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

HESSEN

Agriculture, Forestry and Climate Change



Climate Change in Hesse

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Foreword

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

Climate change affects our environment already today and will do so even more in the future. Therefore, forestry, agriculture, fruit and vegetable growing, as well as viticulture must adapt to the changing climate.

Will beech and spruce continue to be the typical forest trees in Hesse? Will we still be able to grow the same field crops? Will crop yields remain stable? Will we need more or less fertiliser, or additional irrigation? And what are the effects of climate change on special crops such as vegetables, fruit or wine?

All these questions determine the look of our landscape today and in the future and how we will be able to use it.

This brochure presents the results of research into these questions.

Further information is available on the websites of the HLNUG.

Introduction

More than 40 % of the Hessian land surface are covered by forests, and another 40 % are used agriculturally. This is why Hesse is very strongly characterised by these types of land use.

The hilly landscape in many parts of Hesse with its fields, meadows and woods, which are often rather small in comparison to the national average, is a characteristic cultural landscape.

The Hessian uplands are home to large wooded areas which – apart from timber production – are frequently used by many Hessians as recreation areas, hiking trails or for sports. Fruit and wine growing define special landscapes and yield regional products of high recognisability – e.g. cherries from North-East Hesse, apples from the meadow orchards of the Wetterau, wine from the Rheingau and the Hessian Bergstraße, or asparagus from the Hessian Ried.

Agriculture and forestry are particularly affected by climate change, but they can also help to mitigate climate change. Well-thought-out strategies for climate change adaptation will be necessary to successfully carry on with this way of land use.

The effects of climate change on livestock farming (e.g. availability of animal feed, animal diseases, heat in barnstables) are not discussed in this brochure.

Plants already respond to climate change

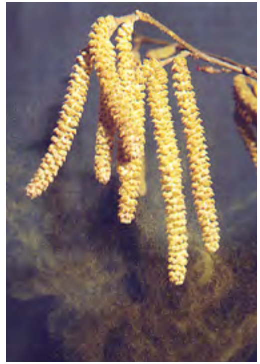
Plant phenology describes the change of seasons based on periodic developmental stages in plants. Different developmental stages of selected plants are used to identify the so-called phenological seasons. The onset of spring (green) is indicated by the blossom of the hazelnut tree, the beginning of summer (red) by the elder blossom, and the phenological autumn (yellow) commences with the ripening of elderberries. The dormant period (blue) already starts in late autumn which is indicated by the leaf colour change in the common oak.

The right-hand illustration shows a phenological clock: The phenological seasons are arranged in a clockwise manner. There is already a distinct change in the mean starting dates of the phenological seasons in Neukirchen (Knüll) between 1951–1980 (outer colour ring) and 1981–2010 (inner colour ring). Spring and summer begin significantly earlier nowadays resulting in shorter dormant periods: these decreased from 129 days (1951–1980) to 116 days (1981–2010).

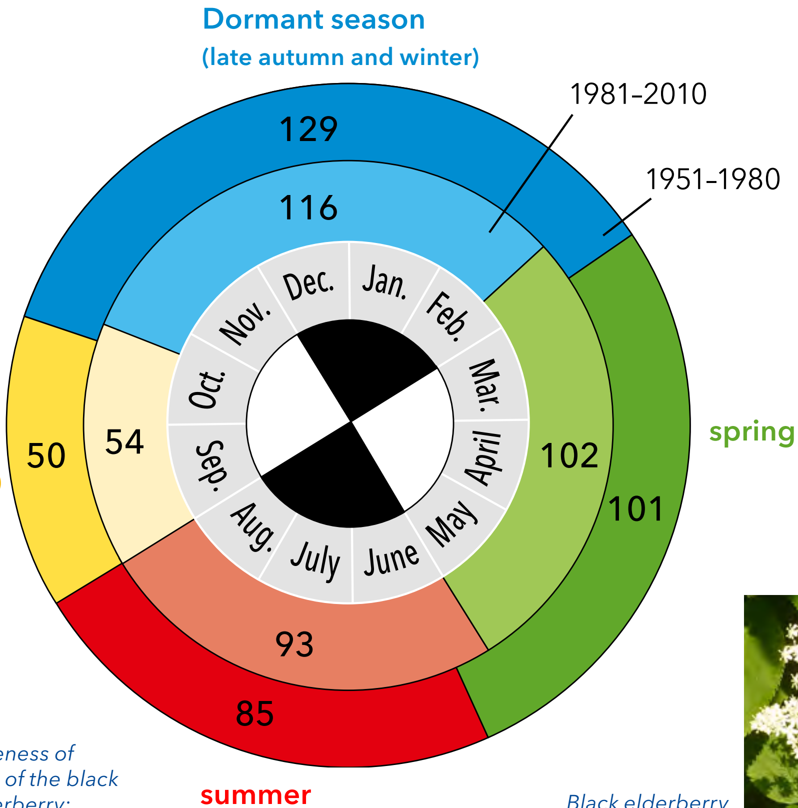
Similar changes, often even more pronounced, can be found throughout Hesse: In Geisenheim (not illustrated), the dormant period shortened by 31 days within the same stretch of time – from 124 to 93 days.

Volunteer observers form the backbone of the phenological monitoring network of the German National Meteorological Service (DWD). There were 96 observers in Hesse in 2014. The DWD is looking for passionate people throughout Hesse who are ready to take on this task. Photo © L. Igiel

Leaf colour change in the common oak: Onset in late autumn (dormant period). © L. Grünhage, Gießen University



Hazel blossom: Beginning of spring. © German National Meteorological Service



Ripeness of fruit of the black elderberry: Beginning of autumn

Black elderberry blossom: Beginning of summer

Phenological clock for Neukirchen (Knüll). The outer colour ring shows the phenological seasons for the period 1951–1980, the inner one for the period 1981–2010. Source: Prof. L. Grünhage, Gießen University

Forestry

In a commercial forest, trees often live for more than 100 years. Therefore, forests have to cope with existing environmental conditions for a long time, with soil and climate in particular. If site conditions change, the forest must adapt and is herein supported by forestry. The effects of climate change on Hessian forests were investigated in several studies in collaboration with the Northwest German Forest Research Institute (NW-FVA).

The area of deciduous forests in Hesse has increased to 59 % thanks to silvicultural measures. About half of these forests is made up of the common beech, which is typical of Hesse and therefore especially beneficial to the natural forest stand. The area of mixed forests has also increased. On the other hand, the percentage of coniferous trees has decreased. However, many wood products require the use of coniferous wood.

Hesse is located in the centre of the natural habitat of the beech. Its distribution is mainly limited by low soil water availability, drought at the beginning of summer, continental climate as well as extreme temperatures.

Limiting factors such as the ones outlined above are particularly likely to be seen more frequently with ongoing climate change, and they can lead to reductions in tree health and growth.

An increase in temperature in early summer can boost flowering and fructification in the beech trees ("beechnuts") in the following year. Hence, there is a delay between cause and effect. Beech trees do not usually develop fruits every year. However, there has been an increase in the frequency and intensity of beechnut formation in individual trees over the last decades.

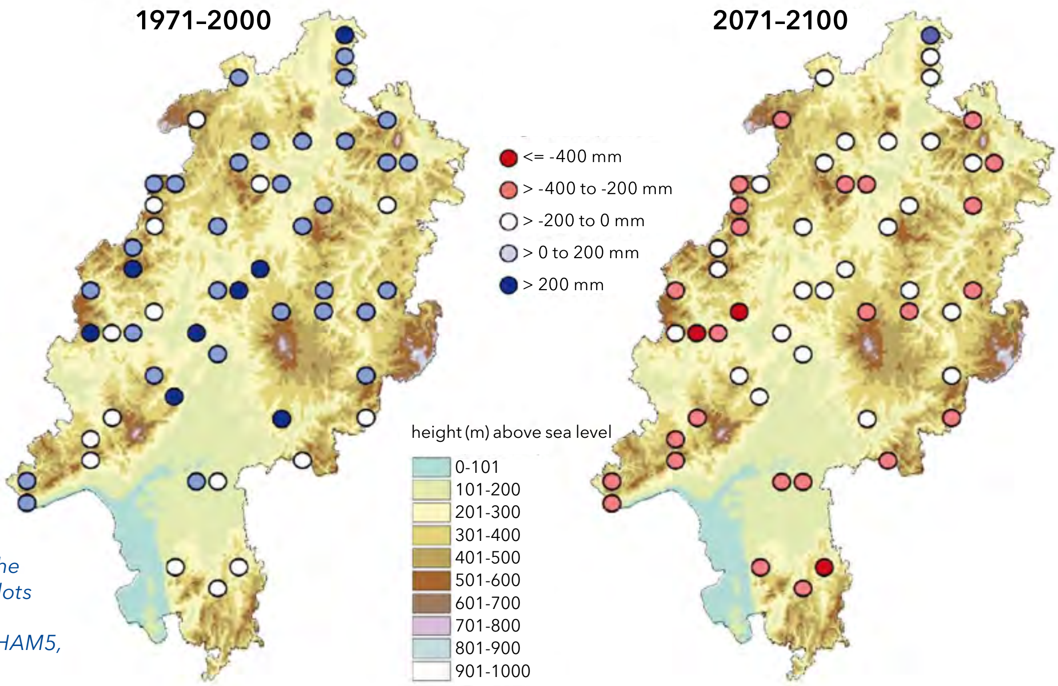
The formation of beechnuts is the prerequisite of a natural regeneration of the beech stands. However, an increase in fructification comes at the cost of the growth of trunks and roots.

Another question is whether and to what extent increased fructification impairs the vitality of the beech. This has been closely observed in Hesse since 1984 in the monitoring network on the forest condition inventory and soil condition inventory (BZE). In recent years, however, no beech trees have died off at these observation plots; Hessian beech forests are currently stable.

Beechnuts. © NW-FVA

However, this situation will change in the wake of climate change. Research findings on past extreme years indicate that beech trees are particularly sensitive to a succession of very warm and dry years. Such series of years of drought stress are expected to occur much more often in the future.

The maps show the regions with an increase in drought stress years (red dots) for the beech until the end of the century, based on climate model results.



Climatic water balance + usable field capacity in the vegetation period of the 55 Hessian beech-BZE observation plots for the climatic cycles 1971–2000 and 2071–2100 (climate model CCLM/ECHAM5, Scenario A1B). Source: NW-FVA

Climate change not only impacts tree growth, but also changes the conditions for insects and fungi living on and with the trees. Here again, the combination of various damaging factors is critical. If, for instance, older beech trees stand alone in sunny areas, they are particularly exposed to increased drought. This can foster beech borer infestation and rapidly deteriorate tree health. This kind of damage was found in particular after the extremely dry vegetation period in 2003.

Similar effects have been observed in the spruce tree. Increased warming favours the propagation of bark beetles, which can seriously harm the spruces in Hessian forests in warm and dry years.

Climate change threatens to overburden possible forestry adaptation measures.

Nonetheless, forest management must do everything possible to increase the forest's resilience against these risk factors. This includes regeneration practices favouring the development of mixed forests, and nursing and harvesting activities supporting tree vitality.

Beech tree damage caused by beech borer infestation. © NW-FVA

Agriculture

Climate change can cause serious damage to agriculture. Apart from the ongoing increase in temperature, harvests are particularly jeopardised by the higher year-to-year variability of spring temperatures, the shift of precipitation from summer to winter and the rise in the frequency and intensity of heavy rainfall events. Research has shown that yield stability will decrease with ongoing climate change if today's field crops and agricultural practices are maintained.

At the same time, agriculture offers the possibility to limit climate change. Plants take up carbon dioxide (CO_2) from the atmosphere and capture the carbon in their biomass. After the harvest, part of the biomass remains in the soil and thus contributes to the storage of carbon. The type of crop and soil management determine to what extent soils take up or emit greenhouse gases (GHG).

Agriculture strongly depends on the weather in the respective year. The weather conditions of each individual year must be taken into account as best as possible not only for sowing and harvest times, but also for fertilisation. If fertiliser is used too early or too late, or if it does not rain for a long time after fertilisation, the nutrients contained in the fertiliser cannot be used by the plants for growth. If fertiliser is administered incorrectly, there is a risk of nitrogene (contained in the fertiliser) leaching into the groundwater and thus impairing the water quality.

To ensure an optimal supply of agricultural crop plants (e.g. cereal, potatoes) with nutrients under climate change, a research project aims at optimising the use of fertiliser in terms of amount and timing.

Grassland farming

Compared to farmland, grassland used for mowing and grazing has a better greenhouse gas balance (GHG balance), because the soil is never ploughed and the biomass of the grass roots remains underground.

To investigate the impact of an elevated CO_2 concentration in the air on plant growth, among other things, the HLNUG has been operating the Environmental Monitoring and Climate Impact Research Station Linden in collaboration with the University of Gießen since 1993.

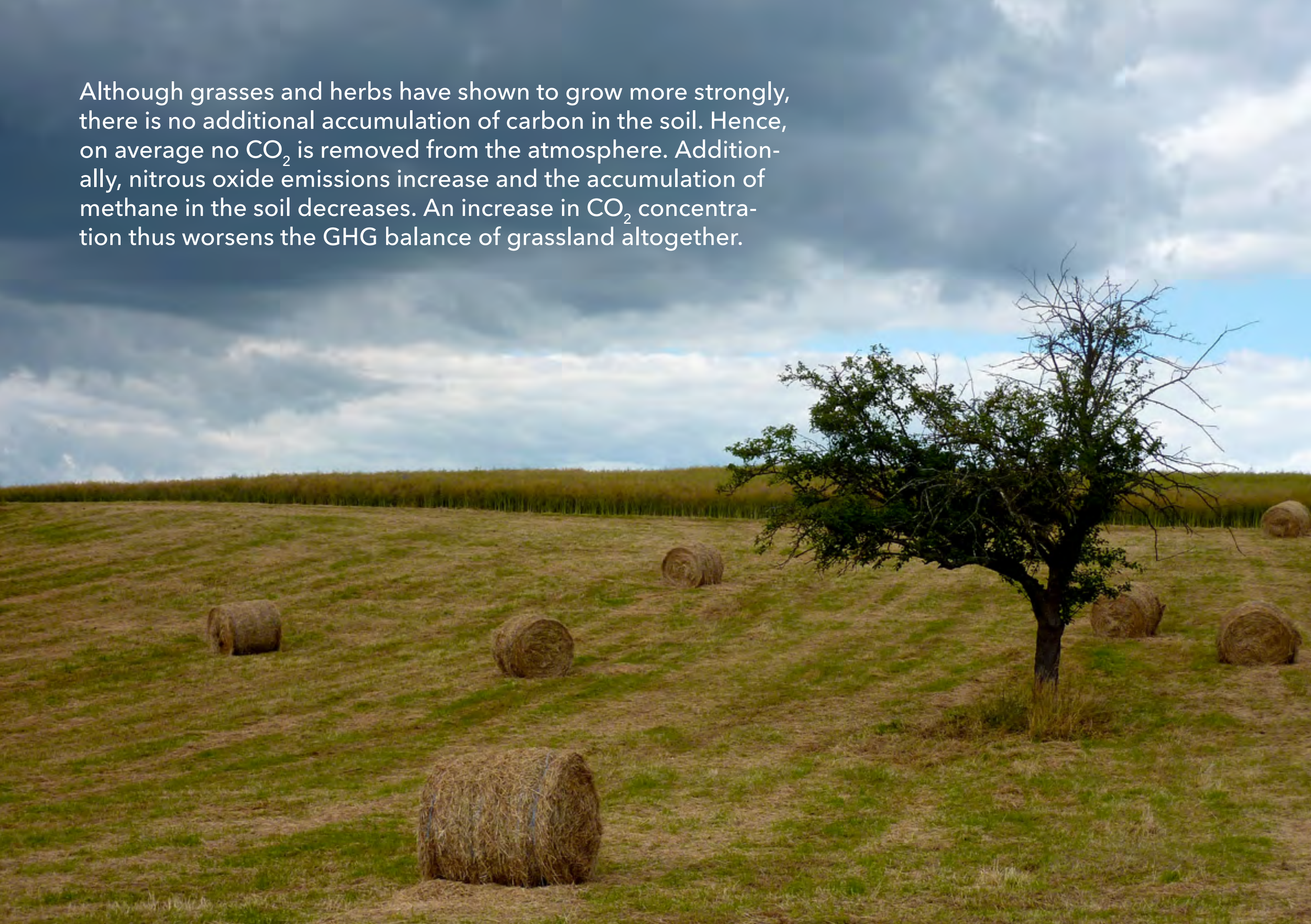
Plants grow by binding CO_2 from the air. This process is called photosynthesis.

In so-called "free air CO_2 enrichment rings" (see illustration below), additional CO_2 is released in the air above the grassland in order to find out:

- whether plants grow faster,
- whether their compounds change,
- whether some plants (e.g. grasses) grow more strongly than others (e.g. herbs)
- and whether or not the GHG emission of CO_2, nitrous oxide and methane contained in the soil (e.g. through microbial decomposition of dead plant material) change.

In three experimental rings CO_2 is added to the air within the ring, depending on the wind direction. By this, CO_2-concentration inside the rings is increased by 20 % (as expected for 2040–2050, approximately). Three control rings without additional CO_2 fumigation serve to compare the results with the current conditions. © L. Grünhage, Gießen University

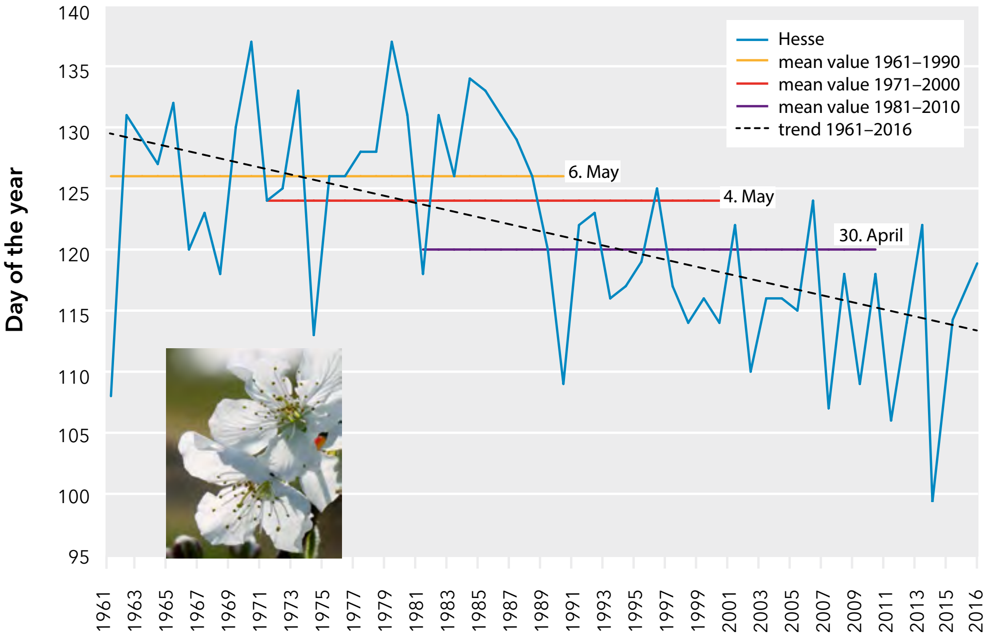
Although grasses and herbs have shown to grow more strongly, there is no additional accumulation of carbon in the soil. Hence, on average no CO_2 is removed from the atmosphere. Additionally, nitrous oxide emissions increase and the accumulation of methane in the soil decreases. An increase in CO_2 concentration thus worsens the GHG balance of grassland altogether.



Fruit growing

The increase in temperature causes fruit trees to bloom much earlier on average. The illustration below shows the annual onset of the apple blossom from 1961 to 2016. The mean values over 30 years (horizontal lines) show how much earlier the apple blossom has already become.

Recent research has shown that the risk of late frost events is likely to remain virtually unchanged in the future. Plants start flowering earlier in early spring due to the higher temperatures. Therefore, frost events can still occur during flowering.



Beginning of the apple blossom in Hesse, 1961–2016. In 2014, the apple blossom in Hesse began as early as April 9th (day 99)! Data: DWD; Photo: © F.-M. Chmielewski, Berlin University

The harvest time also sets in earlier for some varieties, although not quite as much as the time of flowering. The entire development period of woody plants has thus moved forward.

In addition, many fruit cultures need a cold stimulus in winter before new shoots can emerge in early spring. Different species and varieties have different cold demands. Higher temperatures in the dormant period resulting from climate change may lead to the effect that the cold demand of cultures is impaired or remains completely unsatisfied. Most fruit trees will still meet their cold demand in most years until the end of the century. However, some strawberry varieties are already suffering from unusually mild winters (e.g. 2006/2007 and 2013/2014). If they do not receive the necessary cold stimulus in winter, their flower stalks remain too short and their fruits too small. Such mild winters are likely to become the norm by the end of the century.

Climate-change-induced increases in summer drought must be counteracted by means of irrigation. The "fertilisation" through additional CO_2 from the atmosphere boosts fruit growth.

© L. Grünhage, Uni Gießen

The warming climate will likely increase the abundance of certain insect pests. Between 1971 and 2000, the apple codling moth used to produce only one generation – or at most a second partial generation a year. Until the end of this century, it will be normal for the apple codling moth to produce a full second generation, sometimes even a partial third one. This will lead to an increase in damage so that additional control measures will be necessary.

The apple codling moth. © O. Leillinger, Wikipedia

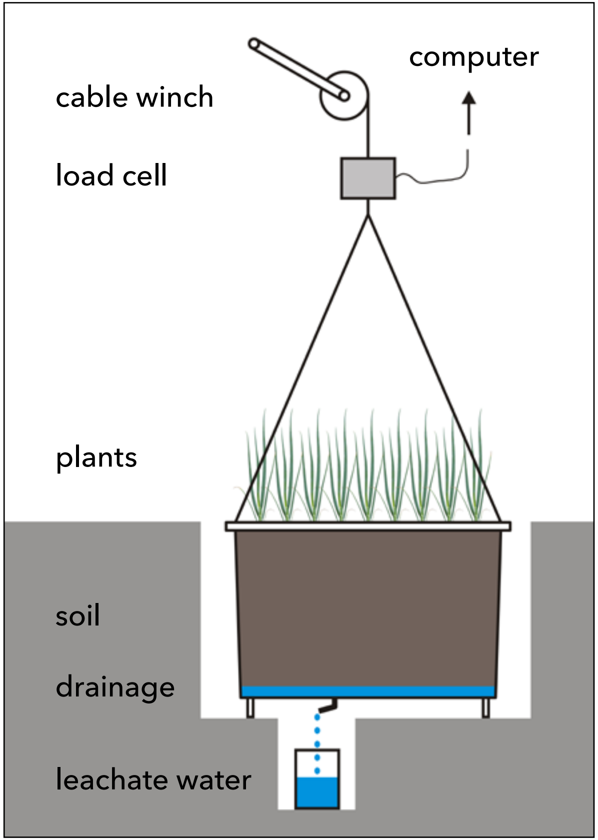
A bee on an apple flower. © F.-M. Chmielewski, HU Berlin

Bees only fly at daytime, at temperatures above 5.4 °C, if there is no rain and not too much wind. Due to warming climate conditions, the fruit tree blooming period starts earlier, and the bees also start flying earlier in the year. However, the earlier in the year, the shorter the days are. Thus, a bee can pollinate fewer flowers per day than at a later time of the year. The impact of climate change on bee flight activity and pollination must yet be looked into more thoroughly, since further aspects (e.g. how many bees usually die over the winter) have not been taken into consideration so far.

Vegetable growing

The majority of the crops grown in the Hessian Ried are special crops, particularly asparagus, onions and bush beans. 96 % of the agricultural area in the Hessian Ried are already irrigated these days. Climate change causes the precipitation to shift from summer to winter. This may not only lead to an increase in demand for summer irrigation, but also to an increased risk of nitrate (from fertilisers) leaching into the groundwater, which in turn results in a deterioration of the water quality.

A research project investigated the effects of climate change on the cultivation period, irrigation demand and nitrate leaching in vegetable growing. Measures suitable for water supply, efficient water use and groundwater protection were derived from simulations and plant growing experiments.



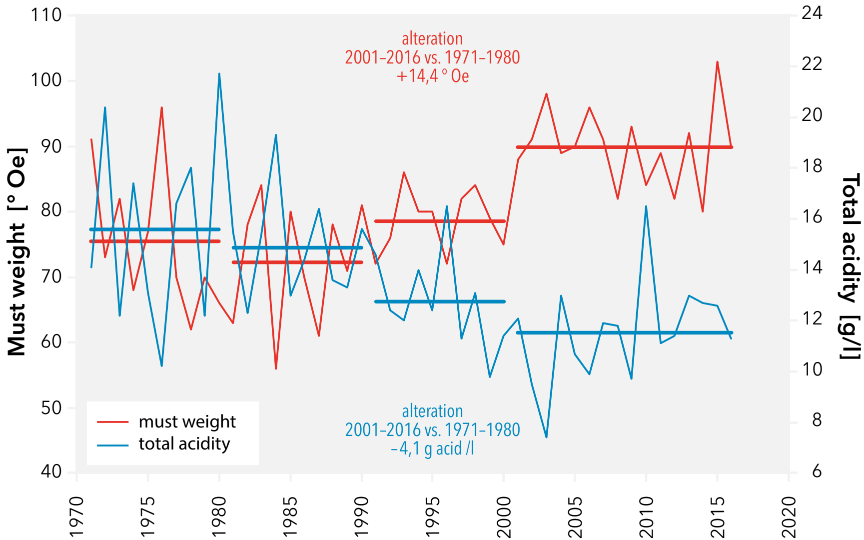
An irrigation test using onions in a lysimeter serves to investigate the impact of a future precipitation shift on plant development, yield, water demand and nitrate discharge into the groundwater. © N. Mayer, Hochschule Geisenheim University

Viticulture

There hardly seems to be any other food or beverage where the product quality is as widely discussed as the quality of wine. Two of the most important grape constituents determining the character of a wine are the sugar content (the must weight expressed in degrees Oechsle influencing the alcohol content of the wine) and total acidity. Both are influenced by the climate and hence also by climate change.

The relatively cool climate in German wine-growing regions is particularly suited for the local grape varieties – although the quality of the wines has indeed benefited from the warming so far. The combination of location characteristics, climate and grape varieties forms the basis of typical regional wines that are Germany's unique contribution to the global wine market.

With ongoing climate change, the characteristics of our typical wine can noticeably change.



Alterations in must weight (red, ° Oe) and total acidity (blue, g/l) from 1971–2016 in the Riesling wine at the Eltviller Sonnenberg. Data: Department of viticulture, Darmstadt Regional Council. Diagram: L. Grünhage, Gießen University

Today, budding in Eltville ("Sonnenberg" vineyard) takes place about 7 days earlier than in the past 40 years on average; flowering begins 10 days earlier, and the beginning of grape harvest has already advanced by 13 days.

From a viticultural point of view, such early development is particularly relevant to the onset of ripening (time of veraison), which takes place under much higher temperatures. This has an impact on the formation of wine constituents. In addition, the development of grape rot is favoured in warm and moist years.

The extremely hot and dry year of 2003 resulted in a shortening of the ripening stage, an unusually early timing of grape harvest and wines that were low in acidity and rich in alcohol. Therefore, the Riesling of this vintage did not show its usual freshness and lightness. Long periods of drought can cause formation of uncharacteristic flavours especially in white grape varieties. On the other hand, a wide range of outstanding red and also white wines was produced in that year.

Piety column Regina, Eltville
© A. Booß, RP Darmstadt

Conclusions

Climate change poses a serious problem to the Hessian agriculture and forestry. Today, plants already show earlier times of flowering and ripening.

The beech trees in Hessian forests are still coping with the changing climate. However, several consecutive years with high levels of summer drought stress can put a heavy strain on beech trees in the future. Forestry measures aim to support forests in adapting to climate change and increase their resilience against the impacts of climate change.

Increased CO_2 concentration in the air has a fertilisation effect on plants. But according to current knowledge, a possibly higher productivity in the future will not lead to a reduction of the greenhouse effect as, for example, microorganisms in the soil become more active and thus produce more greenhouse gases when temperatures continue to rise.

As a result of the increase in temperature, the cold demand of some fruit varities may no longer be met by the end of the century, which in turn would lead to insufficient vegetation rests. The risk of late frost events in spring will remain about the same, since higher temperatures in early spring are compensated by an earlier blooming season.

Another effect of ongoing climate change is the increase in the abundance of pest insects, such as the apple codling moth, beech borer and bark beetle.

In viticulture, red wines can benefit from higher temperatures, but the Riesling in particular might lose its characteristic freshness owing to warmer and drier summers.

Further information is available on the websites of the HLNUG:

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