Hessian Agency for Nature Conservation,
Environment and Geology
Centre on Climate Change and Adaptation

HESSEN

Climate Change and Water

Climate Change in Hesse

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Edited by: Dr. M. Banning, Dr. G. Berthold, Dr. G. Brahmer,
M. Hergesell, Dr. H. Hübener, A. Gründel, W.-P. v. Pape

Layout: Nadine Monika Fechner, Christine Zarda

Translation with the help of Dr. E. Pischtschan, C. Wellié-Reeve

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Hessian Agency for Nature Conservation, Environment and Geology
Centre on Climate Change and Adaptation
Rheingaustraße 186
65203 Wiesbaden

Phone: 0611 6939–111
Fax: 0611 6939–113
Email: vertrieb@hlnug.hessen.de

www.hlnug.de

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Foreword

Prof. Dr. Thomas Schmid
President of the Hessian Agency for Nature Conservation, Environment and Geology

Climate change affects many aspects of our lives. Changes in precipitation in particular have far-reaching implications, for instance on plant growth and thus the harvests, on our rivers and the groundwater. Do we have to expect flooding more often in the future? Or rather increasing low flow events? Maybe both? Will enough groundwater continue to be available everywhere? Will our water quality change? And how do animals and plants react to these changes?

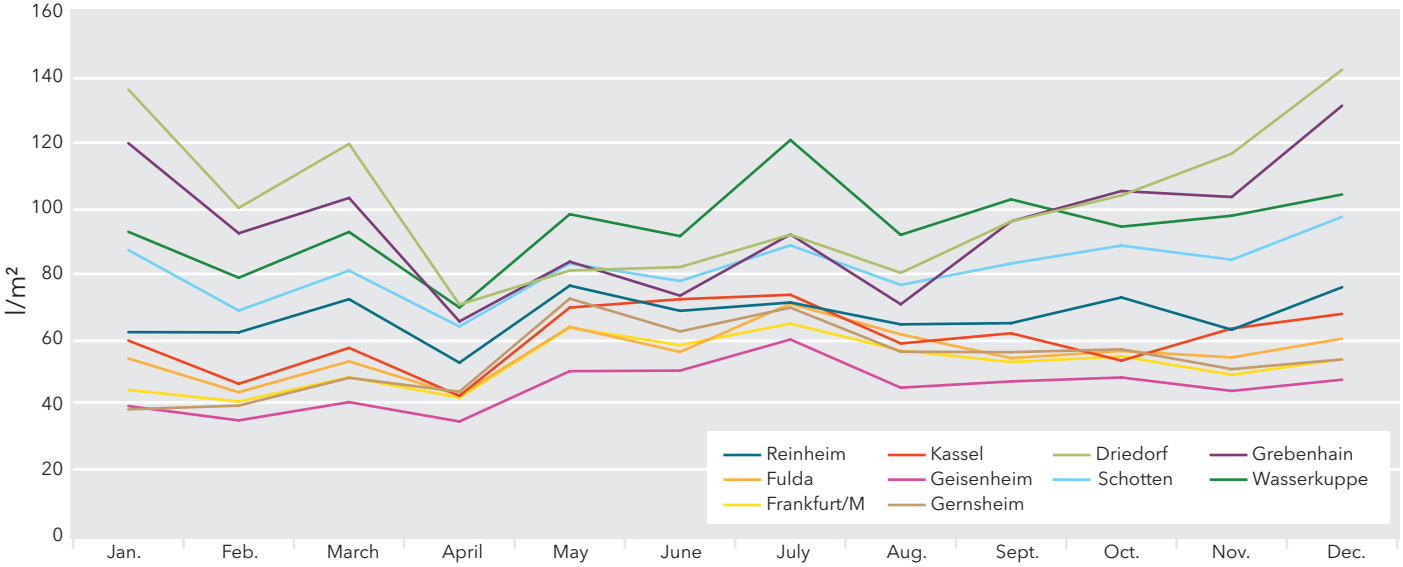
In this brochure, we look into these issues. We describe changes that already happened and explain which further changes to the environmental medium of water may be expected as a result of changing climate in Hesse.

Further information is available on the websites of the HLNUG.

Precipitation

An average amount of 839 mm (i.e. l/m²) of precipitation was recorded from 1981 to 2010 throughout Hesse. Its distribution varies by region: The highest total amount of precipitation was measured in Driedorf, the lowest in Geisenheim.

The lowest number of rain days throughout Hesse was recorded in Geisenheim (105 per year) and the highest number at the Wasserkuppe station (156 per year) on average.



Mean precipitation per month from 1981 to 2010. Data Source: DWD

Climate projections for the future do not indicate any changes in annual mean precipitation in the scenario of a medium rise of greenhouse gas concentrations (the so-called "Scenario A1B"). However, a seasonal shift of precipitation from summer to winter becomes apparent. By the middle of this century, these trends are relatively weak compared to the year-to-year-fluctuation in precipitation. With ongoing climate change, the shifting rainfall distribution between the seasons becomes increasingly clear.

Mean precipitation in Hesse based on observations and future projections for hydrological half years (winter: Nov–April; summer: May–Oct) and the entire water year

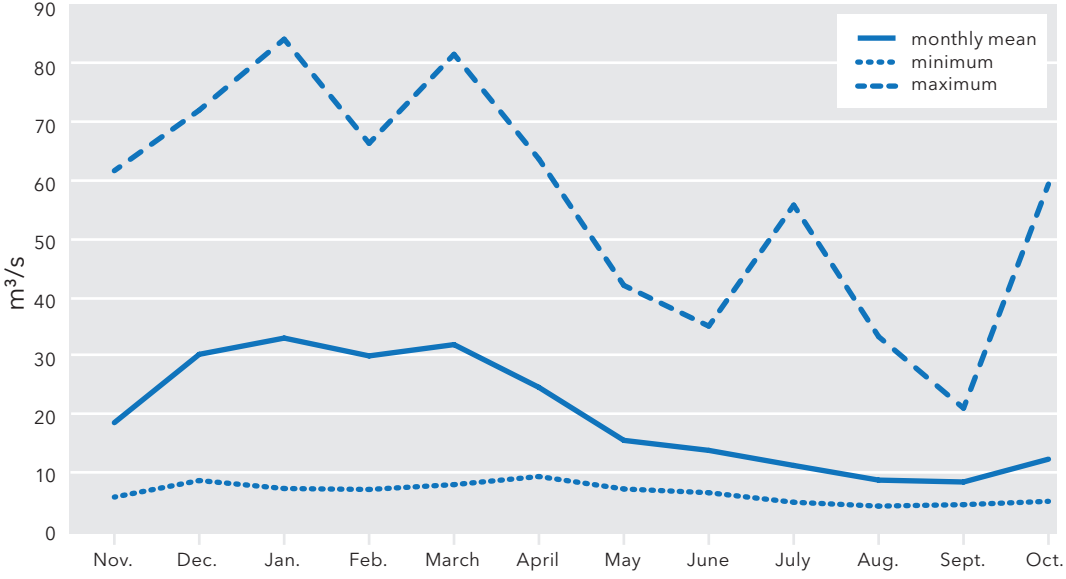
Period	Winter	Summer	Year
1961–1990	384 l/m²	409 l/m²	793 l/m²
1971–2000	375 l/m²	402 l/m²	777 l/m²
1981–2010	387 l/m²	418 l/m²	805 l/m²
2021–2050 (rel. to 1971–2000)	+3 % * (-4 % to +14 %)	-5 % * (-13 % to +5 %)	-1 % * (-7 % to +9 %)
2071–2100 (rel. to 1971–2000)	+8 % * (-5 % to +26 %)	-16 % * (-24 % to -2 %)	-4 % * (-13 % to +12 %)

* Band width based on simulations using 21 regional climate models

Changes in river discharge

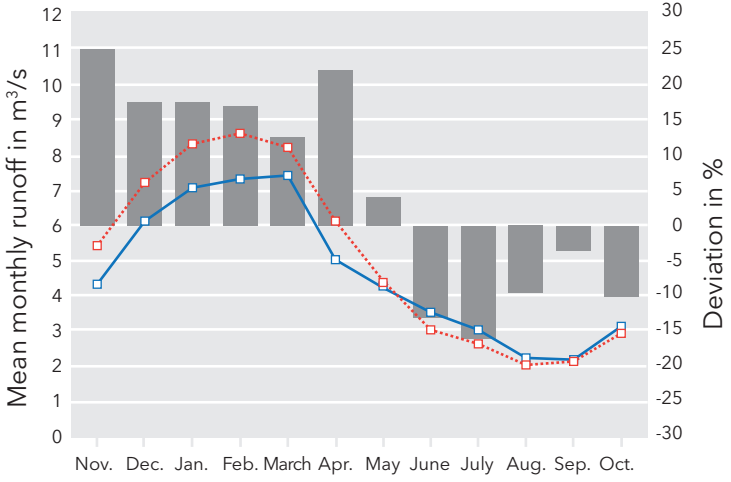
The state of Hesse operates 108 gauges to measure water stages and river discharge. Hessian water bodies have their runoff maximum in the winter half year and the minimum in summer due to increased evaporation. Depending on the amount of precipitation per year and its distribution over the months, the discharge varies greatly from year to year.

The measured gauge-data are also used to assess the impact of climate change on future runoff. For this purpose, regional climate simulations for Hesse are fed into a water balance model which in turn simulates changes in the river discharge.



Discharge at the gauge in Bad Hersfeld (Fulda): monthly mean, minimum and maximum values for the period 1971–2000

With ongoing climate change, changes in the discharge of Hessian water bodies are to be expected: namely a shift towards higher runoff in the winter half year and lower runoff in the summer half year. The water level at times of low flow will be even lower.



Simulated runoff at the Harreshausen gauge, one climate model, scenario A1B

Gauge in Harreshausen (Gersprenz)

Left axis:

Simulated runoff
for the reference period 1971–2000

for the future period 2021–2050

Right axis:

Relative change in the future period with respect to the reference period in %

Floods

Floods are caused by various processes. Wintertime floods mostly result from prolonged rainfall in a large area. They often affect major rivers, especially when the tributaries also contribute with floods. Floods in winter are often associated with frozen soil, permitting the infiltration of rainwater into the ground. In the spring, snowmelt concurring with heavy rainfall can lead to flooding.

Eberbach Odenwald: Heavy rainfall caused the formation of small islands and streambed expansions © Ecolo-Gis 2012

In summer, floods are most often caused by heavy rainfall, e.g. during thunder storms. These heavy rainfall events are often limited to small areas, affecting small river catchments. Flooding and soil erosion are particularly furthered by limited or absent infiltration resulting from asphalt sealing, when the surface is crusted due to previous drought, or when the soil is already waterlogged.

On the other hand, flood events are part of the essential, shaping forces of flowing waters. Their biotic communities are principally adapted to such events. Therefore, changes in the river course in the wake of flooding should be left unchanged as far as possible, or even developed further. Restoring a “hydromorphological equilibrium” of rivers is one of the most urgent objectives of today´s water management.

Climate change leads to more precipitation in winter that increasingly falls in the form of rain instead of snow, making wintertime floods more likely in the future. However, decreasing snow cover also reduces the risk of spring floods caused by melting snow.

Less rainfall is expected during the summer in the future. Yet, heavy rainfall events can still occur and potentially become more intense. Hence, the risk of summertime floods will remain.

There is currently no clear trend as to future extreme flood events, apart from an increase in the number of mean flood events.

Flooding at the Werra in Eschwege © A. Müller-Brandl, Stadt Eschwege

Low flow

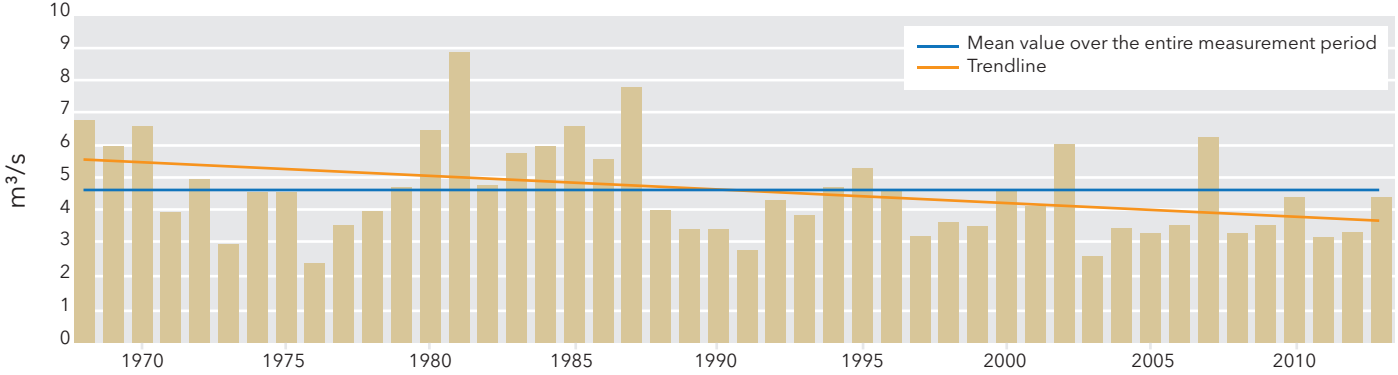
Prolonged drought can lead to low flow in rivers, which in turn can e.g. cause shipping closures. Moreover, it may cause the abstraction of irrigation water or water for cooling in power plants or industrial facilities to be restricted or even prohibited.

Low water events in Hesse mostly occur during the months of August and September. Data recorded by 64 of the 108 Hessian gauges indicate a trend that low flow events occur about 2 weeks earlier in the year within the last 30 years.

For the past 30 years, the Hessian gauges recorded the following changes in low flow runoff, i.e. the amount of water still flowing when water levels are low:

- significant decreases at 24 gauges
- significant increases at 4 gauges
- no significant trend at 80 gauges

With ongoing climate change, the decrease in summer precipitation will worsen low flow problems.



The lowest minimum discharge per year at the gauge in Bad Hersfeld (Fulda), 1968–2013, showing a significant decrease

The spring of 2011 was the second-driest spring in Germany since measurements began in 1881. In March 2011, precipitation in Hesse only amounted to 21 % of the average precipitation recorded between 1961 and 1990.

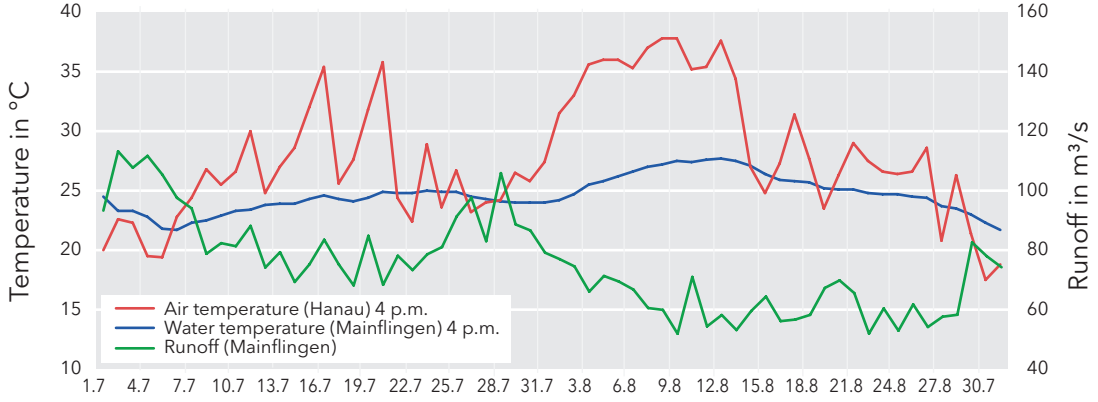
November 2011 was the driest November on record. Hesse experienced only 2.8 % of the average November precipitation. Some gauges registered no precipitation at all.

The Rhine river at Rüdesheim/Bingen, November 2011

Water temperature

The high summer air temperatures in 2003 and 2006 led to higher water temperatures and low flows. This caused, for example, the river Main to exceed the 25 °C threshold for the so-called "Barbel Region" to which the Main belongs (diagram on this page). If this threshold is exceeded frequently or for a long time-period, flora and fauna of the water body will very likely be damaged.

The simulated temperature profile along the reach of the Main in Hesse for 13 August, the day with the highest water temperature in 2003 (diagram on the next page), shows an increase in water temperatures from the Hessian-Bavarian border to the entry point into the Rhein. Cooler inflows from the Kinzig and Nidda rivers as well as discharge from the sewage treatment plant in Niederrad decreased the temperature. Discharge of waste heat from the Mainova and Höchst industry facilities raised the water temperature.

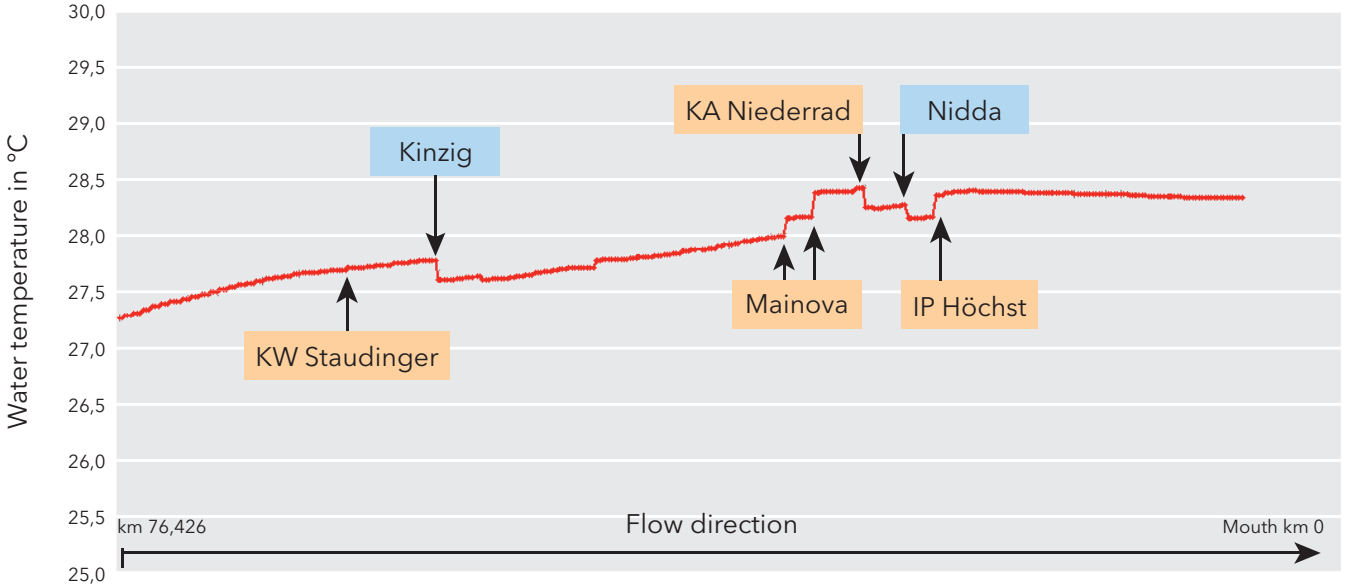


Runoff as well as air and water temperatures in the afternoon (4 p.m.) at the gauge in Mainflingen (Main) in July and August 2003

The Staudinger power plant, usually the top thermal polluter at the Hessian Main, already had to cease operations on 9 August 2003 as it was no longer allowed to extract cooling water.

Climate change will lead to higher water temperatures in Hessian rivers and creeks.

A comprehensive study carried out by the International Commission for the Protection of the Rhine against Pollution (IKSR) discovered that the summer of 2003 gave a taste of which water temperatures will be normal for the Rhine by the end of the century (2071–2100).



Daily mean water temperatures of the Main from the Hessian border to the mouth on 13 August 2003

Groundwater

In Hesse, 95 % of the drinking water is sourced from groundwater. Groundwater is mainly formed from precipitation infiltrating into the ground, and – to a minor extent – from the percolation of rivers, creeks and lakes. In Hesse, groundwater is predominantly replenished in the winter half year when a large percentage of the rainfall infiltrates. At present, about five times more groundwater is formed than used in Hesse every year. The groundwater level varies over the course of the year and from year to year. Very high or very low groundwater can damage buildings and infrastructure.

Extremely high…

… and extremely low groundwater level

As a result of climate change, precipitation distribution will shift from summer to winter. According to current knowledge, climate change will not reduce groundwater recharge in Hesse. The seasonal fluctuation of groundwater levels will increase, however. The drinking water supply is not expected to be at risk despite an increase in peak demand in warmer and drier summers, since the average demand is decreasing owing to the decline in population.

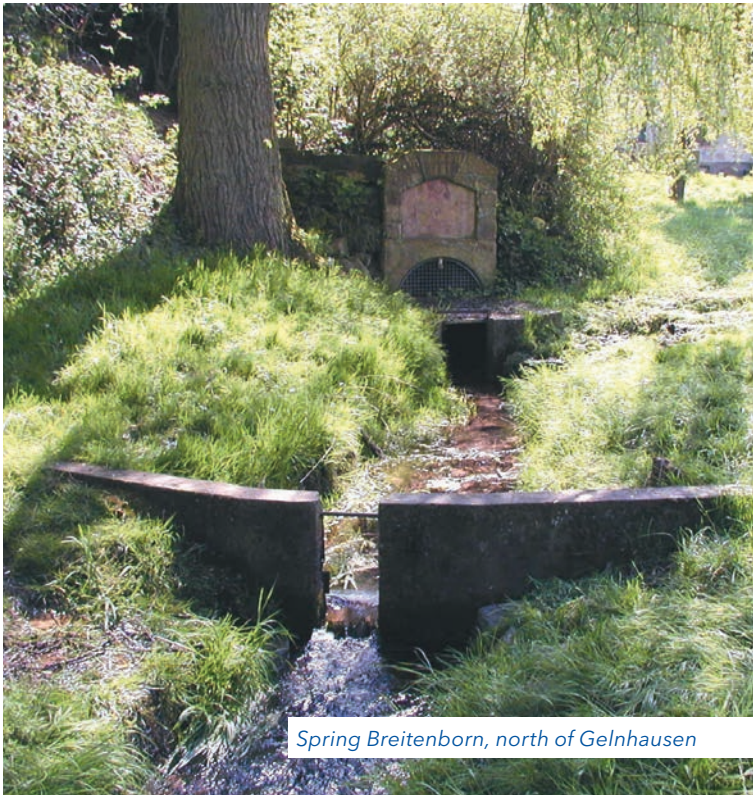
Springs

In the Hessian uplands, drinking water is sourced from local springs. Here, decreasing discharge in summer and autumn might cause future problems. Increasing heavy precipitation can lead to water turbidity.

The water temperature of 48 Hessian springs is regularly measured – usually once a week. Over the last decades, the water temperature of many springs has increased, which corresponds to the observed increasing near surface air temperature. Only one of the 48 springs shows a slight decrease in temperature; 10 springs show no trend; in 22 springs, the temperature has slightly increased (by up to 0.5 °C), and in 15 springs the temperature has strongly increased (by up to 1.9 °C).

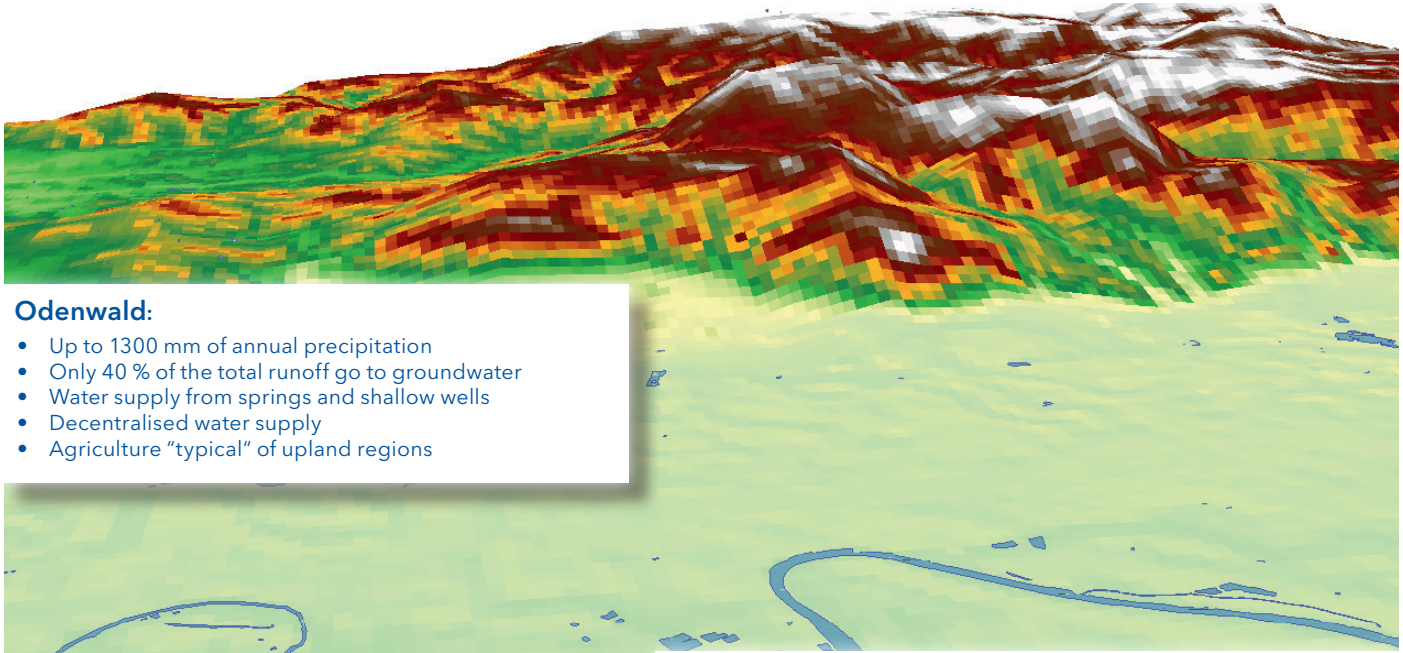
With ongoing climate change, the groundwater levels could drop, wells could fall dry or springs could dry up following prolonged dry periods in summer.

The warming of groundwater and hence of the spring and well water will continue.



Spring Breitenborn, north of Gelnhausen

Irrigation



Odenwald:

- Up to 1300 mm of annual precipitation
- Only 40 % of the total runoff go to groundwater
- Water supply from springs and shallow wells
- Decentralised water supply
- Agriculture “typical” of upland regions

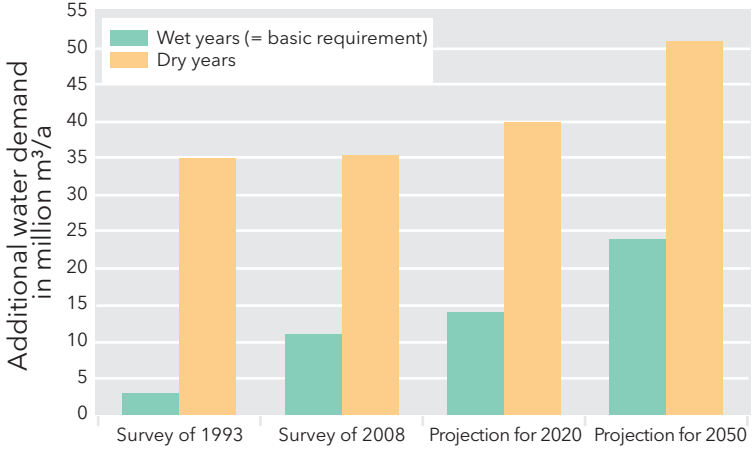
Hessian Ried:

- 600 to 700 mm of annual precipitation
- Up to 100 % of the total runoff go to groundwater
- 5 % of the land surface supply 25 % of the drinking water in Hesse
- Water supply from wells
- Centralised water supply
- Intensive agriculture using irrigation, high portion of cash crops (asparagus, onions, strawberries, among others)

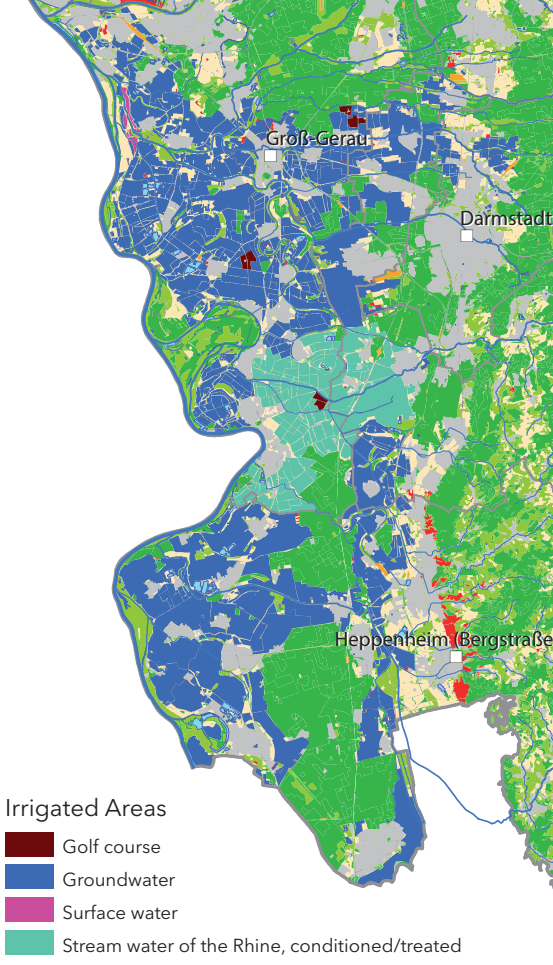
Elevation model of the Hessian Ried and the Odenwald

Summer drought often leads to crop failures – particularly in agriculture -, since many agricultural crops depend on rainfall. In the Hessian Ried, however, about 96 % of the agricultural land is already irrigated today. While between 5 and 10 million m^3 of water is used for irrigation in the Hessian Ried in wet years, this value increases to around 35 million m^3 in dry years.

With climate change, summer precipitation will decrease, resulting in more dry periods in the future. More irrigation will become necessary even in wet years. This applies to vegetable crops in particular.



Additional annual demand for water used for irrigation in the Hessian Ried (Results obtained from surveys as well as extrapolated from climate projections).



Irrigated areas in the Hessian Ried

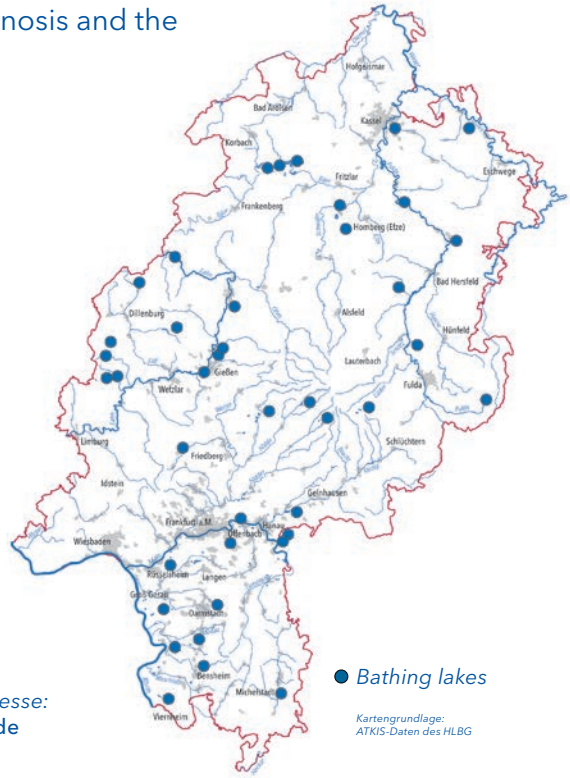
Lakes in Hesse

There are altogether 773 lakes and reservoirs in Hesse covering an area of more than one hectare. 63 of these lakes are public bathing lakes, which are monitored for their water quality.

The lakes are not of natural origin, but were created artificially or by dammed rivers. Artificial lakes were created by gravel extraction (flooded gravel pits) or coal mining (surface mining lakes). Reservoirs are rivers dammed to prevent floods or to elevate low flow discharge. Even if the Hessian lakes are artificial or heavily modified water bodies, they nevertheless are valuable habitats that are home to various biotic communities.

Climate change will cause rising lake water temperatures. In addition, the stored water volume in the reservoirs will drop due to reduced summer precipitation. In lakes and reservoirs, climate change can lead to increasing growth of algae and thus impair the water quality if the nutrient load remains unchanged.

Certain species of cyanobacteria produce toxins which are harmful to the lake´s biocoenosis and the bathers.



Bathing lakes in Hesse:
badeseen.hlnug.de

Blue-green algae bloom in the Werratal lake, 2012

The biological quality of rivers and creeks

Climate change puts great demands on the ability of animals and plants to adapt. Besides increasing water temperatures, the seasonal fluvial dynamics of creeks and rivers (high or low water stages) also changes. In addition, the chemical water quality can deteriorate (pollutants are less diluted at low flows). Warming leads to stress in or displacement of cryophilic species and to an expansion of habitats for frost-sensitive or thermophilic species. In addition, alien species can also invade.

Considering the impact of climate change on the biological quality of water bodies, it is important to note that the climate factors are generally also superseded by other factors (e.g. water extraction, discharge of waste heat, discharge of noxious substances).

Since individual animal or plant species have different adaptive capacities, hitherto existing species communities decompose. Thus, climatic changes that are too fast or too strong burden the ecosystems – right up to their destruction.

Rising water temperatures in rivers and creeks could lead to a situation where, for example, cryophilic fish species like the river trout or the bullhead are no longer able to live in the trout zone (head waters) of some creeks. Additional strain results from decreasing low flow runoff during prolonged dry periods in summer.

Furthermore, plants and animals are exposed to more stressors, such as nutrient discharge (e.g. phosphorus, nitrate) or water extraction for cooling or irrigation purposes.

The Asian clam is native to East Asia. It probably came to Europe in the ballast water of ships and was spread in Germany via the shipping lane network. The clam was first found in 1987 in the Lower Rhine region. Today, it is very common in major rivers. Since the Asian clam cannot tolerate cold, this species is found in Hesse particularly often downstream the waste heat discharge of power plants. Therefore, this clam will very likely benefit from climate change. It is still unclear whether or not it causes harm to the ecosystem.

The Bullhead is threatened by climate change © Hecker

The Asian clam benefits from climate change © Eiseler

Climate Change and Water: conclusions

The good news first: In Hesse, there will still be enough drinking water available in the future. The annual mean groundwater level will very likely remain roughly the same. However, the expected shift of precipitation from summer to winter caused by climate change will lead to a stronger fluctuation between high groundwater levels in winter and low groundwater levels in summer. Communities in upland regions that source their water from local springs may need additional water supply in the future if the springs deliver less water during summer.

Due to the seasonal changes in precipitation, winter flood events will increase. Despite the mean summer rainfall reduction, floods in smaller rivers or creeks might still occur. Low flow events will occur more often, particularly in summer and autumn.

Due to the future decrease in summer rainfall, demand for agricultural irrigation will continue to rise.

The warming of the air coincides with an increase in water temperature. If certain thresholds are exceeded, damage to the aquatic biocoenosis must be expected. New species that are not native to the area could invade. It is not always clear whether or not these species harm the existing ecosystem. And finally, the warming impairs the quality of the Hessian bathing lakes by strengthening the growth of algae – given a continued discharge of nutrients into the water. Furthermore, since blue-green algae produce noxious substances, bathing is disadvised in the event of an algae bloom.

Further information on Hessian climate is available on our websites:

https://www.hlnug.de/themen/fachzentrum-klimawandel/english-information.html

http://atlas.umwelt.hessen.de

The following information brochures in the **'Climate Change in Hesse'** series have been published:

- Observed Climate Change
- Climate Change in the Future
- Extreme Weather Events in Hesse
- Climate Change and Water
- The Impacts of Climate Change on Human Health
- Agriculture, Forestry and Climate Change
- Observing the Effects of Climate Change – Climate Impact Monitoring
- Hessian Soils under Climate Change

An information brochure for schoolchildren is available in German:

- Have you heard …? The Climate is changing!

Hessisches Landesamt für
Naturschutz, Umwelt und Geologie

Für eine lebenswerte Zukunft