinitiative)
NOAA National Oceanic and Atmospheric Administration
NQ Low-water run-off
PID Foundation for pollen information services (association registered in Germany) (Stiftung Deutscher Polleninformationsdienst e. V.)
PtG Power-to-Gas facility
RKI Robert Koch Institute (Robert Koch-Institut)
SROCC Special Report on the Ocean and Cryosphere in a Changing Climate
SRP Special Framework Plan
StBA Federal Statistical Office (Statistisches Bundesamt)
THW Federal Agency for Technical Relief (Bundesanstalt Technisches Hilfswerk)
UBA German Environment Agency (Umweltbundesamt)
USD US Dollars
WFD EU Water Framework Directive
WHG Water Resources Act (Wasserhaushaltsgesetz)
WMO World Meteorological Organization


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