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

HESSEN

# Observing the Effects of Climate Change

## –Climate Impact Monitoring–

FACHZENTRUM KLIMAWANDEL UND ANPASSUNG

## Climate Change in Hesse

# Imprint

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# Foreword

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

Climate change has an impact on animate as well as inanimate nature and on the environment. This impact can be measured in various areas such as agriculture, forests and water bodies, as well as human health.

The effects of climate change are not only a global problem. Also in Hesse, the consequences of climate change can already be observed.

In order to document these consequences, so-called indicators are being developed by the Hessian Agency for Nature Conservation, Environment and Geology (HLNUG) – signs of changes or developments in nature and the environment.

This brochure presents a selection of indicators chosen for various areas. They serve to elucidate climate-induced changes and reveal the effects of climate change already detectable in Hesse. Adapting and reacting to climatic changes is only possible if these changes are made visible.

The term climate impact monitoring denotes the observation of effects caused by climate change with the help of indicators. The monitoring serves to detect the resulting effects of climate change very early on in order to decide which areas need urgent action. Major changes experienced to date are presented by the indicators chosen by the HLNUG.

Selected developments are taken into account which – from a scientific and research point of view – can largely be attributed to the effects of climate change.

Furthermore, long and reliable data time series are necessary to serve as indicators – ideally of a minimum length of 30 years.

In Hesse, indicators have so far been developed for the following areas of action: water management, biodiversity, forests, agriculture, fruit-/wine-growing as well as human health.

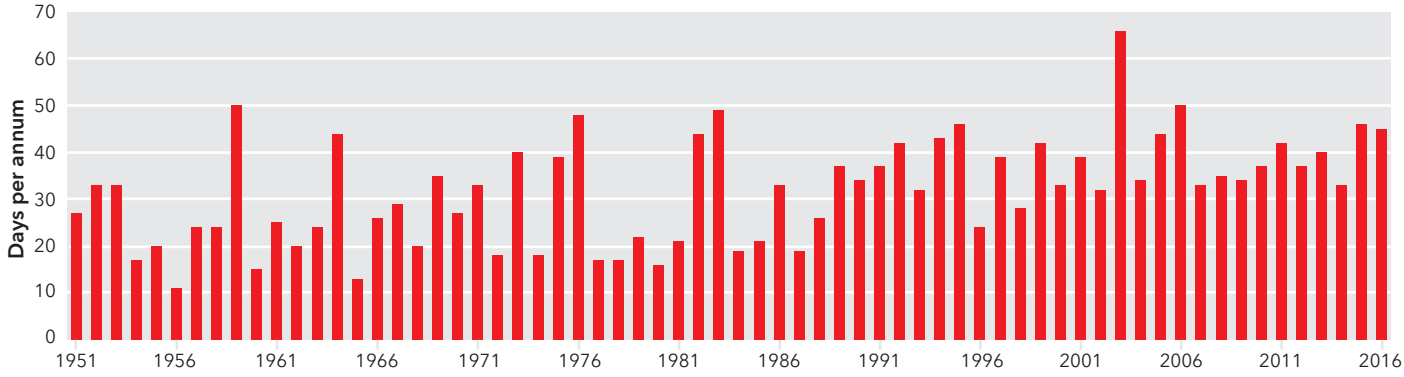
The Hessian indicator system is regularly updated and, if needed, supplemented by new indicators. Even if climate impact indicators merely illuminate selected aspects of the effects of climate change, they can help to focus more sharply on developments that require our action.

*View of the Rhine river at Rüdesheim © W. Fehlinger*

# Meteorological information

The meteorological parameters most commonly used to depict climate are temperature and precipitation. These meteorological parameters have manifold effects on other areas, such as the state and development of flora and fauna, but also on water bodies or people. Monitoring temperature and precipitation allows conclusions on changes in climate and the environment.

Furthermore, climatic changes and the occurrence of extreme weather events such as heat waves are relevant to humans and nature. Climate indices like **summer days** and **icing days** are characterised by overstepping or staying below a certain upper or lower limit. Temperature-related climate indices make good indicators of climate change.

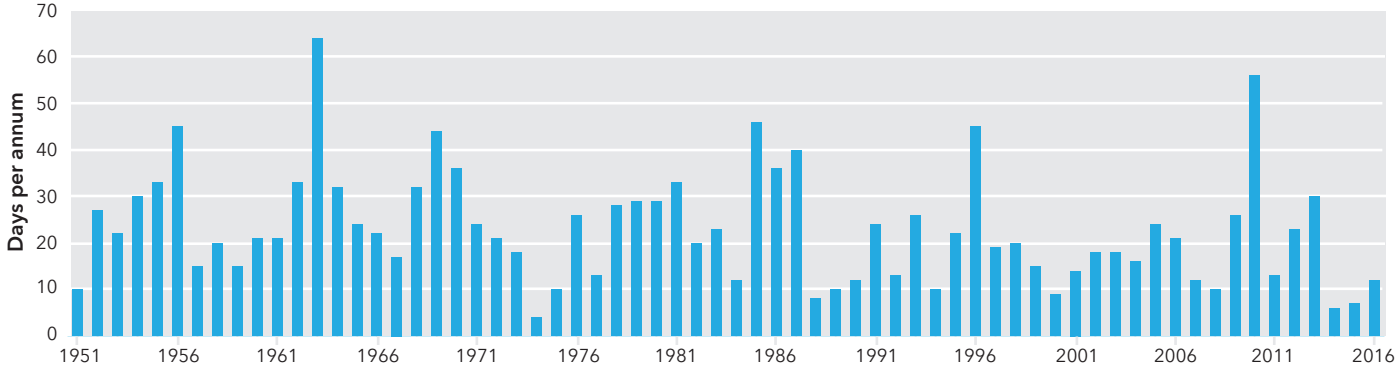



*Number of summer days in Hesse (Tmax ≥ 25 °C). Data source: DWD*

On a **summer day** (see left-hand illustration), the daily maximum temperature reaches or exceeds 25 °C. On an **icing day**, the air temperature constantly remains below 0 °C.

It can be observed that the number of summer days has slightly increased since 1951, while the number of icing days – with continuing high fluctuations – has slightly decreased. Thus, the year 2010 with 56 icing days was well above the average of the previous 30 years (21 days), while the following year 2011 with 13 icing days was clearly below average.






*Number of icing days in Hesse (Tmax < 0 °C). Data source: DWD*

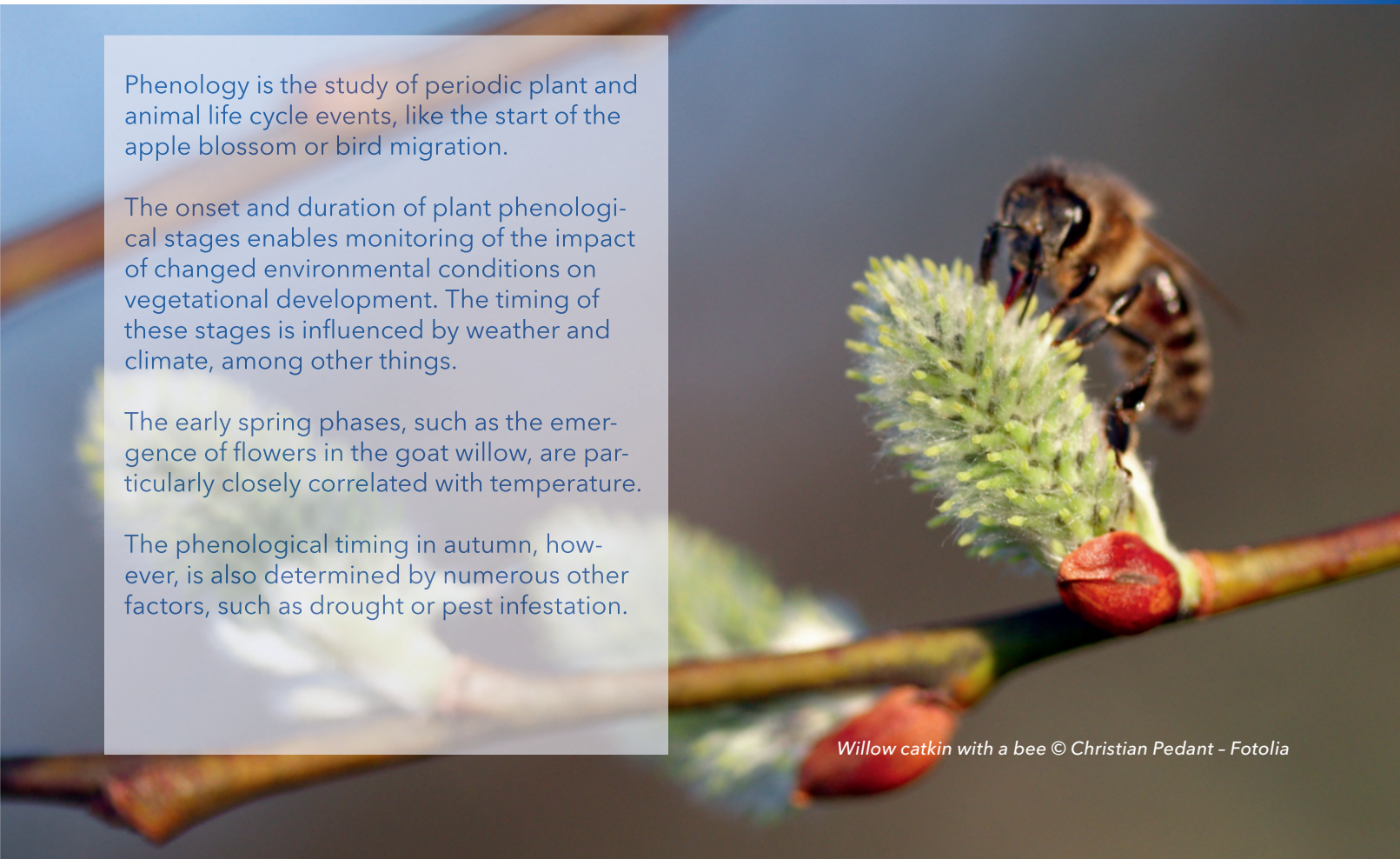
# Duration of the vegetation period

Phenology is the study of periodic plant and animal life cycle events, like the start of the apple blossom or bird migration.

The onset and duration of plant phenological stages enables monitoring of the impact of changed environmental conditions on vegetational development. The timing of these stages is influenced by weather and climate, among other things.

The early spring phases, such as the emergence of flowers in the goat willow, are particularly closely correlated with temperature.

The phenological timing in autumn, however, is also determined by numerous other factors, such as drought or pest infestation.



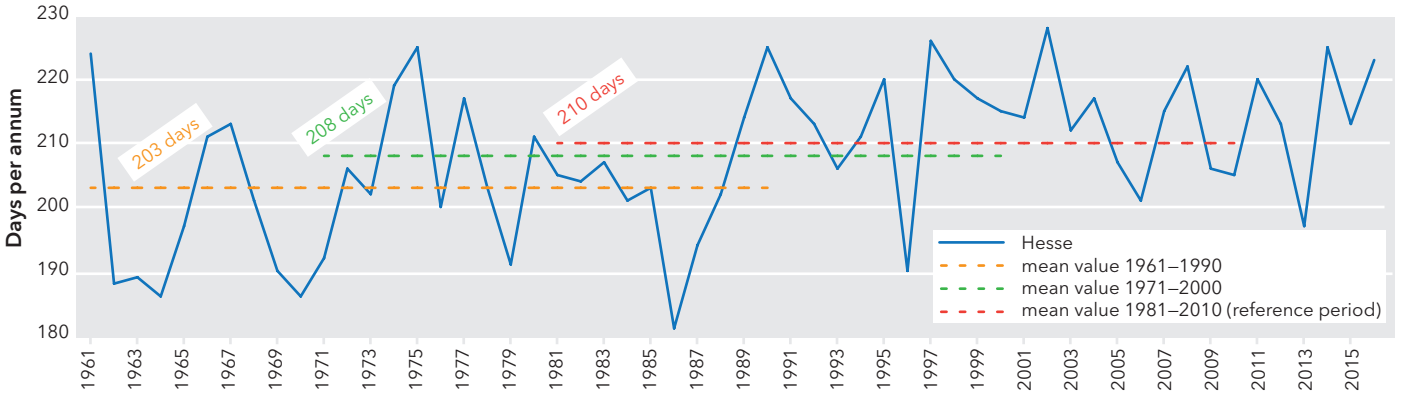
*Willow catkin with a bee © Christian Pedant – Fotolia*

The **duration of the vegetation period** is defined as the time span between the relatively early emergence of flowers in the goat willow and leaf colour change in the common oak as an indicator of late autumn. Choosing the onset of the blooming season of the goat willow allows an approximation to the agricultural vegetation period.

The shortest vegetation period ever recorded in Hesse was 181 days in 1986, and the longest was 228 days in 2002. The onset of the goat willow´s blooming season lay by more than 40 days apart in these two years.

The significant extension of the vegetation period is particularly due to its earlier onset; changes at the end of the vegetation period are less pronounced.

The shift of these phases may affect fruit and wine growing, agriculture and the forests as well as species and biotic communities. It is also conceivable that new forms of competition and interdependency will emerge.

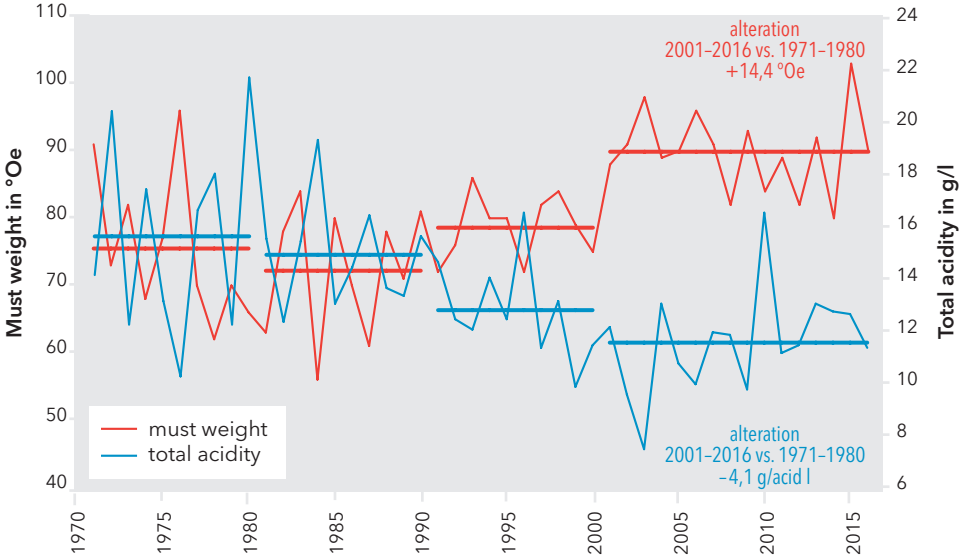



*Duration of the vegetation period. Data source: DWD*

# Challenges posed to viticulture

The impact of climate change has also become noticeable in viticulture – and has important consequences on the wine-growing regions of the Rheingau and Hessische Bergstraße.

**Wine constituents** and cultivated grape varieties alike are affected by climate and can thus be used as indicators for monitoring climate change impacts.

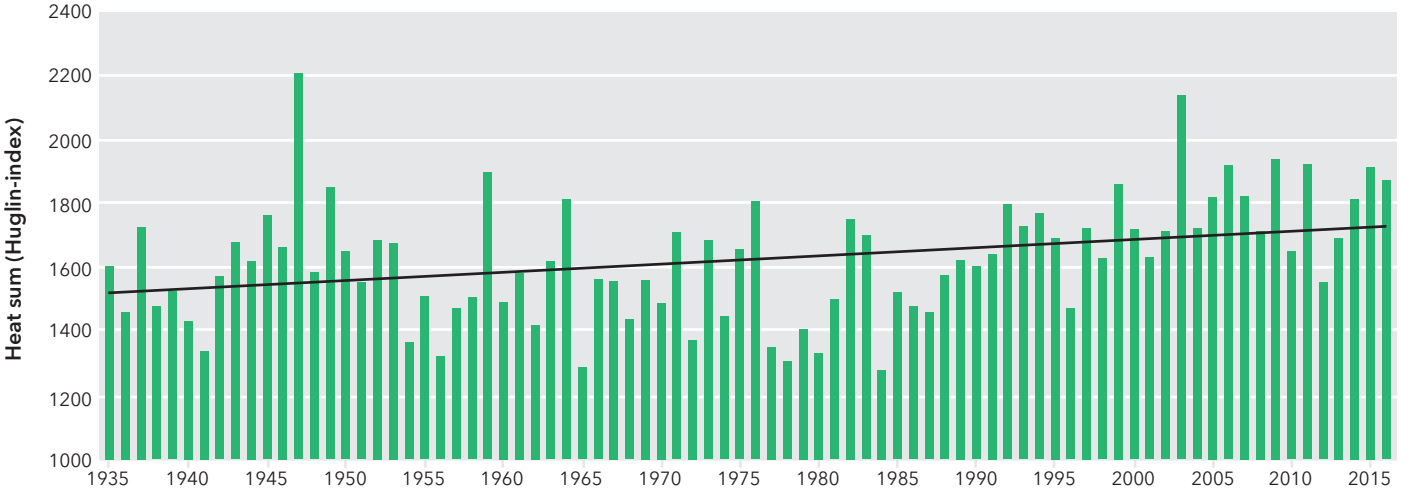



*Wine constituents of Riesling at the time of vintage (reference vineyard „Eltviller Sonnenberg"). Data source: regional council Darmstadt, department of viticulture Eltville; Diagram: L. Grünhage*

Since the 1990s, the ratio of total acid content and must weight has clearly changed owing to warmer climate conditions. At the time of vintage, grapes show lower acidity and higher must weight. In most years, these changes are beneficial; however, winemakers are facing new challenges in wine growing and wine maturing if they want to preserve the typical taste of Riesling wine even in hot years.

## Suitability of grape varieties

One indicator for viticulture is the **varietal suitability** in the Rheingau. A heat summation index (Huglin) serves as a criterion for evaluating the arability of certain grape varieties; for this purpose, the daily mean and maximum temperatures are averaged. If these values exceed the threshold of 10 °C, they are accumulated for the period from 1 April to 30 September of the respective year. However, this index merely specifies the lower boundary for the cultivation of certain varieties. The Riesling, which is typical of the Rheingau, has a Huglin optimum between 1700 and 2000. In unusually warm years, it would have been possible to cultivate varieties requiring higher temperatures like Merlot (optimum 1900–2000) and Syrah (optimum 2100–2200) in Hesse. A positive trend of the heat index has been charted since records began, but particularly so in recent decades.




*Huglin heat summation index for Geisenheim. Data source: DWD*

# Animal health and climate change

The changing climate can also pose a risk to animals. Therefore, one of the indicators deals with **heat stress** and the **health** of poultry. This indicator is deemed to represent animal husbandry on the whole. The combination of high temperature and high humidity in particular causes stress in the animals.

Chickens cannot sweat! At high temperatures in the coop, chickens start panting with their beaks wide open („beak breathing"), indicating a high level of stress.

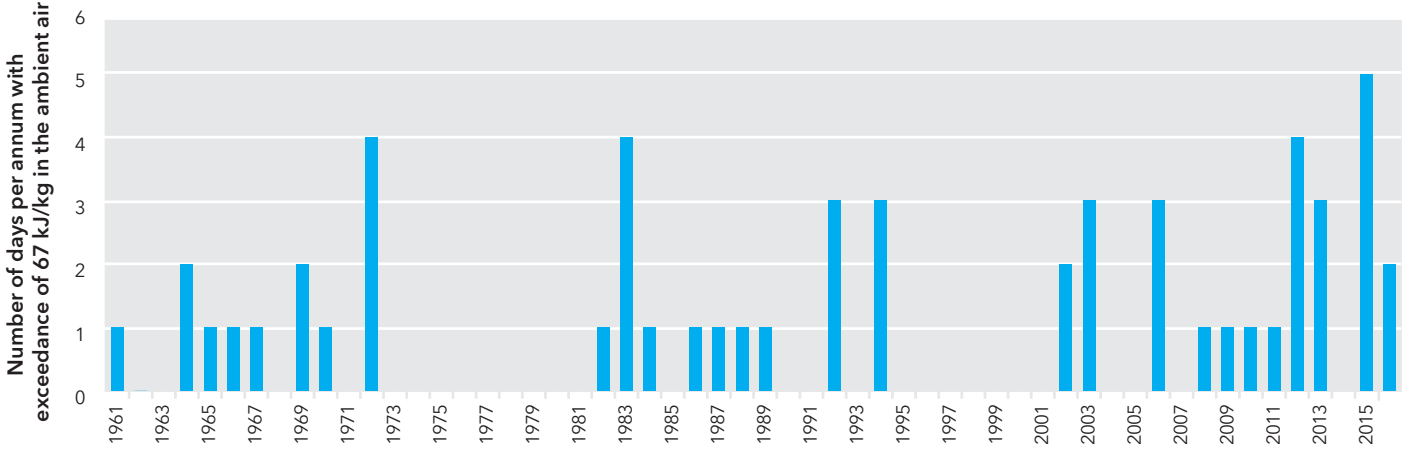
To estimate the effect of temperature and humidity on poultry, the total energy content of the ambient air („enthalpy value") is determined; it is measured in kilojoules per kilogramme (kJ/kg). Starting from a value of 67 kJ/kg (daily maximum), a critical thermal load for poultry sets in, indicating the beginning of heat stress.

Heat stress can usually be prevented by measures like airing, cooling and taking good care of the animals. Even below the guiding value, the wellbeing and health of the animals are at risk; e.g. they lay fewer eggs.

Monitoring temperatures in the coop is important in summer. Farmers can obtain information on the current enthalpy values from the German National Meteorological Service (DWD).

Number of days per annum exceeding the guiding value of 67 kJ/kg in Frankfurt:

There are great regional differences in Hesse regarding the frequency of such exceedance. In Frankfurt, the value has been exceeded on at least one day in many years, and every year since 2008. (In the Rhön Mountains, exceedance of the guiding value on one or two days per year has not been recorded until 2012.)




*Frankfurt / Main. Data source: DWD*

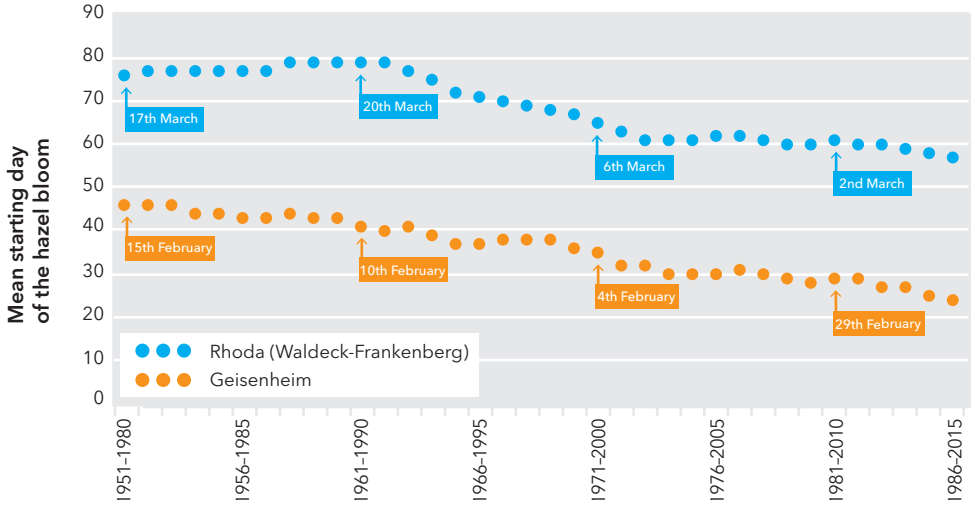
# Health threat due to pollen exposure

The beginning of pollen dispersal, especially in early flowering plants (e.g. hazelnut, alder and birch trees) strongly depends on temperature. With temperatures rising as a result of climate change, an ever-earlier beginning of flowering is evident, leading to altogether longer periods of high pollen count and shorter breaks for allergy sufferers.

The indicator used here is the onset of the flowering time of the common hazel, which indicates **changes in the pollen season**. Besides, significant differences in the beginning of the hazel blossom evidently depend on the station's elevation. Blooming starts significantly earlier at lower altitudes than at higher ones.

The illustration shows the moving 30-year average of the beginning of the hazel blossom in Geisenheim (120 m above sea level) and Rhoda (420 m above sea level).

It is mainly the height difference of 300 m between these stations that gives rise to a gap of more than a month between the onset of blooming.




*Data source: DWD*

*Hazel catkins under snow © hjschneider – Fotolia*

# Forests in danger

In a state like Hesse with more than 42 % of forest cover, the condition of the forests is a matter of great importance.

Warmer summers and longer dry phases mean heat and drought stress for forests, also resulting in a **higher risk of forest fires**.

The risk of forest fires is rated with the help of the Canadian Forest Fire Weather Index (FWI), which is calculated from meteorological components like air temperature, relative humidity, wind speed, amount of precipitation and ground cover. A danger class is allocated to each day from early March to late October (on 229 days altogether), with class 1 indicating "very low", class 2 "low" up to class 5 "extreme" danger.

Along with rising summer temperatures and reduced precipitation during the growing season, a mixture of tree species which are not adapted to the ecological and climatic conditions can also increase the risk of forest fires. Thick pure stands of conifers are extremely vulnerable to fire risk.

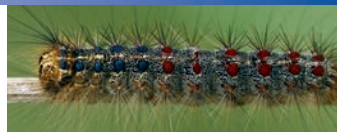
The table shows the average number of days allotted a certain danger class in several 30-year periods. An increase in the number of days with higher danger classes (class 3 to 5) over the last 50 years can be observed; hence, the number of days with a low danger class dropped.

| Days with forest fire warning classes (30-year mean value Hesse) | | | |
|---|---|---|---|
| **Risk of forest fires** | **1961–1990** | **1971–2000** | **1981–2010** |
| Class 1 and 2 | 192 | 186 | 180 |
| Class 3 | 25 | 28 | 31 |
| Class 4 and 5 | 12 | 15 | 18 |

*Data source: DWD*

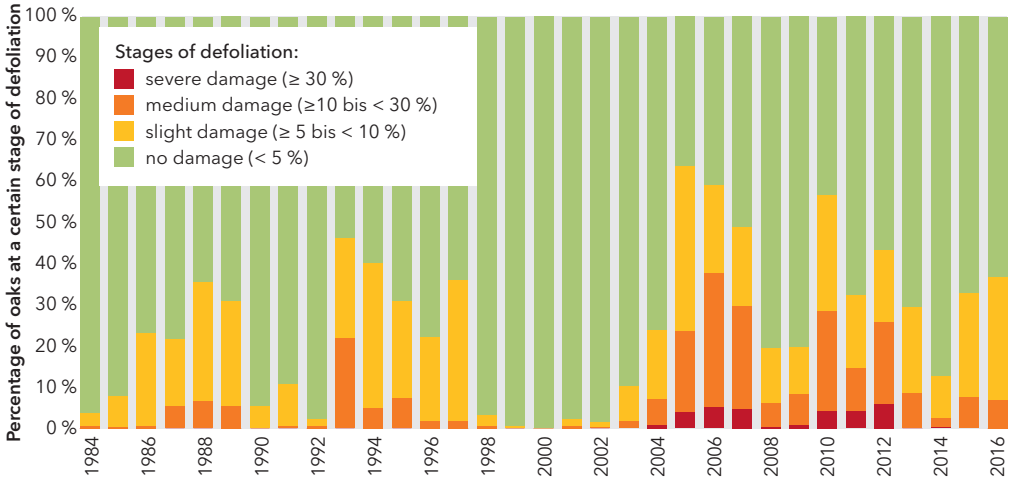
# Damage from insects in forests

Climate change can lead to changes in forest ecosystems. This is also true for the interrelationship between trees and insects. The development and distribution of tree pests can change. The indicator captures the extent of damage to oak leaves caused by the **oak defoliator complex** in the areas of the annual forest condition inventory.



*Gypsy moth*
*© Eileen Kumpf – Fotolia.com*

Winter moth, oak leaf-roller, oak processionary moth and the gypsy moth are thermophilic insects. In the wake of climate change, they might spread and undergo mass propagation more often. Extreme weather conditions like aridity and drought weaken the natural defences of trees and further the development of such insect pests. This might explain the occurrence of high pest populations during the years 2004 to 2007 after the extremely hot summer of 2003, when oaks suffered heavy damage (red areas in the chart). As a result of severe, repeated damage from insects, trees can increasingly die off.




*Oaks damaged by insects of the oak defoliator complex – Percentage of trees at different stages of defoliation (mean value of Hesse). Data source: Hessian forest condition inventory by the Northwest German Forest Research Institute*

# Lichens as indicators of climate change

Lichens have long been observed in Hesse and used as indicators for air quality. They are composed of a fungus and a partner that is able to photosynthesise (e.g. an alga or a cyanobacterium).

All year round, they show extremely sensitive reactions to changing environmental and climatic conditions (temperature, precipitation). This makes them ideal indicator organisms.

Thermophilic species of lichen are increasingly found in Hesse, as evidenced by a larger number of individuals and newly immigrated lichen species. They are representative of further **changes in ecosystems.**

*Punctelia subrudecta is a thermophilic lichen species © U. Kirschbaum*

*Caloplaca techolyta is a thermophilic stone-dwelling lichen © U. Kirschbaum*

Thermophilic species of lichen are quite rarely observed at the permanent observation plots in the Rhön Mountains, the Spessart Mountains and in the town of Melsungen. However, in the towns of Limburg and Biebesheim, and in the Rheingau they have occurred far more frequently in recent years.

Investigations have shown a clear correlation between annual mean temperatures and the abundance of such lichen species. Therefore, they are particularly well suited as indicator species for the variations in temperature resulting from climate change.

# High and low water in Hessian streams

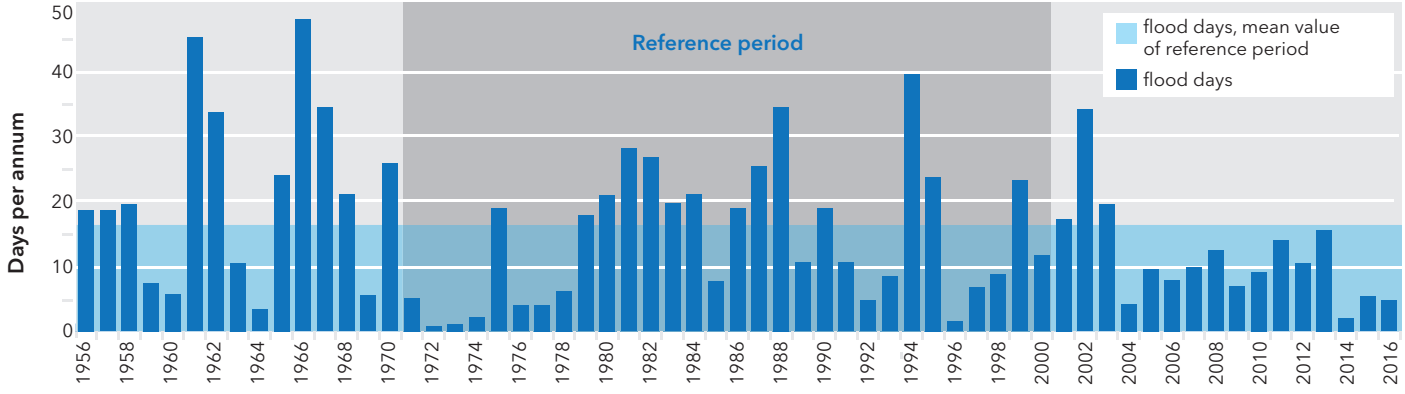
Watercourses are closely related to the climate. **Duration, intensity** and the **dimensions** of high and low water events are used as indicators for change.

The "flood duration" indicator shown here as an example is derived by comparing the number of flood days per year at five representative gauges. The calculation is based on the hydrological year, stretching from 1 November of the previous year to 31 October of the year under consideration.

The chart shows the average flood duration in a hydrological year at the gauges in Bad Hersfeld (Fulda), Bad Vilbel (Nidda), Hanau (Kinzig), Helmarshausen (Diemel) and Marburg (Lahn). The area shaded in blue shows the average number of flood days within the reference period 1971–2000 (reference period with a grey background).

*Flood duration as the mean number of flood days per annum (Mean value of five selected gauges).*

*Data source: HLNUG*



*Flood in Frankfurt in January 2011. It was triggered by the sudden melting of the extensive snow cover as a result of a sharp increase in temperature and the beginning of rainfall.*

# Understanding climate change impacts: conclusions

The indicator-based monitoring of climate change impacts in Hesse provides a good opportunity to detect the emerging impact of climate change at an early stage.

Some developments are already noticeable and can be directly observed "on the door step", as it were. Examples include the earlier beginning of flowering of fruit and hazelnut trees.

For some areas, it is now very clear that we need to act: Walkers in the woods are cautioned against the danger of forest fires by means of weather alerts provided by the DWD, and farmers are made aware of the impact of heat stress on their animals!

Some indicators taken into account are still clouded with uncertainty as regards the direction of future development. Hence, it is e.g. not yet possible to come to a definite conclusion as to changes in frequency of high and low water in Hessian rivers.

Therefore, further monitoring as well as the development of additional indicators are of great importance.

**Further information on the climate in Hesse is available on our German websites:**

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

**http://atlas.umwelt.hessen.de**

**You can also find English information on research projects:**

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


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

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