Ministerium für Klimaschutz, Umwelt,
Landwirtschaft, Natur und Verbraucherschutz
des Landes Nordrhein-Westfalen

2016 Environmental Report
North Rhine-Westphalia

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2016 Environmental Report
North Rhine-Westphalia

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Minister Johannes Remmel

The 3.3 factor – the goal and prospects of sustainable lifestyles in North Rhine-Westphalia

Dear reader,

Our state's Environmental Information Act (Umweltinformationsgesetz) requires that North Rhine-Westphalia publishes regular reports on the state of the environment. The 2016 Environmental Report for North Rhine-Westphalia fulfills this statutory requirement and presents an extensive new ecological survey of our state on the basis of current data material, thorough individual analyses and both national and international political frameworks. This new ecological survey has been carried out with three objectives in mind: observing – forming an opinion – taking action.

Observing: Just like its predecessor, the 2016 Environmental Report for North Rhine-Westphalia is a "monitor." In short: It shows the state of our environment and how it changes over time. Environmental reporting is at its center. It portrays North Rhine-Westphalia's ecological situation in four main categories and principal conservation interests: (1) climate, energy and efficiency; (2) environment and health; (3) waste, soil and water; and (4) nature and rural areas. At the same time, the report makes use of a navigation system that is just as proven as it is reliable: the state's "environmental indicator sets." These include, for example, the environmental indicators "greenhouse gas emissions," "noise pollution" and "land consumption," as well as the new indicators "biodiversity and landscape quality" as well as "surplus nitrogen on agricultural land." Many of the indicators comply with official standards and are now established in the indicator set of the German Environment Ministers' Conference and/or the German Strategy for Sustainable Development, but some of them have been especially customized to reflect the specific situation in North Rhine-Westphalia. The environmental indicator set can be used to record and analyze both the current state of the environment as well as changes, trends and objectives in the areas under consideration. Another "monitor" – and for the first time at that – is North Rhine-Westphalia's "ecological Footprint." By including the Footprint in its environmental report, our state is leading the way for the German

“What we see and the findings and imperatives we derive from it will only help if they enable and unleash practical action.”

states. In very simple terms, the ecological Footprint provides an answer to the following question: How large is the piece of “earth pie” that each person claims de facto to lead their lifestyle and how many pies would we actually need if everybody in the world claimed a piece that was just as large for themselves? At this point, I would like to reveal the central insight of the ecological Footprint for our state: In 2012, it would have taken 3.3 earths for everybody on the planet to lead the same lifestyle as the inhabitants of North Rhine-Westphalia. This brings me to the second objective of the 2016 Environmental Report for North Rhine-Westphalia that I mentioned at the beginning: forming an opinion – that is: carrying out an analysis geared toward taking action. As we know, there is no second earth and we certainly do not have 2.3 earths tucked away in reserve in addition to our current one. We only have this one and only earth, the one we are accustomed to and that we have been entrusted with, which means that the following realization is a confronting one: Each North Rhine-Westphalian consumes too much of the planet’s resources – seen in terms of the entire planet Earth – by a factor of 3.3. If it remains this way, it will – once again, translated onto a global level – inevitably lead to a medium to long-term planetary burnout. The first indications of this cannot be overlooked: Climate change arrived in North Rhine-Westphalia a long time ago; we are consuming far more water, air and soil than is ecologically sustainable; biodiversity is decreasing; and ecological waste is endangering human health in a myriad of ways. This Environmental Report provides us with extensive insights into these complex issues and indisputable risk potentials and shows us the only logical solution, which is transforming the risky over-use quotient of 3.3 into an “sustainable one” – that is, a real correlation between each individual’s use of the earth and the earth’s objective supply at a ratio of 1:1. The key findings of the environmental report can be summarized as follows:

- Climate change has become a reality in North Rhine-Westphalia. An increase in the mean annual air temperature is as good as to be expected, even if the state does implement the objectives agreed to in the United Nations climate agreement. It is up to us humans to limit climate change to an at least partially tolerable level.
- Particulate matter pollution with particulates smaller than 10 micrometers is in decline; EU emissions allowances have been complied with everywhere since 2014. Nitrogen dioxide concentrations in the urban background are also in decline; nevertheless, 31 municipalities are exceeding the annual EU emissions allowance.
- High amounts of industrial mercury pollution – there were roughly three metric tons in 2012 alone – are forcing decision makers to make further policy adjustments. By comparison, new dioxin pollution has sunk to 10% to 20% of 1980s levels.
- Traffic noise remains a serious challenge. A good 1.4 million people are being subjected to night-time noise levels higher than 55 decibels; of those, approximately two thirds live near very busy roads.
- Even if land consumption has slowed down in the last few years, it is still progressing. In 2015, an average of nine hectares – the equivalent of about 13 football fields – were transformed into settlement and traffic areas every day.
- New mapping of domestic waters has shown the first positive effects of renaturation efforts. However, only a fraction of surface waters and only 60% of groundwater bodies are in a "good status."
- The species diversity and landscape quality situation is far from ideal; there has been a significant negative trend with regard to agricultural land. Flora and fauna are endangered: 45% of the state's plant, fungus and animal species are on the Red List.
- The proportion of deciduous trees in forests has increased to the benefit of mixed forests. According to 2016 Forestry Report, 28% of forest trees did not display any crown damage and were deemed healthy, 43% displayed weak crown damage and 29% significant crown damage.
- A federal comparison has shown that the nitrogen surplus on agricultural land was exceptionally high in 2014 at 93 kilograms per hectare. Only 13% of the agricultural landscape was of high nature value, which, for example, contributes to biodiversity with species-rich grassland.

The third objective of the 2016 Environmental Report is ultimately geared toward taking action: What we observe, the conclusions that we draw and the obligations that arise from it will only help if they enable and unleash practical action. But this gives rise to a widely discussed dilemma: Many say that the gap between our knowledge of what is and our knowledge of what is necessary is wider today than ever before. If this were true, the famous sentence of the English philosopher Francis Bacon "knowledge is power" would be reversed into its opposite: Knowledge would be powerlessness or could at the very least provoke fatalistic feelings of hopelessness in the face of the way the world is going. Even the knowledge that we have about the state of North Rhine-Westphalia that is condensed in the Environmental Report at hand would fail to trigger change and would instead contribute to saying a premature farewell to a future in which everybody is able to thrive in a world worth living in. But this is not what this report wants to be – by no means. And this is not what it is either – quite the opposite! By laying out how things are, it shows what is possible and encourages action: "But where danger is, deliverance also grows", as Friedrich Hölderlin once said.

In the last few years, the State Government has set the statutory framework for successful climate change policy with its Climate Protection Starting Program, the Climate Protection Act and the Climate Protection Plan. With its Biodiversity Strategy, the State Nature Conservation Act (Landesnaturschutzgesetz) and the State Water Act (Landeswassergesetz), it is providing our valuable natural heritage with effective legislative protection. In 2016, the state government adopted the North Rhine-Westphalian Sustainability Strategy, creating a framework for sustainable development within the state and the implementation of the UN's global Sustainable Development Goals. The Environment and Health master plan is establishing a systematic connection between a pristine environment and the preservation of human health as the highest good. By promoting agriculture and the production and distribution of food in a way that is fair to the climate, animals, the environment and consumers, the State Government is helping to create a link between generating food and appreciating its value and making it sustainable. With its Green Economy Strategy (Umweltwirtschaftsstrategie), the state is supporting the economic potential of the ecological transformation of North Rhine-Westphalia as an industry and energy state. Beyond the rigorous debate between critics and proponents of growth, it is showing that: It's not about more or less – it's about doing things differently: living differently, doing business differently, producing and consuming differently, getting from A to B differently. It is about doing all of this in a way that ensures that everybody in our state should and can get a taste of this single earth pie while making sure that every other of Earth's inhabitants can also enjoy a piece that is just as large. This includes those who haven't been born yet but already have a human right to their piece, especially seeing as they are not yet able to assert this right. The 2016 Environmental Report for North Rhine-Westphalia is a guide for living ecologically: By putting its trust in the ability of individuals and society as a whole to learn and to change, it describes what is, what should be, and what we have to do. It reinforces the "imperative of responsibility" according to Hans Jonas. And it is an expression of the vitality of our democratic community, in which free citizens strive openly and fairly to help the world to find its way toward a good future – in difficult times, this is not the smallest service that this report can render to our state and its citizens.

For this reason, I would like to thank everybody who was involved in the creation of this 2016 Environmental Report for North Rhine-Westphalia. I thank the two authors, Dr. Mathis Wackernagel and Dr. Paul Becker, who have enriched the report with their extremely topical contributions. And I am delighted that I am able to present you with this shortened English version the 140-page German Environmental Report, highlighting the international dimensions of the tasks before us. Because it is clear: North Rhine-Westphalia is not an island. And the future that we have been called upon to work toward is everybody's future.

Your Johannes Remmel

Minister of the Ministry for Climate Protection, Environment,
Agriculture, Conservation and Consumer Protection
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Dr Mathis Wackernagel

Measure What You Treasure: From the global Ecological Footprint to that of North Rhine-Westphalia

Dr Mathis Wackernagel is the President of Global Footprint Network with its headquarters in Oakland, California. He created the Ecological Footprint together with William Rees. After studying engineering at ETH Zurich, he completed a PhD in Community and Regional Planning in 1994 at The University of British Columbia in Vancouver, Canada. He researches and teaches throughout the world, advises governments and non-governmental organizations, and has authored numerous essays and books.

We go to the refrigerator and it's full. Our shopping centres are even fuller, with an overwhelming range of products. And at the holiday party, the conference dinner or the hotel breakfast, there is the infinitely inviting buffet. It takes everything we have to convince ourselves not to have another croissant, another salmon roll, another sausage or some more Black Forest cake. We fight against the temptations of constant excess – but in reality our global resource situation looks very different. This excess goes hand in hand with the global overexploitation of our planet. How exactly? And what does it mean for us?

It's easy to measure things in terms of money: Every company listed on the German Share Index (DAX) has a market value, every public transport ticket has a fare, every commodity has a price tag. But what is the cost of our need for the goods and services that we produce and consume daily, in another, crucial currency – that is, environmentally? The answers to these questions enable us to carry out a kind of ecological accounting. We call it the Ecological Footprint. This kind of accounting provides answers to fundamental questions: How much nature do we need, and how much do we have? We measure nature's supply on the basis of its biologically productive land area – its biocapacity. What is the world's biocapacity? What is Germany's or North Rhine-Westphalia's share of it? The Footprint is the demand we place on nature. It provides us with answers to questions such as: How much biocapacity does it take to provide us with everything that we use in our lives?

Obviously, this kind of resource accounting does not measure every aspect of sustainability, but it illuminates a necessary, quantitative bottom-line condition for sustainability: how much a state, a nation or humanity requires overall in comparison with what nature can regenerate. This kind of knowledge is crucial for understanding a population's sustainability situation. This is why North Rhine-Westphalia chose to focus on examining the overall demand it places on nature, and called in an international team of scientists from Global Footprint Network to measure its Footprint.

Global Footprint Network
www.umwelt2016.nrw.de/001

> "We at Global Footprint Network are convinced that it is possible for everybody on this planet to thrive. But in order for that to become a reality, we have to take resource security seriously. The environment also has a budget."

Ecological Footprint: The Ecological Footprint is an accounting system that shows how much biologically productive land and water area an individual or a population uses to produce all of the resources it consumes and to absorb the waste it produces. The Footprint of a country or region quantifies the environmental impact of the way a population consumes products and energy, regardless of where it takes place in the world, thus taking into account both imports and exports.

Biocapacity: Biocapacity quantifies an ecosystem's ability to produce biologically useful material and to absorb the waste produced by humans under today's prevailing technology. It is calculated by multiplying the amount of land actually available by what are referred to as yield and equivalence factors. We can use these to convert differences in productivity within a certain land-use category in different countries, as well as different land-use categories such as cropland or forest, into global hectares.

Global hectare: The central unit of measurement for the Footprint and biocapacity is the global hectare (gha). This "single currency" accounts for different levels of fertility in different soils, as land in a cropland area is able to produce more than the same surface area in a semi-desert. The gha is a surface area of 100 meters by 100 meters with average global productivity. This standardized measurement unit enables us to compare different countries and regions worldwide.

Carbon Footprint: The carbon Footprint (CO_2 Footprint) refers to the biocapacity that is required in the form of forest land to sequester all CO_2 emissions minus the emissions that are sequestered by the oceans. The amount of land needed reflects the amount of land required to burn fossil fuels.

Global Footprint Network Glossary
www.umwelt2016.nrw.de/002

Methodology: The calculations for North Rhine-Westphalia are based on the current data and methods of the National Footprint Accounts 2016. The basis for this was a high-resolution input-output model used to analyze the flow of goods and services, from which a consumption and land-use matrix was derived for Germany. This, in turn, was adjusted using an abundance of state-specific data, for example using remote sensing data, overall economic calculations, emissions inventories, census data, energy balances, traffic statistics, information about the way food is consumed, regional heating behavior and much more.

How we measure our resource consumption

Let's start with the supply side: Earth's surface measures 51 billion hectares. Three quarters of this area is barely biologically productive at all: deserts, high-altitude mountains, sheets of ice and open seas that are low in fish, as well as land that has been buried under infrastructure. Only about one quarter of the earth is biologically productive: cropland, grazing land, wetland, fishing grounds (in lakes and especially in the oceans' coastal waters) and forests. This adds up to a total of around 12 billion gha in credit. This is the supply of nature that we have to contend with.

This biocapacity of roughly 12 billion gha is the budget for humanity's Footprint. But human beings should not exploit the world's entire biocapacity as it also needs to serve wild species: whether it's the whales in the oceans, orangutans in tropical rain forests or the 43,000 species of animals and plants at home in North Rhine-Westphalia. The International Union for the Conservation of Nature and Natural Resources (IUCN), which maintains the international Red List of Threatened Species for animals and plants, estimates that, at the moment, only around 15% of the world's landmass and 10% of its coastal waters are protected, representing possibly far less than 10% of Earth's biocapacity, since much of it is area with low productivity. In his book "Half-Earth: Our Planet's Fight for Life," Edward O. Wilson, an expert in the field of biodiversity, calls for us to leave half of the earth exclusively to wild animal and plants species in order to preserve biological diversity as an important foundation of human welfare.

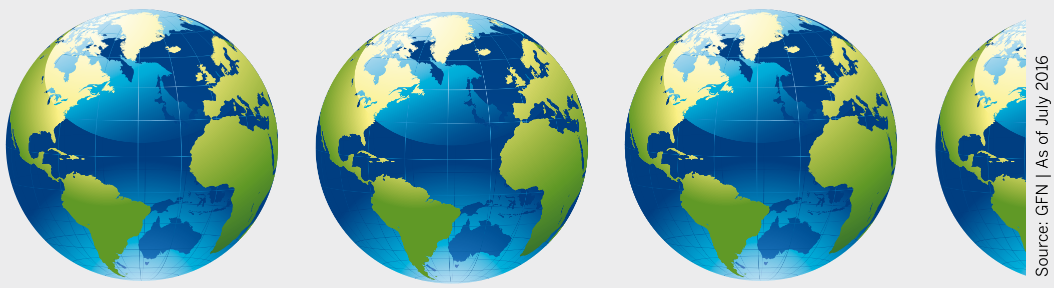
With a global population of more than 7 billion people, biocapacity currently averages at roughly 1.7 gha per capita. Germany has 2.3 gha of biocapacity per capita. Ecologically speaking, in spite of its high financial earnings, Switzerland is comparatively poor, with 1.3 gha of biocapacity per capita. In comparison, France has a biocapacity of 3.1 gha per capita. Sparsely populated but relatively dry Australia has as much as 16.6 gha per capita. And North Rhine-Westphalia? Its biocapacity is significantly lower than the global average and is currently only 1.1 gha per capita due to its comparatively high population density of more than 500 inhabitants per square kilometre.

How much biocapacity on average does a human being living in North Rhine-Westphalia need today? To calculate the Ecological Footprint, we have to take into account all of the materials consumed in the state, including food, raw materials, energy, car kilometres, and products such as cell phones and clothing. We also must consider all of the resulting waste and emissions – especially emissions of carbon dioxide (CO_2) from fossil fuels, and from providing the corresponding residential areas and traffic infrastructure. We must also consider the Rhine and the Ruhr, which are natural resources that account for part of this consumption and waste absorption. Taking all these variables into account allows us to determine that North Rhine-Westphalia has an Ecological Footprint of 5.8 gha per capita, according to most recent figures. Annualized, North Rhine-Westphalia is only able to cover 68 days of its requirements with its own ecosystems or biocapacity. This means that North Rhine-Westphalia has already exhausted its "eco-budget" for the year by March 8. The state runs a significant "ecological deficit."

In 2012, North Rhine-Westphalia's Footprint was roughly 9% higher than the German federal average of 5.3 gha per capita. At the same time, biocapacity in North Rhine-Westphalia in 2012 was less than the federal average of 2.3 gha per capita, dropping by about 53% – and was about 38% below the biocapacity available globally of 1.7 gha per capita. North Rhine-Westphalia's "ecological deficit," based on the state's available biocapacity of 1.1 gha and consumption of 5.8 gha per capita, was therefore 4.7 gha per capita in 2012. This means that the North Rhine-Westphalian Footprint was 5.4 times larger than the biocapacity available in the state. It was also 3.3 times higher than the biocapacity available globally per capita. In 2012, it would have taken the biocapacity of more than three earths to enable the global population to live the lifestyle of North Rhine-Westphalians (see figures 1 to 7).

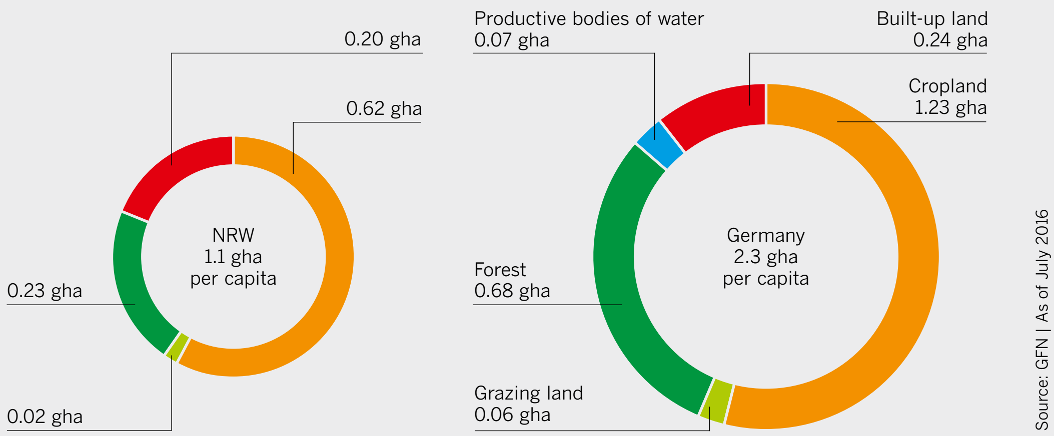
The Ecological Footprint of Nations
www.umwelt2016.nrw.de/003

Figure 1 The North Rhine-Westphalian Footprint, projected onto the global population in 2012



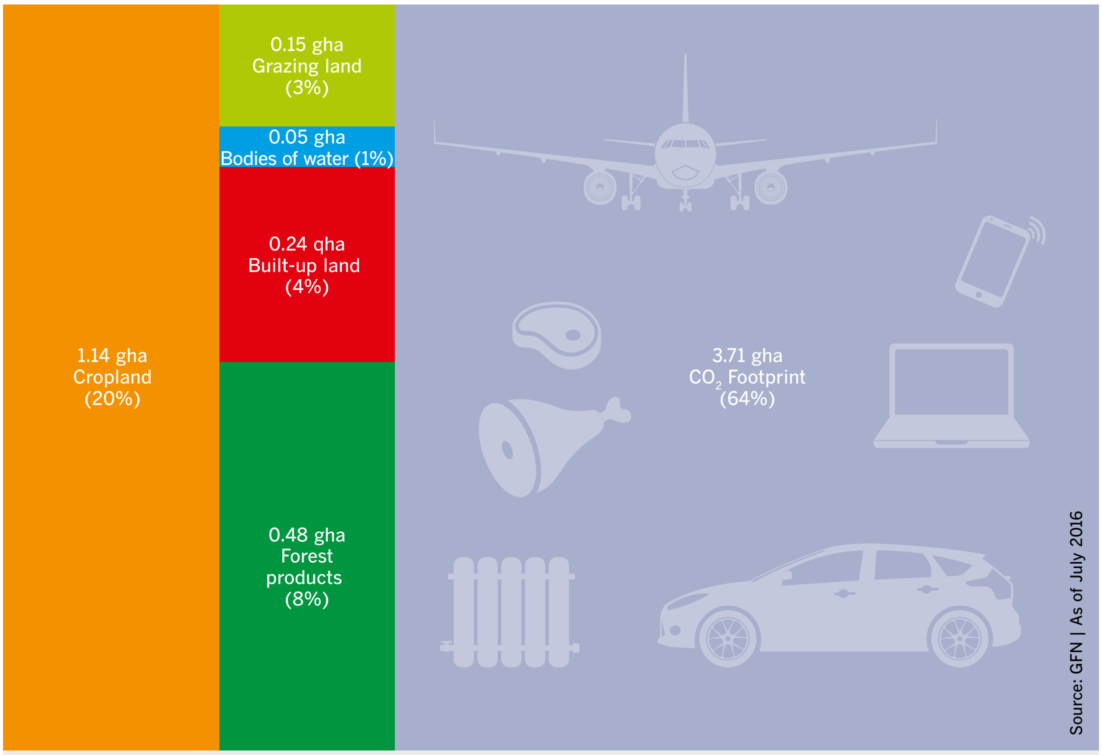
Based on a global population of roughly 7 billion people, the results of the most recent data collected by Global Footprint Network showed an average Footprint of 2.8 gha per capita with a biocapacity of 1.7 gha per capita. Annual consumption amounted to a total of about 1.6 times what is renewed during the course of one year. The figures calculated for North Rhine-Westphalia with the living standards of a industrialized country with high incomes are even larger: If all of the world's 7 billion people led a North Rhine-Westphalian lifestyle with its current levels of resource consumption and its energy mix, we would need about 3.3 earths in the long term.

Figure 2 Biocapacity per capita for NRW and Germany by land-use category in 2012



Germany had a biocapacity – ecosystems able to produce biologically useful material and to absorb the waste produced by people including CO_2 – of around 2.3 gha per capita. North Rhine-Westphalia's biocapacity, on the other hand, amounted to around 1.1 gha per capita, partially due to its population density which, at 500 inhabitants per square kilometer, is more than twice that of Germany as a whole. The largest share was comprised by cropland and grazing land at a combined 0.64 gha per capita (48% of land area is agricultural land), followed by the forest category at 0.23 gha per capita (for forest products and CO_2 sequestration). A similar area is occupied by built-up land and infrastructure at 0.20 gha per capita. North Rhine Westphalia does not have any noteworthy productive bodies of water.

Figure 3 NRW Footprint per capita by land-use category in 2012



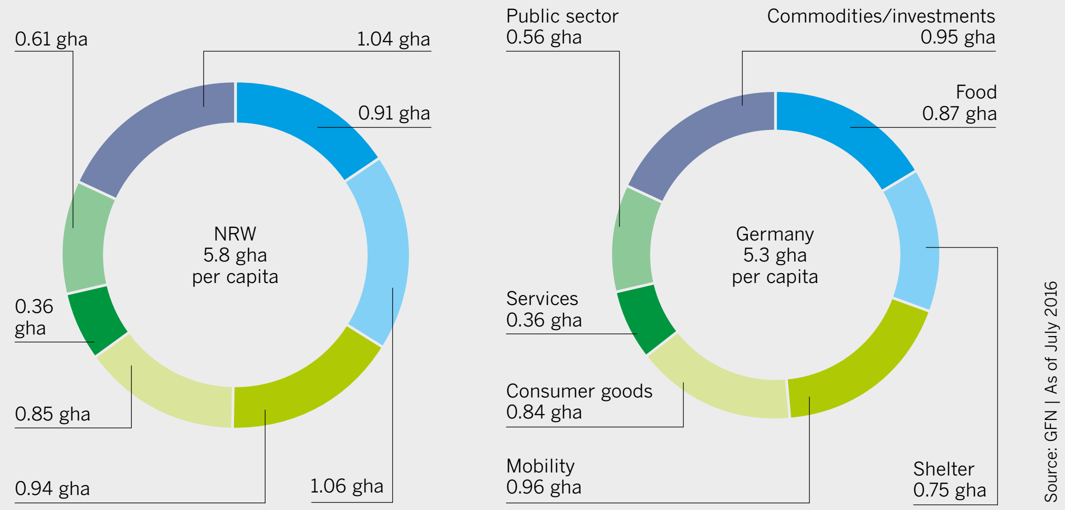
A Footprint of around 5.8 gha per capita for North Rhine-Westphalia is represented here by surfaces sized in proportion to each category's share. The breakdown by land-use categories shows that, at 3.7 gha per capita, 64% corresponds to the CO_2 Footprint alone: land for the sequestration of CO_2 emissions caused by the combustion of fossil fuels for power, heating, mobility and consumption (estimated in the form of forest land needed to sequester the CO_2). There is great potential here to reduce the Footprint (climate mitigation). The second largest portion is "cropland" at 1.1 gha per capita for food, animal feed and clothing fibers. The third largest is forest area for extracting wood.

This places North Rhine-Westphalia in the upper-third of European Footprints. At the same time, North Rhine-Westphalia performs similarly to the German federal average in all aspects of consumption – with the exception of energy use. The reason for its large Footprint and less favourable results when compared with Germany overall is, in particular, the energy mix in North Rhine-Westphalia or, more specifically, the carbon intensity of the electricity it generates and uses. Electricity in North Rhine-Westphalia is often generated using carbon-intensive lignite and stone coal.

Can we afford to live like kings?

North Rhine-Westphalia needs more than five times the amount of resources that its own ecosystems are able to renew. Why do we care? North Rhine-Westphalia is a strong economic power and can use its money to buy what it does not have from elsewhere. The greenhouse gases that it emits into the Earth's atmosphere only incur seemingly negligible costs since we do not pay monetarily for CO_2 emissions. But for how long? North Rhine-Westphalia is competing with the rest of the world: The global Ecological Footprint is 2.8 gha per capita with a biocapacity of 1.7 gha per capita. This means that the world's citizens are now using roughly 60% more than they have available in the long term or that the Earth can regenerate. The competition for resource access might increase, or lead to disruptions in supply chains. This global over-demand leads to increases in the atmosphere's CO_2 levels, the depletion of groundwater reserves, overexploited soils and the disappearance of tropical rain forests.

Figure 4 **NRW and German Footprints per capita by consumption category in 2012**



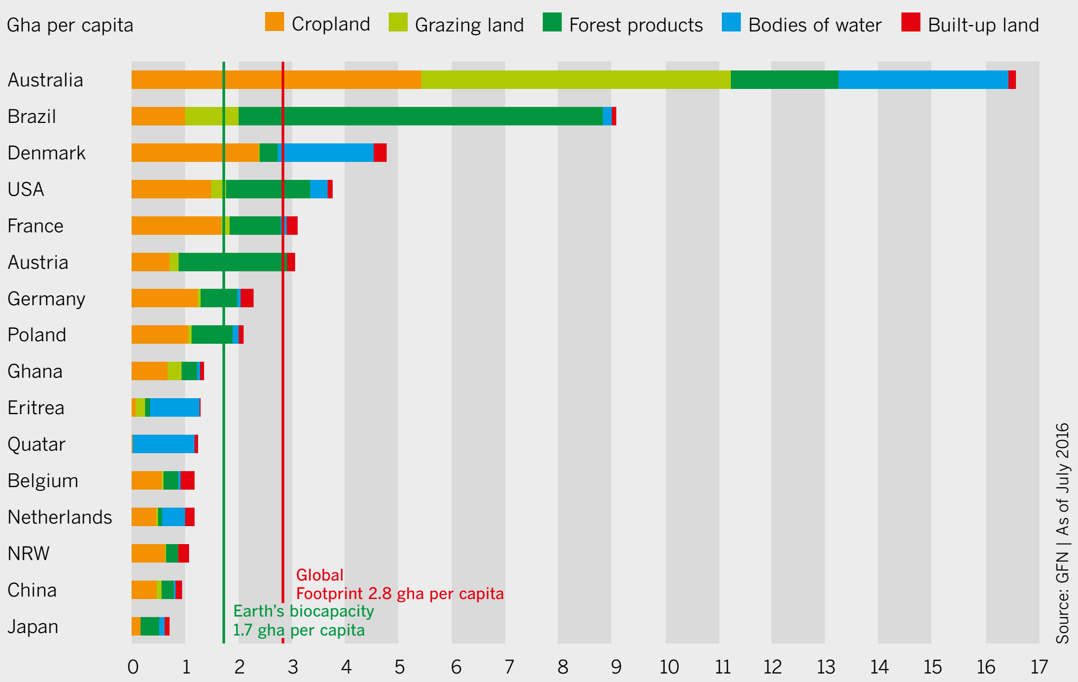
The categories food, shelter, mobility, consumer goods and services add up to around 4.1 gha per capita for North Rhine-Westphalia; the impact of the public sector and commodities/investments adds up to 1.7 gha per capita. In comparison to Germany's Footprint of 5.3 gha per capita, the 41% difference in shelter is striking, due to North Rhine-Westphalia's unfavorable, coal-heavy energy mix with a larger CO_2 Footprint per kilowatt hour of electricity. Important factors with high savings potential include the consumption of meat and animal-based products that can contribute up to 75% of food; power and heating, which constitute almost 90% of shelter; fuel-burning combustion engines in the "mobility" category; and lifestyles shaped by consumption.

It remains to be seen where North Rhine-Westphalia will turn to import all of the resources necessary to maintain its current lifestyles in the future. For mathematical reasons, not all states can import more than they export. Also, because supplies of land and raw materials are limited, growing demand will increase competition for those natural resources. The proportion of the world's income that a German or North Rhine-Westphalian resident receives has been decreasing rapidly, as incomes are growing faster in emerging markets such as China or Brazil. Today, Germany's average share of global earnings is only half of what it was 35 years ago. Given the large resource dependence of Germany vis-à-vis the world, shrinking relative incomes combined with a large ecological deficit could become a risk for Germany – and thus, for North Rhine-Westphalia.

The setting of the two-degree Celsius goal at the World Climate Summit in Paris on December 12, 2015, represented an implicit resolution to entirely abandon the use of fossil energies well before 2050. Globally, the remaining CO_2 budget available in order not to miss the two-degree target is significantly less than 800 metric gigatons of CO_2 emissions (which is about 20 years of humanity's current CO_2 emissions). Although humanity will most likely have less biocapacity available in a world two degrees Celsius warmer, it will have even less biocapacity available in the future if it accelerates climate change through "business as usual" economics. For instance, if we continue to use fossil fuels without significant restraint, we stand the risk of losing much more biocapacity. If we prolong the age of coal and oil, extreme climate change and its consequences will significantly weaken the globe's biocapacity.

The Paris Agreement was initially signed by 190 countries, confirmed by most of them on April 22, 2016, and enacted on November 4, 2016. In spite of its clarity, there is almost no country that is preparing itself quickly enough for a significantly "scarcer" world. Economic strategies are being laid out as if resource security was going to last forever. The situation is often played down in a fatalistic manner by people who interpret our resource and climate challenge as a diffuse, global tragedy, believing that we as individuals or even as a significant, industrialized country cannot deal with this resource challenge on our own.

Figure 5 Biocapacity of select nations (with populations of over 2 million) and NRW per capita in 2012



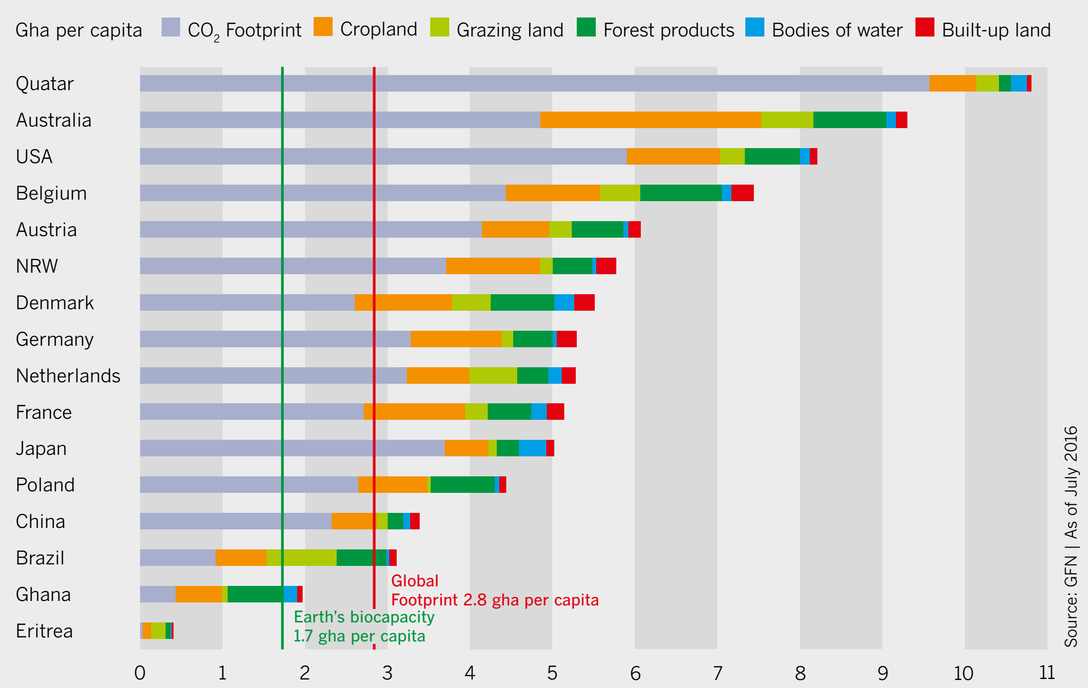
Australia, with its sparse population of 4 inhabitants per square kilometer, has a biocapacity of around 16.6 gha per capita, putting it in second place globally behind Bolivia with 16.7 gha per capita, a country that is criss-crossed by the Andes, by savannas and rain forests (Footprint 3.0 gha per capita). The island nation of Japan has the lowest biocapacity in the diagram at 0.7 gha per capita (population density roughly 335 inhabitants per square kilometer). But worldwide, the two countries in last place are Jordan in the Middle East with its high proportion of dessert and a biocapacity of 0.2 gha per capita (Footprint 2.1 gha per capita) and Singapore – the South-East Asian nation with more super-rich citizens than anywhere else – with 0.1 gha per capita (Footprint 8.0 gha per capita).

An example: How is my native country, Switzerland, reacting?

It's not as if there wasn't enough information available or enough awareness of the risks. North Rhine-Westphalia is not the first state to measure and report on its Footprint. The Swiss Federal Statistical Office tested the Ecological Footprint calculations for the first time in 2006 and recently published that, in 2012, Switzerland's Ecological Footprint was 5.8 gha per Swiss citizen, or four times that of Switzerland's biocapacity of 1.3 gha per capita. 3.3 Earths would be required for everybody to live like the Swiss. This ecological deficit cannot be maintained in the long term, especially in light of rapid growth in income and demand in China and India. And pressure will increase even more as the global population continues to grow.

The Swiss Federal Councillor Doris Leuthard, who heads the Swiss Federal Department of the Environment, Transport, Energy and Communications, makes reference to the Footprint in her speeches. In spite of this, the Swiss Federal Chancellery asked us if one-planet living – or the goal of living with a Footprint that can be replicated worldwide – is "realistic." But the much more essential question is whether living on the equivalent of three planets is "realistic." On September 25, 2016, the Swiss population voted on a popular referendum that proposed to establish a "Green Economy." Its goal was to lower the Swiss Footprint to a "one-planet" level by 2050 (currently, that would mean less than 1.7 gha per capita). At the end of the day, 36% of the voting public did vote in favor of this proposition.

Figure 6 **Footprints of select nations (over 2 million residents) and NRW per capita in 2012**



The emirate of Qatar on the Arabian Peninsula, which has become incredibly rich from its oil reserves, has the world's largest Footprint at 10.8 gha per capita (with one third of the land area of North Rhine-Westphalia), followed by Australia with 9.3 gha per capita and the U.S. with 8.2 gha per capita. Tailing the bunch worldwide is Eritrea in North Africa at 0.4 gha per capita, a country shaped by poverty and political challenges. Within a reasonable margin of error, Germany is basically on par with neighboring countries like Austria, Denmark, the Netherlands and France. The global Footprint is 2.8 gha per capita. If the average Footprint was less than 1.7 gha per capita, humanity would be using the entire capacity of the planet. To leave capacity for wild species, the average Footprint would therefore need to be even lower.

Raising basic questions and showing that one-planet living is possible!

Just as the Fifth Assessment Report of the UN's Intergovernmental Panel on Climate Change (IPCC) documented that a corresponding reduction would be practicable for maintaining the two-degree goal, the World Business Council for Sustainable Development's Paper Vision 2050 is showing us ways in which we can achieve Footprint reductions on a global scale that are in line with the earth's biocapacity. Scenarios like this focus heavily on human potential for innovation and technical advancement. Idly sitting by and letting the resource situation get out of hand would, on the other hand, mean an inevitable global resource collapse and social chaos.

Synthesis Report of the Fifth IPCC Assessment Report
www.umwelt2016.nrw.de/004

Vision 2050 – The New Agenda for Business
www.umwelt2016.nrw.de/005

We at Global Footprint Network are convinced that it is possible for everybody on this planet to thrive. But in order for this to become a reality, we have to take resource security seriously. The environment also has a budget. For this reason, promoting this topic and working together with decision makers is Global Footprint Network's “raison d'être,” its core purpose.

One obstacle preventing people from understanding the Footprint could be that they can't or don't want to believe our figures. There are also critics who are bothered by the Ecological Footprint. It is not always clear if they are upset by our views or if they think that our methods are not insightful. But ultimately, everybody has to ask themselves two fundamental questions: What do we have to know about current conditions in order to ensure the quality of our lives and economies in the future? And, how significant is resource security as a parameter for long-term prosperity?

The answers are easier than we think: We human beings, with our food, our consumption and our lifestyles, require resources. Even the manufacturing of ecological flagship products like the classic bike requires resources. Resource security is a significant statistical value.

Not all resources have to be available locally, as, ultimately, there is also foreign trade. But, worldwide, we cannot all be net importers. And if our earnings are not higher than those of other countries, it becomes less and less likely that we will be able to continue buying resources from others. Biocapacity is a limiting factor in a world where burning fossil fuels such as coal, gas and oil – still our most frequently used sources of energy – is limited due to the biosphere's (in)ability to absorb them. We humans, and all other species, are competing for productive land. People use it for the production of food, animal feed, plant fibers and wood, sequestration areas for carbon dioxide, urban use and biodiversity.

What do the Footprint results tell us?

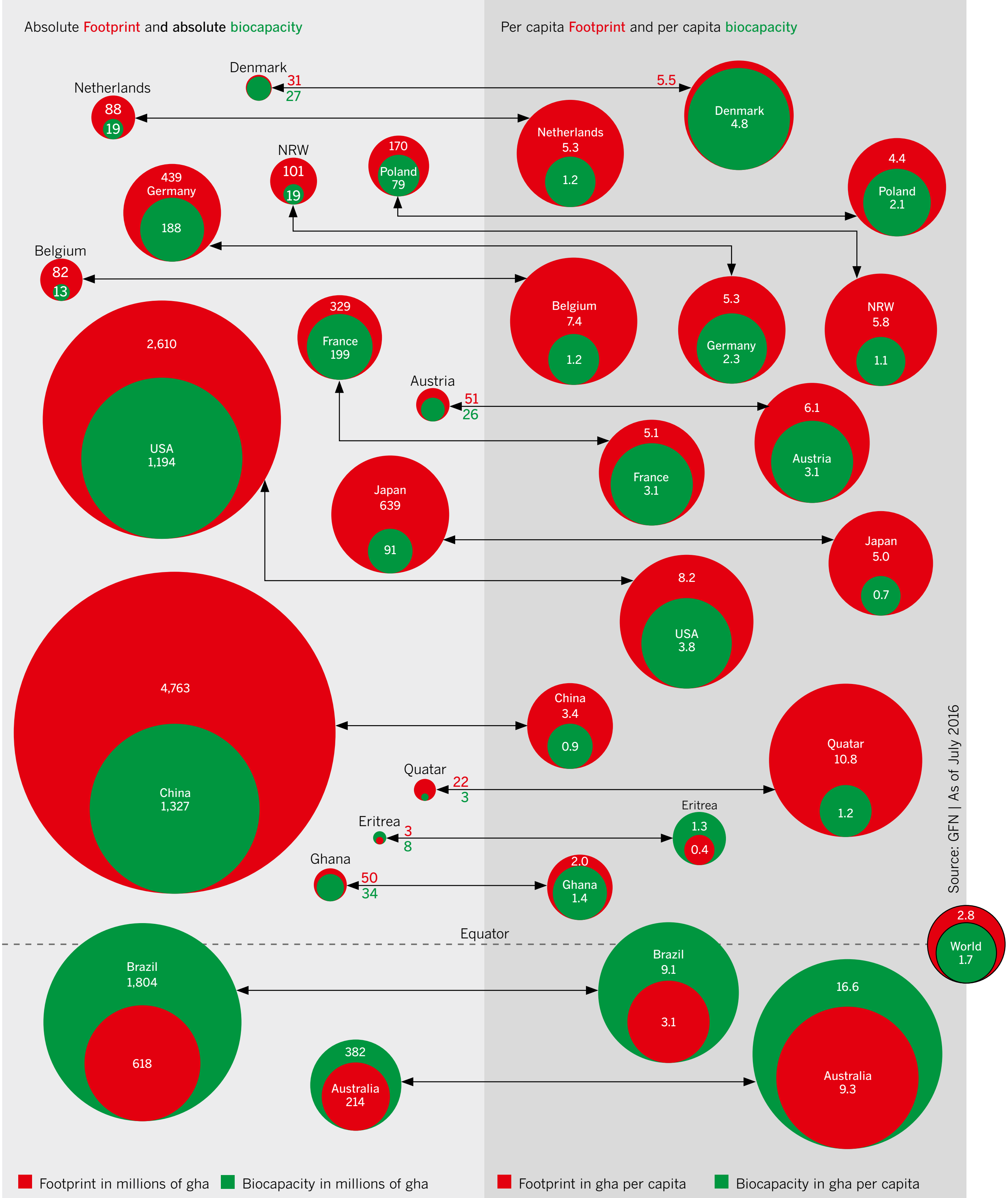
Does the Footprint tell us all we need to know about sustainability? No, it only provides us with a size comparison of human consumption relative to the environment's regenerative capacity. Does it tell us if ecological farming is better than conventional farming? No, at least not here in this brief analysis. Does the Footprint precisely describe the amount of resources that we over-exploit? No, it is primarily a conservative estimate. The Footprint does not describe all factors exactly. In particular, biocapacity is probably portrayed too optimistically, as many kinds of over-exploitation are not included due to a lack of reliable data. Examples of this are activities that lead to land degradation, a loss of freshwater reserves, eutrophication of groundwater, or depletion of soils. This means that – even if over a billion data points go into our global National Footprint Accounts – the Footprint ultimately remains a simplified observation.

To evaluate some of the criticism directed toward the Ecological Footprint, I recommend considering the following chain of four questions: 1) Are you critical because the Footprint assessment does not build upon a clearly enough defined research question? 2) If that is not the problem, is the question not sufficiently relevant? 3) If that is not the problem, are there more precise methods available to give you a better answer to this question? 4) If that is not the problem, are the results just so misleading that society would be better off without these results?

My answers to these four points are: Yes, the Footprint's indicators build upon a clear question: How much productive land does a population use compared to how much productive area is available? Yes, it is a relevant question: If we consume more than what nature is able to renew, it inevitably leads to over-exploitation and ecological deterioration, ultimately undermining our economies' ability to operate. No, there are no other methods available yet that provide sharper and more precise answers to the research questions. Or at least, I do not know of any better assessments than the Footprint, and would be eager to learn about them. And no, the results of the Footprint are not misleading. The results of Global Footprint Network's accounts are consistent and coherent, and would be even if national estimates had an accuracy of +/-20%. The over-exploitation of the planet is at least 60% above Earth's ability to renew. In the case of North Rhine-Westphalia, its Footprint demand exceeds its biocapacity by 440%, meaning that even deviations of +/-20% do not significantly change the conclusions of the results.

In my opinion, this leads to the following questions for North Rhine-Westphalia: This state requires 5.4 times as much as its own ecosystems can yield. Is this a significant risk for North Rhine-Westphalia, particularly in light of the fact that humanity's demand is already exceeding the planet's rate of renewal by more than 60%? Is it a top-100 risk or a top-5 risk? How quickly can North Rhine-Westphalia adjust its consumption patterns to new global conditions if it has to? And what happens if it does not manage to do this quickly enough?

Figure 7 Footprints of select nations and NRW in total and per capita in 2012



The left half shows the total Footprint and biocapacity of select countries to scale in million gha. Here you can see the contributions made to the global Footprint and to the biocapacity available worldwide. The right half visualizes the per-capita Footprints for these countries and the whole world, as well as their respective biocapacity in gha per capita. This is where it becomes clear how much is available for each individual on average – and therefore in total for all nations on the planet. This diagram also reveals ecological deficits (red outside circle) and reserves (green outside circle). In addition to this, it shows how problematic discussions can be if they only deal with total per-country figures and do not mention per-capita figures.

Dr Paul Becker

The latest climate scenarios for North Rhine-Westphalia in 2050

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Deutscher Wetterdienst
www.umwelt2016.nrw.de/006

Changes in the climate system that result from the complex interplay between the atmosphere, the oceans, huge expanses of ice and the biosphere are one of the great challenges facing humanity, as the global increase in average temperatures will not be without consequences. 2014 was the warmest year recorded in Germany since national records began in 1881; we have had eight of the 10 warmest years on record since 1999. Globally, 2015 has topped the list of the warmest years registered so far. The number of hot days in Germany with a maximum air temperature of at least 30 °C has increased in past years and the number of what is referred to as "tropical nights" – nights where the temperature does not drop below 20 °C – continues to grow every year. In contrast, the number of days blanketed by snow has decreased significantly since 1881. The Deutscher Wetterdienst has also been observing changes in the distribution of rainfall over the course of the year: Summers are getting drier and drier, while rainfall in the winter months is increasing significantly. These are just some of the phenomena that show that changes are taking place within the climate system that affect Germany and thus North Rhine-Westphalia too.

Earth's climate has changed throughout history. The last ice age, the "Last Glacial Maximum", ended approximately 20,000 years ago. Using reconstructions of climate data (referred to as "proxy data") collected from climate archives such as ice cores, we are able to infer that powerful changes in the climate system also took place during the earth's transition from the last ice age to the current interglacial period. At the peak of the last ice age, large parts of North America were buried under an ice sheet up to 4,000 meters thick; Scandinavia and North England were also covered in ice. The volumes of water bound up in these ice sheets meant that sea levels were so low that the British Isles could be reached on foot. Central Europe was dominated by a type of vegetation comparable with today's Siberian Tundra.

The proxy data collected lead to the conclusion that the transition from this ice age to the climate state we are accustomed to now lasted roughly 5,000 years and was accompanied by a global increase in temperatures of about 5 °C. This increase took place relatively slowly at a rate of 1 °C per 1,000 years. Since the turn of the last millennium, we have seen global warming that is taking place at a rate ten times faster than that: Current measurements show an increase in the average global temperature of approximately 1 °C per 100 years. This fact already prompted the UN's Intergovernmental Panel on Climate Change (IPCC) to state in its fourth Climate Change Synthesis Report in 2007 that "humanity is warming the global climate faster than nature was ever able to."

”Global climate change does not stop at national borders: In North Rhine-Westphalia too, changes in the climate – some of them considerable – can be expected even during the lifetime of today’s 40 and 50-year-olds.“

Observed climate change: causes

In order to explain the global warming observed in the 21st century – and the changes in other associated atmospheric variables such as, for example, precipitation patterns – we need to take a closer look at the atmosphere’s radiation and heat budget. This article – for which the Deutscher Wetterdienst has provided data specifically for North Rhine-Westphalia, collected from the newest available scenarios – will discuss, in particular, changes in the surface temperature and in precipitation patterns. Making statements about other climate elements – such as the speed and direction of the wind, solar radiation and clouds, which play a large role in the context of renewable energies, for example – is still laden with in part significant uncertainties. This is due to their small scale and the lack of detailed analysis of local vertical structures in available climate models.

Our planet’s only external source of energy is the sun: It emits energy-rich radiation in wavelengths of between 0.2 and 3.0 micrometers. Part of this short-wave radiation – harmful ultraviolet radiation – is absorbed by the ozone (O_3) in the high altitudes of the atmosphere, which means that it does not reach Earth's surface.

The remaining radiation that hits the earth’s surface only transforms into heat in the earth’s surface itself. Earth’s surface reflects the thermal radiation resulting from this transformation, which is retained in the atmosphere by greenhouse gases – alongside CO_2, these are methane (CH_4), nitrogen oxides (NO_x) and the water vapor present in the atmosphere – because thermal radiation can only leave the atmosphere in wavelengths ranges in which it is not absorbed by these greenhouse gases. This “greenhouse effect” has made a significant contribution to our current climate: The natural greenhouse effect is responsible for the earth’s surface being additionally warmed by at least 33 °C. This explains why the average global temperature is measured at 15 °C, instead of the theoretical equilibrium temperature that Earth would have without any atmosphere of -18 °C.

With a surge in economic activity since the beginning of industrialization, the concentration of greenhouse gases in the atmosphere has been increasing, which intensifies the natural greenhouse effect and means that more energy – and as a result more additional heat – remains in the atmosphere. This is the additional, anthropogenic greenhouse effect. Before industrialization, the atmospheric

NOAA: Recent global monthly mean CO_2
www.umwelt2016.nrw.de/007

concentration of CO_2 was approximately 280 ppm (parts per million). This concentration has increased dramatically since then. In May 2016, the United States' weather and oceanographic authority, the NOAA (National Oceanic and Atmospheric Administration), declared a new CO_2 concentration record of 407 ppm. Other greenhouse gases are currently reaching values that have never before been observed in Earth's more recent history. Moreover, in 2015, the highest concentrations of atmospheric CO_2 yet were recorded here in Germany too: The German Environmental Agency's weather stations on the Zugspitze in the Alps and on the Schauinsland in the Black Forest have now recorded average annual values above 400 ppm for the first time.

Looking into the future: climate simulations

Synthesis Report of the Fifth IPCC Assessment Report
www.umwelt2016.nrw.de/008

In order to carry out simulations of the future climate that are as realistic as possible and can estimate the resulting changes, physical processes in the atmosphere are replicated in complex climate models and analyzed in parameters. One indispensable part of this process is creating scenarios for possible future greenhouse gas emissions. These scenarios are based on different hypotheses about the way the global economy will develop in the future. They range from a climate change mitigation scenario employing rigorous climate change mitigation measures to a scenario of unbridled economic growth with high greenhouse gas emissions. These scenarios each lead to different concentrations of greenhouse gases at the end of the 21st century, indicated as CO_2 equivalents (see figure 8). Each of these concentrations would have a significant effect on the atmosphere's radiative forcing value and, as a result, on the greenhouse effect.

The scenario RCP 2.6 (Representative Concentration Pathway) is what is referred to as a "climate change mitigation scenario": It describes a peak in greenhouse gas emissions by 2020 with a resulting concentration of approximately 475 ppm, followed by a decline in greenhouse gas emissions and a decrease in the radiative forcing value to 2.6 watts per square meter by 2100. In scenario RCP 2.6, mean global warming is expected to be less than 2 °C above the preindustrial temperature. This would comply with the United Nations climate agreement passed at the end of 2015 in Paris, which is supposed to be implemented by drastically reducing greenhouse gas emissions to net-zero (with only as many greenhouse gas emissions as forests and other carbon sinks can absorb from the atmosphere) by the end of this century.

In contrast, the "business as usual" scenario, RCP 8.5 – with unbridled emissions of greenhouse gases – would entail an additional radiative forcing value of 8.5 watts per square meter and a much higher increase in the average global temperature.

Climate models are complex and CPU-intensive but very reliable computer models. They can be used to calculate potential future climate developments on the basis of physical patterns and with the help of the scenarios described above. Because they examine the effects that different greenhouse gas concentrations have on the climate, they are referred to as climate projections as opposed to concrete future forecasts.

Figure 8 RCP scenarios from the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)

RCP 2.6 with a relatively low radiative forcing value of 2.6 watts per square meter	475 ppm concentration of atmospheric greenhouse gases, a peak in emissions in 2020, then a decline	Climate change mitigation scenario ("peak and decline" scenario), very ambitious reduction in greenhouse gas emissions
RCP 4.5 with a radiative forcing value of 4.5 watts per square meter	630 ppm concentration of atmospheric greenhouse gases, peak in 2100	Stabilization scenario with a moderate radiative forcing value
RCP 6.0 with a radiative forcing value of 6.0 watts per square meter	800 ppm concentration of atmospheric greenhouse gases, peak not yet reached in 2100	Stabilization scenario with a high radiative forcing value
RCP 8.5 with a very high radiative forcing value of 8.5 watts per square meter	1,313 ppm concentration of atmospheric greenhouse gases, peak not yet reached in 2100	High greenhouse gas emissions ("business as usual" scenario), economic growth continues to be based on fossil energy sources

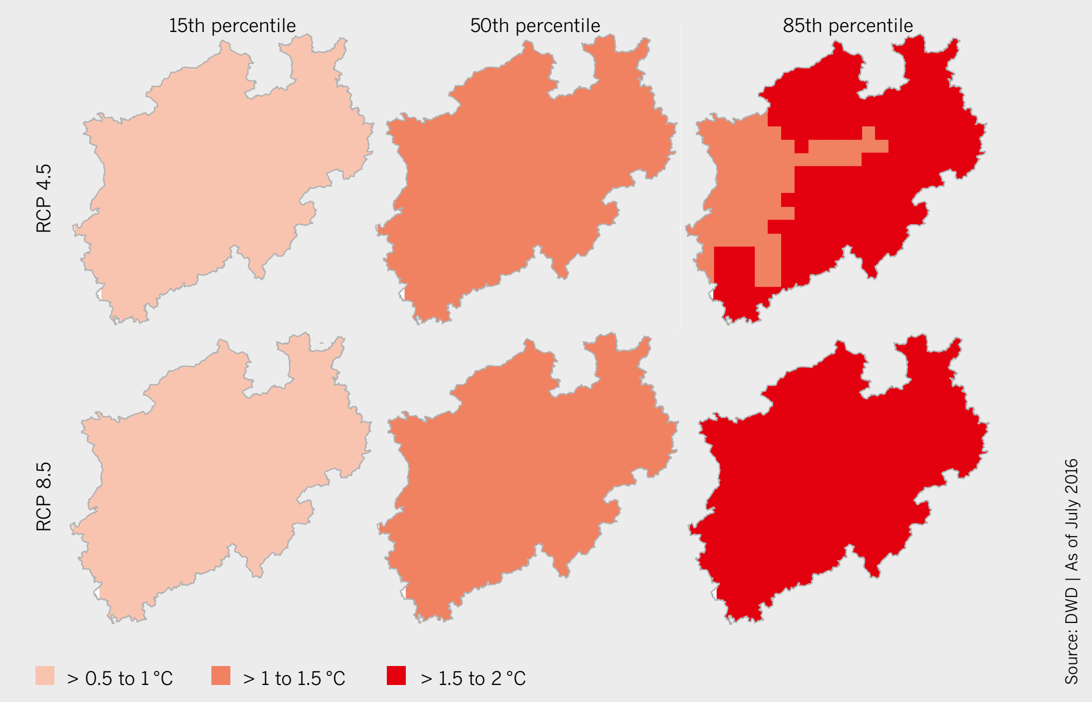
The spatial resolution of the major global climate models is not yet sufficient enough to provide detailed descriptions of the different effects of climate change on specific continents, states or regions. This is where regional climate models come in, whose grid points form a closely knit, three-dimensional network. Just as there are climate models for use on a global scale, there are also a number of climate models that can be used on a regional scale. In particular, numeric-dynamic climate models (RCMs, regional climate models) are used to describe the effects that an altered world climate would have on regional conditions as precisely as possible. RCMs calculate high-resolution spatial and temporal simulations for small sections of the earth that are driven by the surrounding global models. The entire modeling chain – from the creation of the scenarios to global simulations to regional climate modeling – is subject to a number of uncertainties. It is not possible to make a precise prediction of how the climate will change in the years to come. However, a wide variety of model results – what is referred to as a "model ensemble" – can be used to quantify and represent the range of these results.

Information about range in percentiles: Uncertainty about what is being expressed in a range of values increases throughout the modeling chain – from emissions and concentration to global climate models to regional climate models. When listed, the results from climate scenario model calculations usually specify the 15th, 50th and 85th percentiles. This sequence covers 70% of model calculation results and thus provides a reliable picture of the range of expected changes within a particular scenario. A percentile is a statistical measurement that divides a data record into increments of 1% by size. The x% percentile can therefore be interpreted as a threshold value that is not exceeded by x% of all values. For the 85th percentile of a model ensemble, this means, for example, that the results are below or of the same value as 85% of the data models. However, the percentile representation does not indicate the probability of occurrence; the projected changes in the 15th percentile, for example, are no more likely than those in the 85th percentile. – The projections in this article are based on one model for scenario RCP 2.6 and 13 other models for the scenarios RCP 4.5 and RCP 8.5.

Anticipated changes in the future: temperature

A temperature increase in North Rhine-Westphalia is as good as to be expected. For the period 2021 to 2050, the modeled increase in surface-level air temperature is approximately 1.3 °C above that of the reference period 1971 to 2000 (see figure 9). In the different climate scenarios, the difference between the projected changes for the moderate emissions scenario RCP 4.5 and the "business as usual" scenario RCP 8.5 is still slight to begin with; there are no major differences between the two scenarios until the end of the century. The range that the model ensemble covers is a temperature increase of between 0.5 °C and 2 °C above that of the reference period; if scenario RCP 8.5 became a reality, there would be noticeable warming throughout North Rhine-Westphalia. In the 85th percentile of the moderate scenario RCP 4.5, warming is significantly more noticeable in the eastern parts of the state.

Figure 9 Changes in mean annual air temperature in NRW 2021 to 2050 with respect to 1971 to 2000

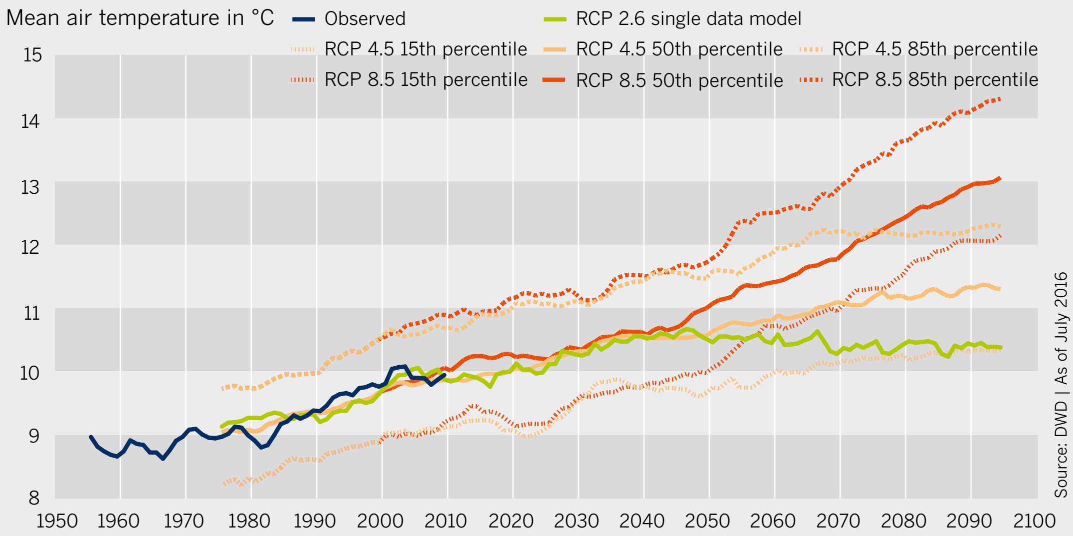


The projections of the upper series in stabilization scenario RCP 4.5 are based on a moderate radiative forcing value with a moderate increase in greenhouse gases; those in the lower series of "business as usual" scenario RCP 8.5 are based on a very high radiative forcing value with high greenhouse gas emissions. According to these projections, an increase in the mean annual temperature of at least 0.5 °C to 1 °C can be expected for the entire of North Rhine-Westphalia. The 15th, 50th and 85th percentiles represent 70% of the model results and provide a reliable picture of the range of temperature changes that can be expected.

If we take a look at modeled temperature changes up until the end of the century, significant differences become noticeable from 2050 on (see figure 10). For example, in the case of a moderate increase in greenhouse gas emissions in the stabilization scenario RCP 4.5, global warming could be limited to a maximum of 3 °C with respect to the observational period, whereas unbridled emissions of greenhouse gases up until the end of the century could lead to a maximum warming of up to 5 °C in North Rhine-Westphalia.

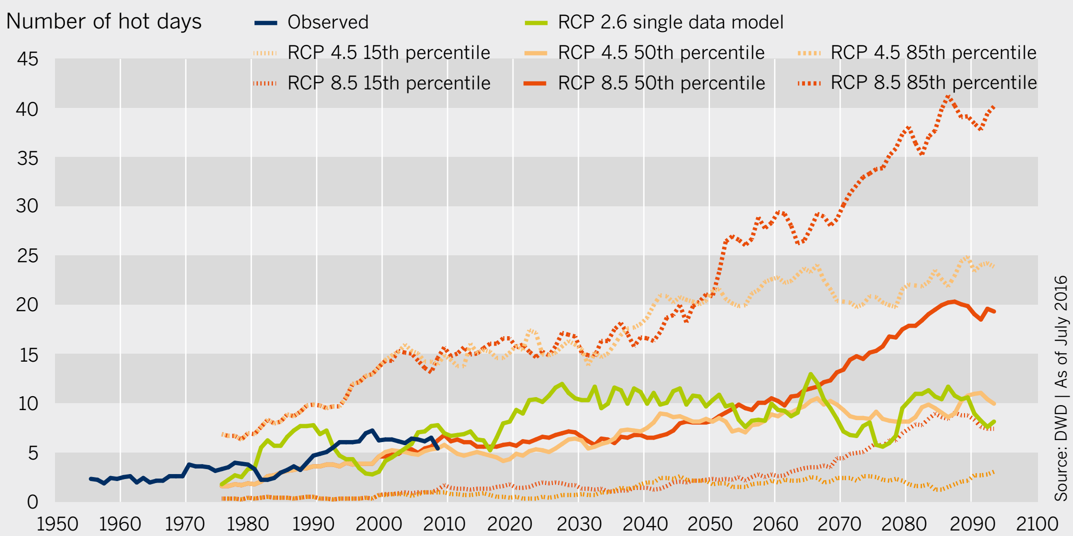
A change in the behavior of extreme values is also expected to accompany mean warming in these projections. Good indicators of extreme values are the hot days mentioned earlier, but also what is referred to as "ice days" where the daily maximum temperature continuously stays below 0 °C.

Figure 10 Observed and projected mean annual air temperatures in NRW



The increase in the mean annual temperature is already a reality; the temperatures measured are increasing significantly. In North Rhine-Westphalia, the mean annual air temperature has increased by about 1.4 °C. Mean annual air temperatures of up to about 14 °C and 12 °C by the end of the century have been projected for RCP 8.5 and RCP 4.5 respectively. In contrast, the climate change mitigation scenario RCP 2.6, which is currently only available as a single model and therefore cannot be displayed in percentiles, will reach its peak of a mean annual air temperature of almost 11 °C in the first half of the century.

Figure 11 Observed and projected hot days per year in NRW



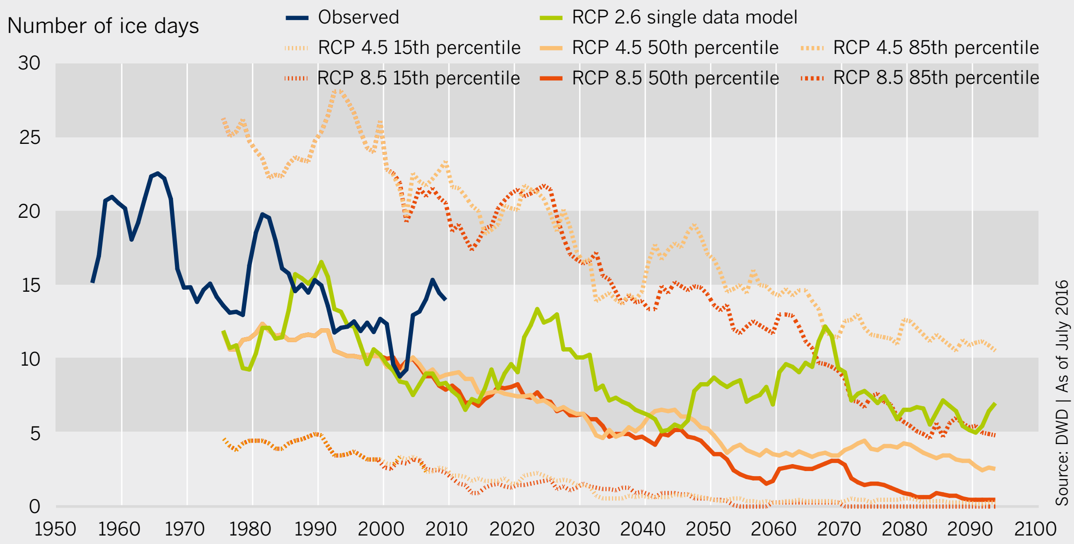
An increase in the number of hot days (with a maximum air temperature of at least 30 °C) per year has already been observed in the last few decades. Whereas a maximum of roughly 20 hot days by 2050 are projected in scenario RCP 8.5 – which is characterized by high greenhouse gas emissions – and RCP 4.5 – which is characterized by moderate greenhouse gas emissions – by the end of the century, up to 40 hot days are projected for the "business as usual" scenario. It would be worthwhile implementing effective global climate mitigation measures soon. According to scenario RCP 2.6, represented here in a single model run, these changes could be limited to about 12 hot days per year (50% more than in the 2003 "summer of the century").

In 2003, the "summer of the century" brought eight days with a maximum air temperature of at least 30 °C to North Rhine-Westphalia – a record value that had not been observed up until then. According to the climate modeling results, these figures will be reached more frequently in the future. In the moderate emissions scenario RCP 4.5, "summers of the century" will appear more frequently up until the middle of the century and even more frequently by the end of the century.

If we go by the 50th percentile of scenario RCP 8.5, the number of hot days per year is already 10 days mid-century and by the end of the century this number has even doubled to about 20 days per year. The maximum estimate of hot days for the end of the 21st century is 40 days per year – five times the number of hot days during the "summer of the century" in 2003 (see figure 11).

In line with the increase in the number hot days, the observed number of ice days of currently roughly 12 days per year will drop to a value of under five days per year; in scenario 8.5 it is even possible that there will be no more extremely cold days like this in the future (see figure 12).

Figure 12 **Observed and projected ice days per year in NRW**



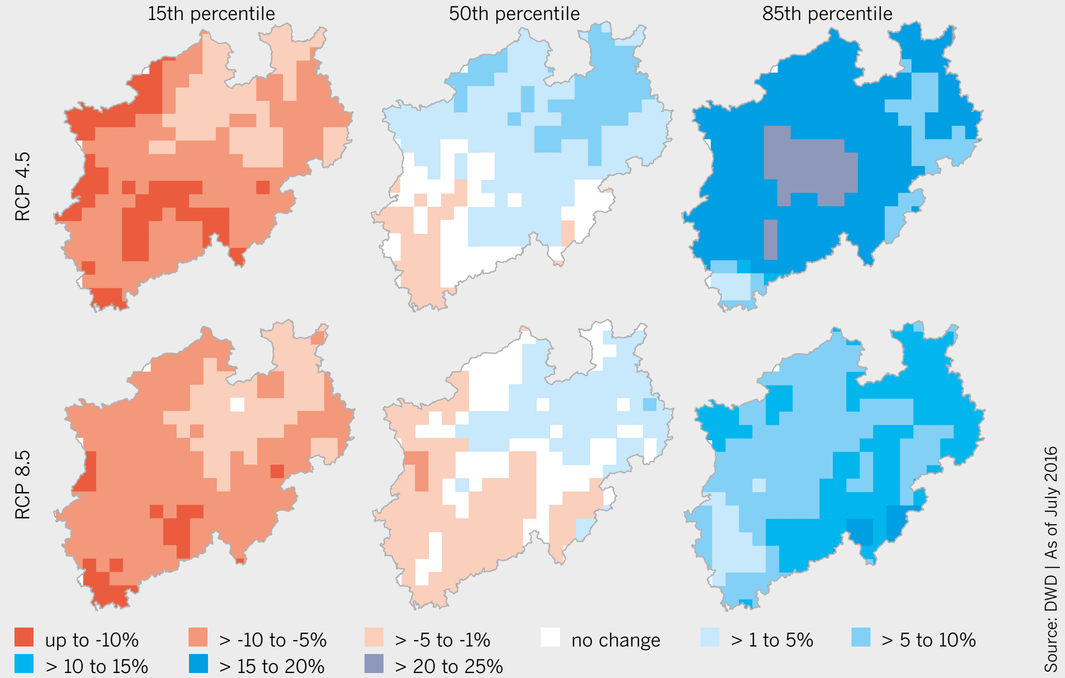
The number of ice days with frost, where the air temperature continuously remains below 0 °C, is subject to major fluctuations. Nevertheless, the number of ice days has significantly decreased in North Rhine-Westphalia in past years. In the "business as usual" scenario RCP 8.5 and the stabilization scenario RCP 4.5, years without ice days could become a reality from about 2050, with corresponding consequences for the winter sport regions in Sauerland and Siegerland-Wittgenstein. In the climate mitigation scenario RCP 2.6, represented in a single model run, the number of ice days could drop to five days per year.

Anticipated changes in the future: rainfall

There is an inconsistent picture for the summer months June, July and August (see figure 13). The changes projected range between a decrease of over 10% (15th percentile) to an increase of more than 20% (85th percentile). These changes only differ slightly, even using different emissions scenarios, although increases and decreases in summer precipitation rates up to the middle of the century appear less pronounced in scenario RCP 8.5. It is therefore impossible to make detailed statements about changes in summer precipitation patterns on the basis of these simulations.

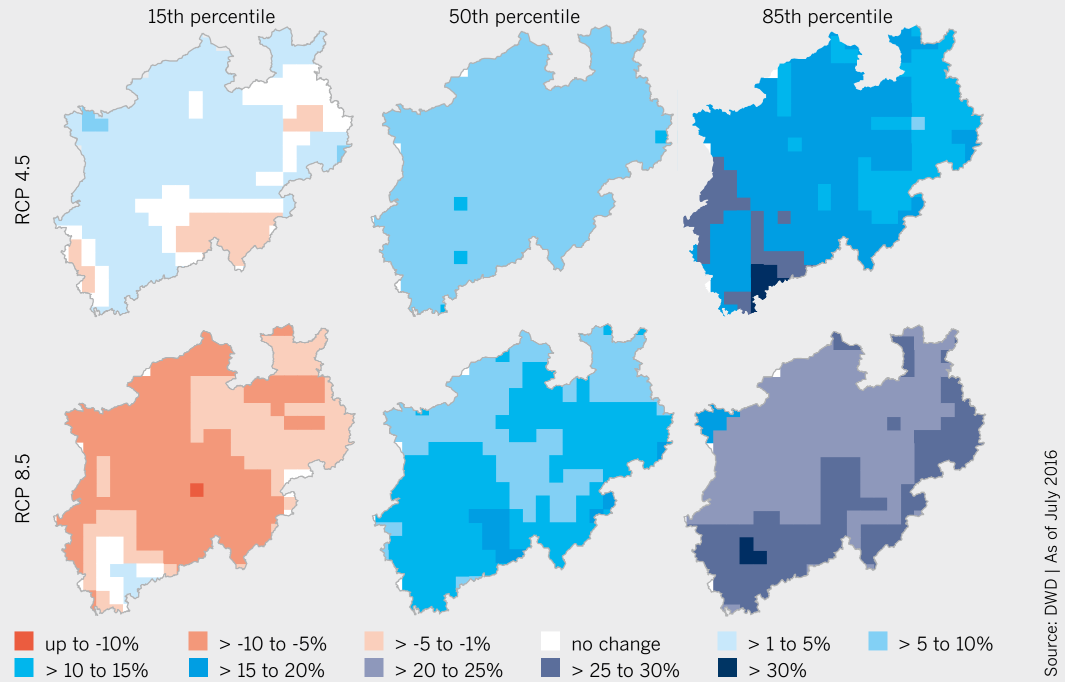
A clearer picture emerges when we take a look at winter precipitation rates for the months December, January and February, which are likely to increase in future. In scenario RCP 4.5, an increase of up to 20% can be expected for the period 2021 to 2050 compared with the reference time period 1971 to 2000 (see figure 14). The expected maximum increase in winter rainfall could be up to 30% in RCP 4.5, although this increase would be more significant in southern North Rhine-Westphalia.

Figure 13 Changes in mean precipitation totals in NRW, summer 2021 to 2050 with respect to 1971 to 2000



These scenarios portray a complex, spatially inconsistent picture that ranges from lower (a decrease of 10% or more) to higher precipitation patterns (an increase of up to 25%) in summer and does not allow us to make any precise statements. But even if no changes take place, as modeled in the 50th percentile for certain regions, we must expect climate consequences resulting from the anticipated increase in the mean annual temperature and the expected increase in the number of hot days.

Figure 14 Changes in mean precipitation totals in NRW, winter 2021 to 2050 with respect to 1971 to 2000



Projections for winter precipitation totals also show considerable regional differences, but are less disparate overall than the projections for precipitation totals in the months June, July and August. Similar to the projections for the mean annual precipitation total, they suggest that rainfall in the months December, January and February is likely to increase by 2050.

Anticipated impacts in the future: health, agriculture, heavy rainfall

Bericht 226 des Deutschen Wetterdienstes (Report 226 of the Deutscher Wetterdienst)
www.umwelt2016.nrw.de/009

Numerous studies have proven the diverse effects that weather and climate have on wellbeing, performance and human health. Thermal conditions are of major significance in this regard; they have a direct effect on the health of certain risk groups. For example, heatwaves have a notable effect on patients with cardiovascular, vascular and respiratory diseases (Koppe 2005). This means that there is a noticeable increase in the mortality rate during a succession of days with high levels of heat stress.

A Germany-wide analysis has shown that the mortality rate for coronary cardiac disease increases by around 15% in connection with heatwaves. Another study has proven that heatwaves of higher intensity and increasing length are connected with higher mean mortality rates (Zacharias et al. 2014). Regional climate projections also clearly indicate future risk scenarios for North Rhine-Westphalia: In the future, heatwaves will occur more frequently, last longer and be more intense. Using current threshold values, it is projected that the number of heatwaves will increase threefold by the end of the century, that they will last 25% longer and that the average daily mean temperature will be about 1 °C higher during heatwaves than during the reference period 1971 to 2000 (Zacharias et al. 2015).

Even if the exact severity of the changes is characterized by a number of uncertainties, the direction this climate signal is taking is clear. It highlights the urgent need to counter the increasing risk potentials of heat with suitable adaptation and prevention measures.

Agriculture is particularly susceptible to the effects of weather, weather conditions and climate. Climate change could significantly alter crop-growing conditions. If we take a look at a defined time period such as, for example, the spring months, climate change decreases the dangers posed by late frosts. On the other hand, increasing temperatures mean that the growing season begins earlier. For the region of North Rhine-Westphalia, the growing season during the period 1981-2010 was observed to begin three to five days earlier on average in comparison with the period 1961-1990. In some years, as in 2003, even more severe deviations from the norm are possible. The growing season will begin earlier and earlier up until the middle of this century. According to climate projections, the growing season is expected to begin between two and 15 days earlier in the period 2021 to 2050 with respect to the period 1961 to 1990. This means that sensitive plant phases such as fruit blossom will begin earlier in the year. In turn, we can also expect an increase in the dangers posed by late frosts under these conditions (Gömann et al. 2015). Temperatures will also have a strong effect on plants' further development. Higher temperatures accelerate plant development, but in terms of grain cultivation, for example, a shorter grain-filling phase leads to a smaller crop yield.

Agrarrelevante Extremwetterlagen und Möglichkeiten von Risikomanagementsystemen (Extreme weather conditions relevant to agriculture and the potentials of risk management systems)
www.umwelt2016.nrw.de/010

The number of hot days during the growing season is increasing. In the Rhine-Ruhr metropolitan region and along the Rhine Valley in particular, the temperature is exceeding 30 °C more and more frequently. If air temperatures are significantly above the plant optimum, it can have an influence on the yield. This means that if the temperature exceeds 30 °C for even a short period of time during wheat flowering, it can lead to a rapid drop in the number of grains harvested. Alongside accelerated plant aging, heat impairs the photosynthesis process (Gömann et al. 2015, Lobell et al. 2012).

Plant transpiration increases with rising temperatures, which means that their need for water increases. If there is then less rainfall, the ground moisture situation intensifies significantly, as it did in summer 2003. That summer, with a mere 20% to 40% field capacity (FC), the ground moisture in North Rhine-Westphalia was 15% FC to 35% FC below the long-term mean. The ground moisture levels calculated using climate projection data show a decrease of up to 15% FC for the period 2021 to 2050.

On the one hand, this means that the artificial irrigation of fields (sprinkler irrigation) will gain in importance in the future. On the other hand, the draining of fields cannot be neglected due to increased rainfall in winter.

Over the course of the last 65 years, a 25% increase in the frequency of heavy rainfall in winter has been observed. According to the projections made in regional climate models, we must assume that this increase in North Rhine-Westphalia will continue on roughly the same scale until 2100. For the summer months, there are no discernible trends in relation to either average rainfall amounts or heavy rainfall. There is still relatively little information available overall with regard to the heavy rainfall of short duration predominantly relevant in Central Europe in the summer half-year. There are some indications that there will be an increase in the intensity of convective events (heavy rainfall of short duration) with increasing temperatures, however, more research is still needed.

Take action now

Global climate change does not stop at national borders: In North Rhine-Westphalia too, changes in the climate – some of them considerable – can be expected even during the lifetime of today's 40 and 50-year-olds. The effects of these changes will be noticeable in many areas of everyday life. This makes it even more important to implement immediate measures to reduce greenhouse gas emissions to net-zero during this century. This is the only way that we can prevent the worst consequences of climate change from taking place, meaning that we will "only" have to contend with the – still considerable – effects projected in scenario RCP 2.6. Besides this, it is essential to take suitable adaptation measures today in order to mitigate the future effects of climate change. In doing so, all parties firstly need to identify their vulnerability and, in a second step, set in motion suitable measures to adapt to the anticipated changes.

The German Strategy for Adaptation to Climate Change: Alongside agriculture and human health, climate change will also affect other areas of everyday life – for example, water resource management, forestry, tourism, and the energy and financial sectors. The German Strategy for Adaptation to Climate Change has created a framework for adapting to the consequences of climate change. It lays the foundations for a medium-term process that – with the involvement of the federal states and community groups – aims to evaluate the risks of climate change, identify any possible action that needs to be taken, define appropriate objectives and develop and implement possible adaptation measures step by step. In 2015, the federal government presented a progress report for further development and concrete implementation, whose central elements comprise a monitoring report, statements on climate change, climate impacts and vulnerability as well as the "Adaptation Action Plan II." This action plan includes future government measures as well as a specific time plan and financing plan.

Netzwerk Vulnerabilität (Vulnerability Network): The Netzwerk Vulnerabilität, an association of 16 federal authorities and institutes, has carried out an analysis of Germany's vulnerability to climate change. German-wide cross-sector regions and systems have been identified that are particularly susceptible to the dangers posed by climate change.

Aktionsplan Anpassung (Adaptation Action Plan)
www.umwelt2016.nrw.de/011

Netzwerk Vulnerabilität (Vulnerability Network)
www.umwelt2016.nrw.de/012

Climate, energy and efficiency in North Rhine

Increase in mean annual air temperature

1.4 °C

increase since 1881

Onset of apple blossom

9 days

earlier since 1951

Increase in no. of hot days > 30 °C[1]

5 days

since 1951

Decrease in no. of snow cover days[1]

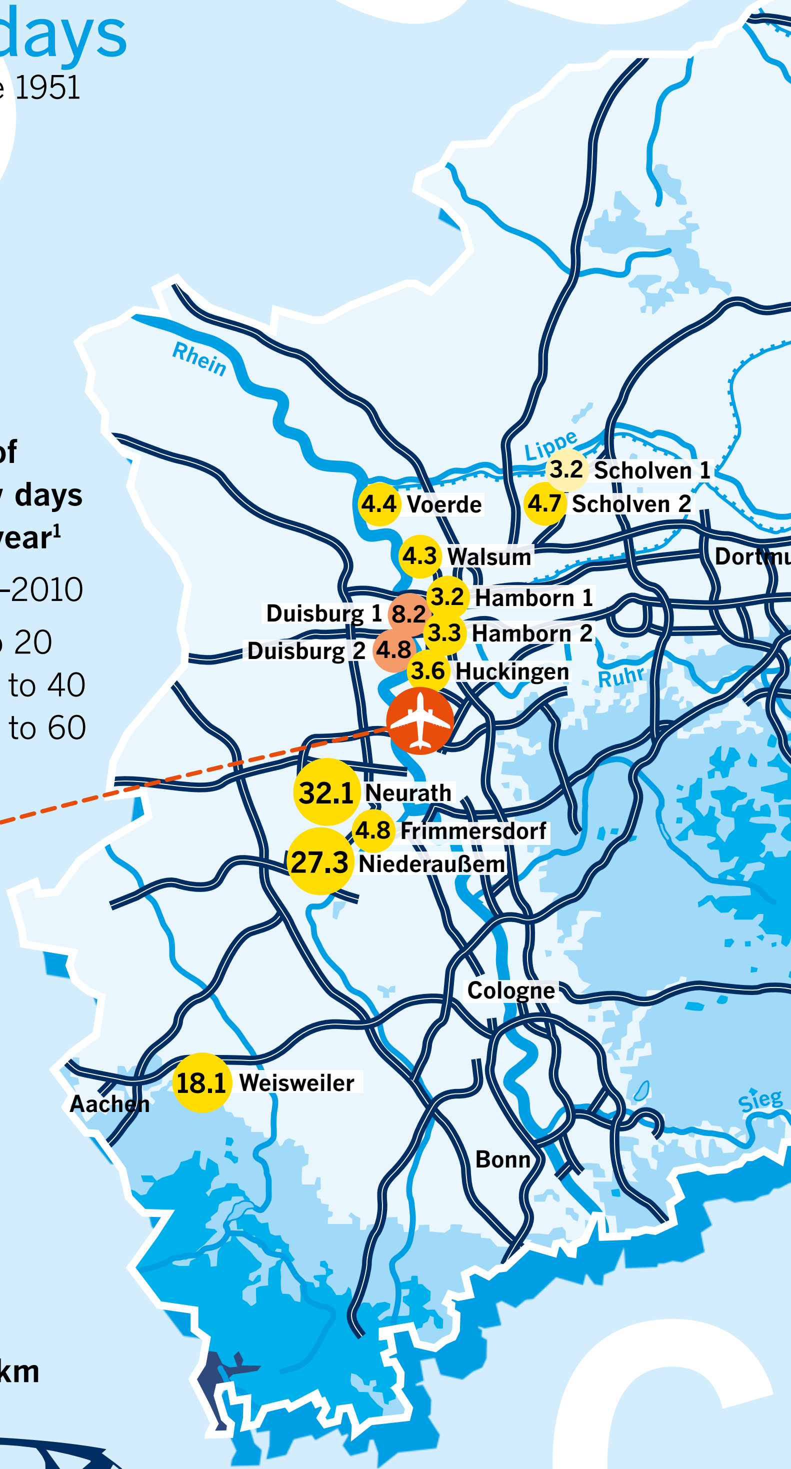
25 days

at Kahler Asten since 1955

No. of snow days per year[1]

1981–2010

- up to 20
- > 20 to 40
- > 40 to 60
- > 60



CO_2 emissions Düsseldorf–Canary Islands/Spain[2]

return flight

1.9 t per person

CO_2 emissions per 10,000km by car (8 l/100 km gas)[2]

2.2 t

1 Source: DWD | As of July 2016 ▪ 2 Source: UBA | As of October 2016 ▪ 3 Source: LANUV | As of October 2016 ▪ 4 Source: DGVN | As of November 2016 ▪ Map: Artalis Kartographie und Design,

-Westphalia

Resource productivity

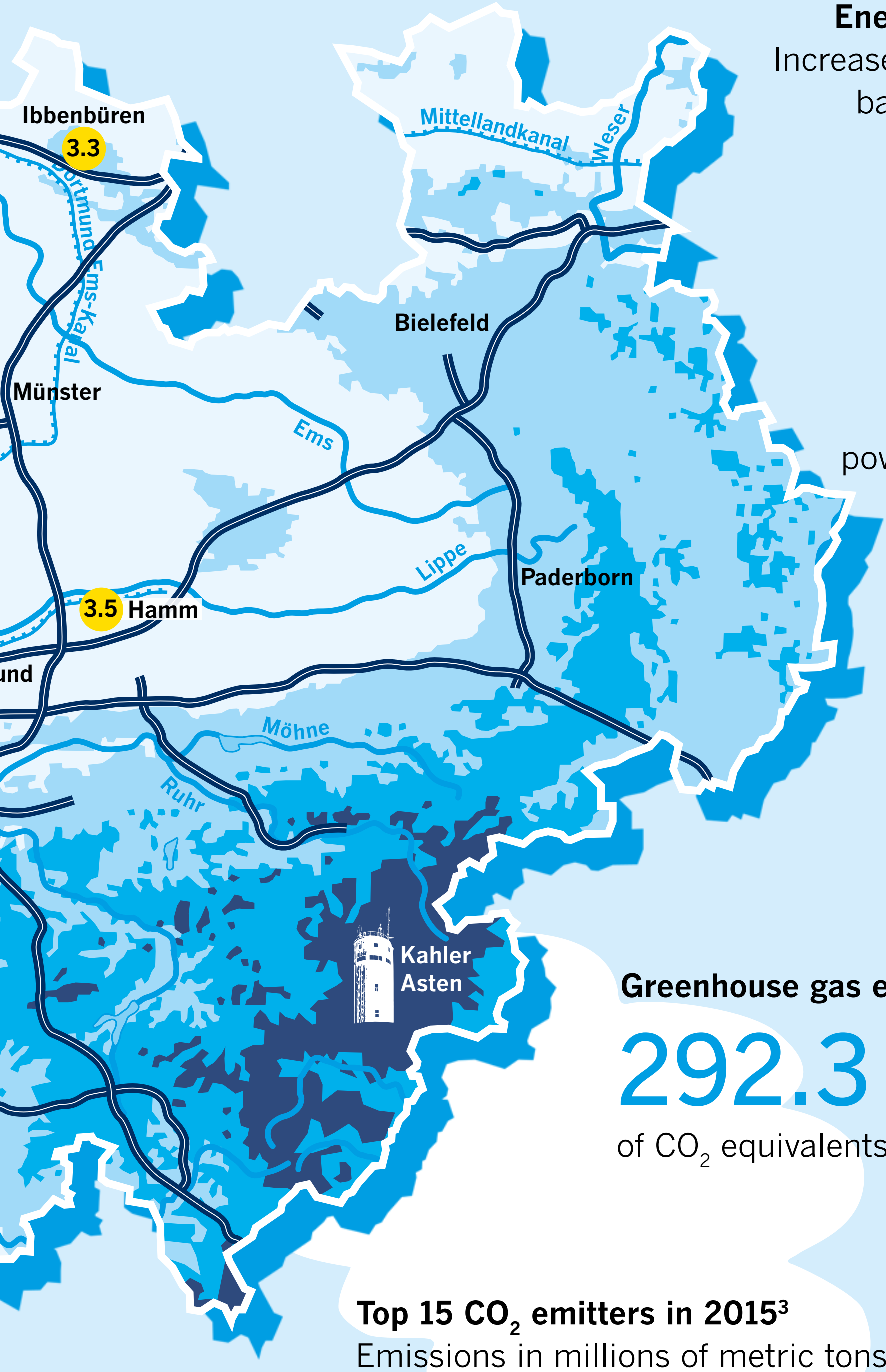
28%

Increase compared with baseline year 1991

Energy productivity

Increase compared with baseline year 1991

18%



Share of renewable energies

11%

of gross power consumption

4%

of primary energy consumption

Climate Protection Plan

for North Rhine-Westphalia

Greenhouse gas emissions

292.3 million t

of CO_2 equivalents in 2014, i.e. 16.6 metric tons per capita

Top 15 CO_2 emitters in 2015[3]

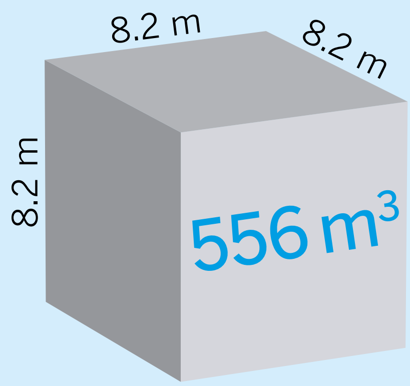
Emissions in millions of metric tons

up to 10 | 10 to 20 | 20 to 35 — 12 power plants

up to 10 — 2 metal-working plants

up to 10 — 1 crude oil refinery

Volume of 1.0 t of CO_2 gas[4]



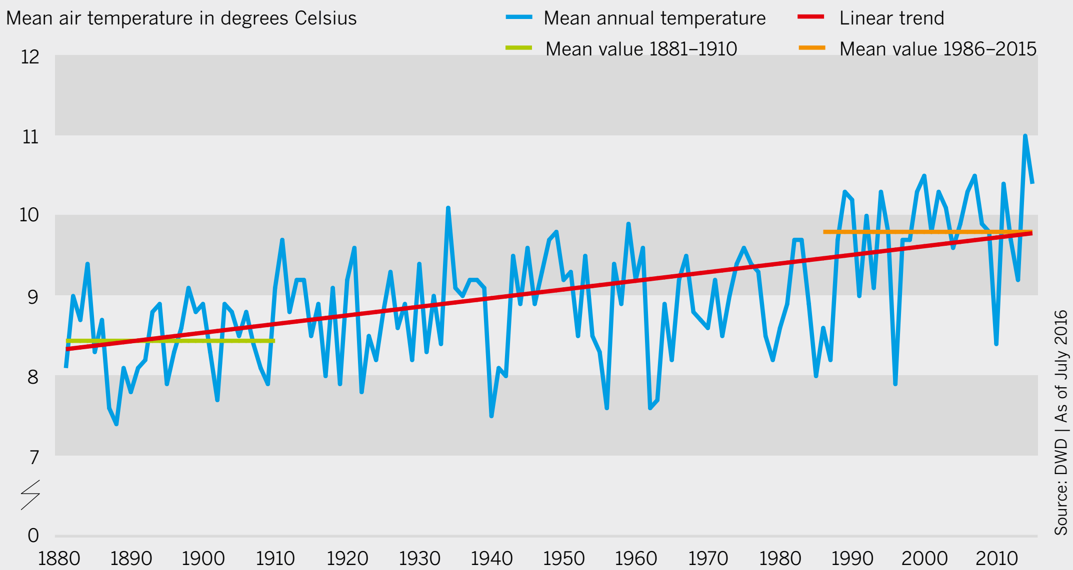
Jacqueline Böttcher

Climate change, impacts and adaptation

The climate is changing worldwide. As the Fifth Assessment Report of the IPCC has shown, since the beginning of industrialization, emissions of greenhouse gases resulting from the use of fossil fuels have led to a warming of the earth's atmosphere. The increase in the average global temperature is the most distinctive, but by far not the only impact of climate change. All over the world, living conditions are changing for humans as well as for fauna and flora in all climate zones – with in part dramatic consequences. What is worrying is that this development has become more dynamic over the course of the last 30 years.

Climate change has arrived in North Rhine-Westphalia too, where, above all, it has led to an increase in the annual average temperature: Summers have become warmer, winters milder. But annual rainfall has increased too. Moreover, a seasonal rainfall shift from summer to winter has been detected. In the future, drier summers could have severe consequences for agriculture and the water balance. Overall, temperatures are expected to rise, precipitation patterns may change and severe weather events will probably become more frequent. In addition to ambitious measures for increased climate change mitigation, measures are now being taken to adapt to climate change in order to catch these changes early on in a preventative sense.

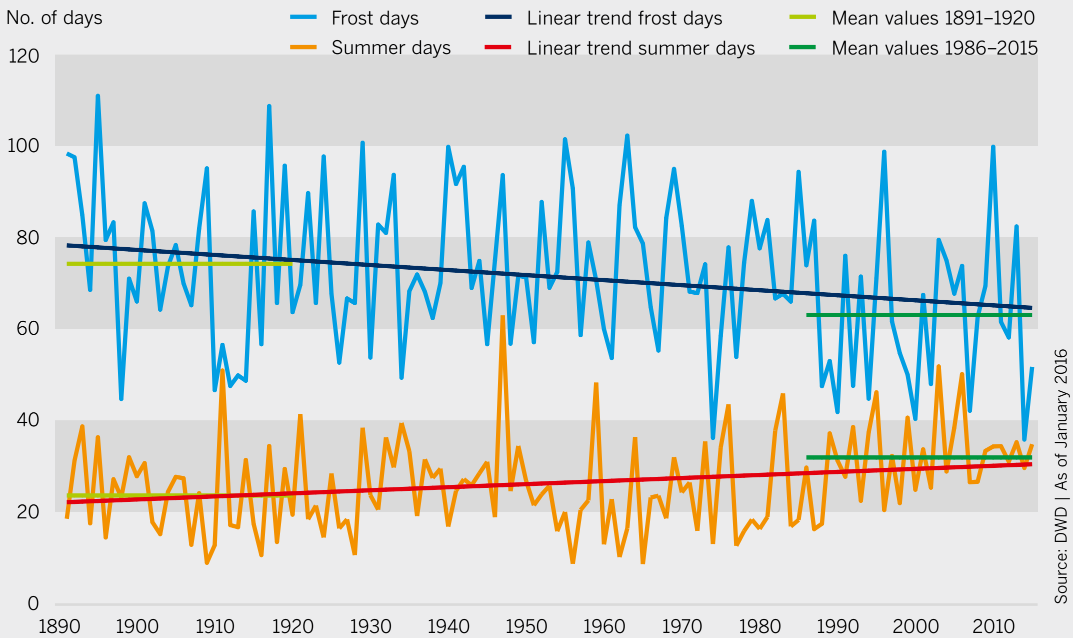
Figure 15 Mean annual air temperature in NRW



The annual mean air temperature for the thirty-year period 1881 to 1910 was 8.4 °C. This value was 1.3 °C higher during the period 1986 to 2015. The average value for the entire period was 9.0 °C. This measurement series has shown a significant upward trend since the beginning of weather records in 1881. The 10 warmest years have reached an annual mean of at least 10.3 °C, and all of them fall within the last 30-year period. The state's lowest mean annual temperature of 7.4 °C was recorded in 1888, and the highest, at 11.0 °C, in 2014.

Monitoring the impacts of climate change Temperature
www.umwelt2016.nrw.de/013

Figure 16 Frost and summer days in NRW

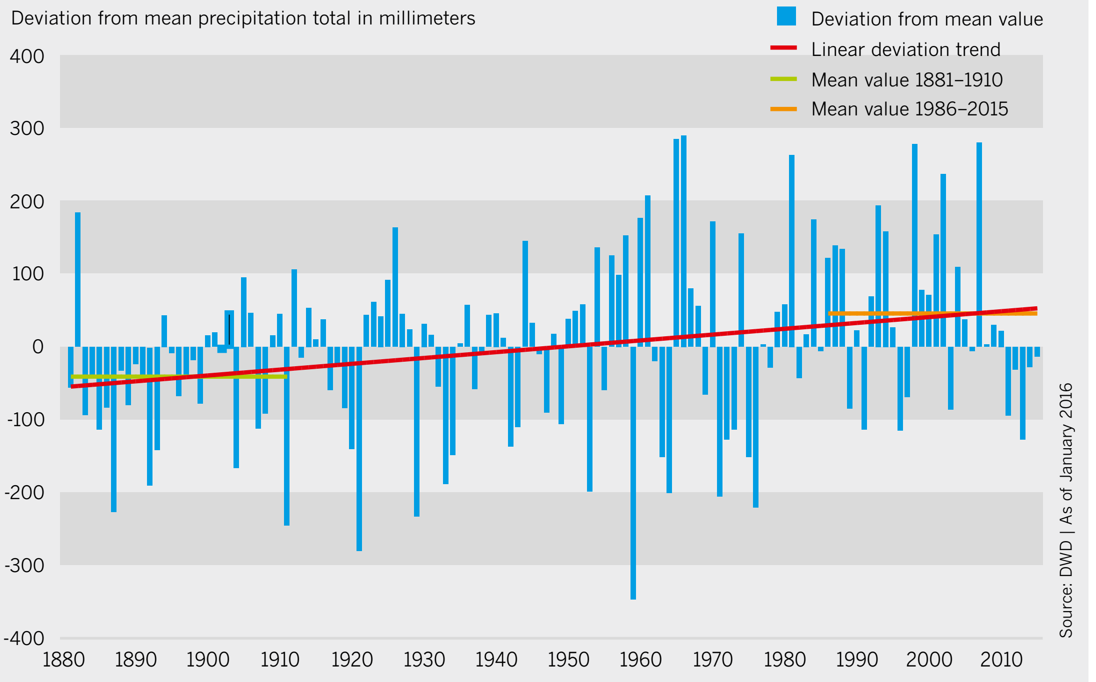


Frost days are days where the minimum daily air temperature is lower than 0.0 °C. In contrast, summer days reach a maximum daily temperature of 25.0 °C or more. In the 30-year period 1891 to 1920, there was an average of 74 frost days per year; during the period 1986 to 2015, there were only 63 frost days per year. The year with the highest number of frost days was 1895 with 111 frost days, and the lowest number of frost days was in 2014 with 36. There is a statistically significant trend toward less frost days. There are more summer days today than at the end of the 19th century and there is a growing trend. Between 1891 and 1920, the annual mean value was 24 summer days; in the last 30 years, the mean value was 32 summer days per year.

Monitoring the impacts of climate change Cold temperature threshold days
www.umwelt2016.nrw.de/014

Monitoring the impacts of climate change Warm temperature threshold days
www.umwelt2016.nrw.de/015

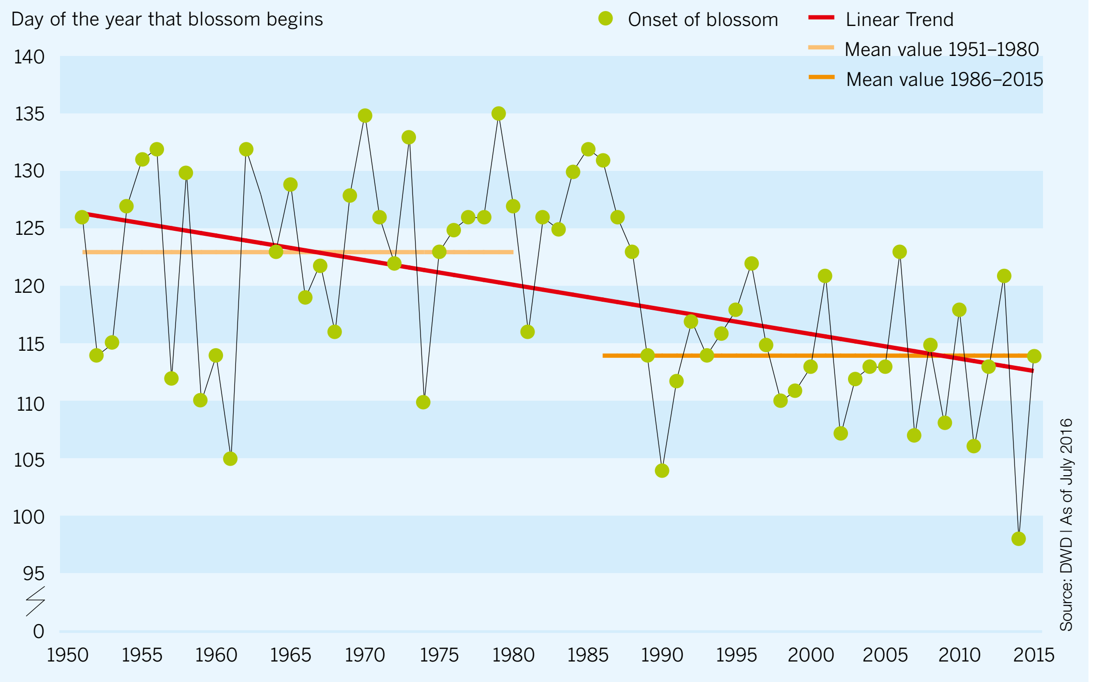
Figure 17 Deviations from long-term annual average total precipitation in NRW



Average annual total precipitation in North Rhine-Westphalia for the period 1881 to 2015 was 848 millimeters. In the 30-year period 1881 to 1910, the average value was 40 millimeters below the long-term mean; in the most recent 30-year period, 1986 to 2015, it was 47 millimeters above it. The lowest precipitation total was observed in 1959 at 501 millimeters, and the highest precipitation total was observed seven years later in 1966 at 1,138 millimeters. Throughout the entire measurement period 1881 to 2015, there was a trend toward higher annual precipitation totals.

Monitoring the consequences of climate change: Precipitation
www.umwelt2016.nrw.de/016

Figure 18 Environmental indicator: apple blossom – impact of climate change in NRW



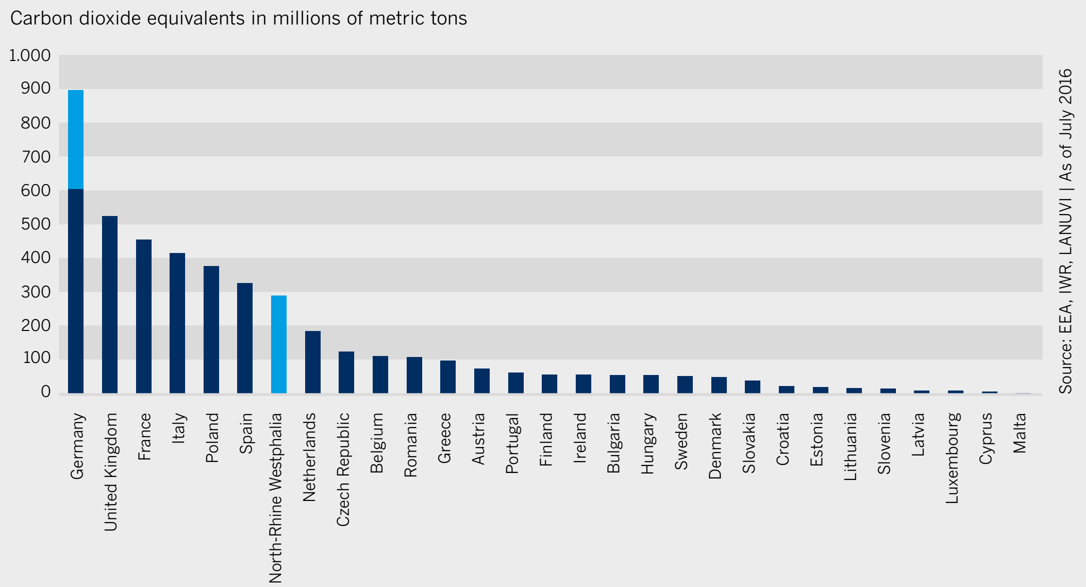
The onset of the apple blossom marks the annual start of full spring. A trend analysis has confirmed a significant trend toward an earlier onset of blossom. The difference between the mean values of the onset of blossom in the 30-year periods 1951 to 1980 and 1986 to 2015 was nine days. The start of full spring has shifted from May to April. This indicator is an example of how ecosystems react to changing environmental conditions and shows that climate change has also arrived in North Rhine-Westphalia.

Environmental indicator: apple blossom – impact of climate change
www.umwelt2016.nrw.de/022

Climate protection and future energies

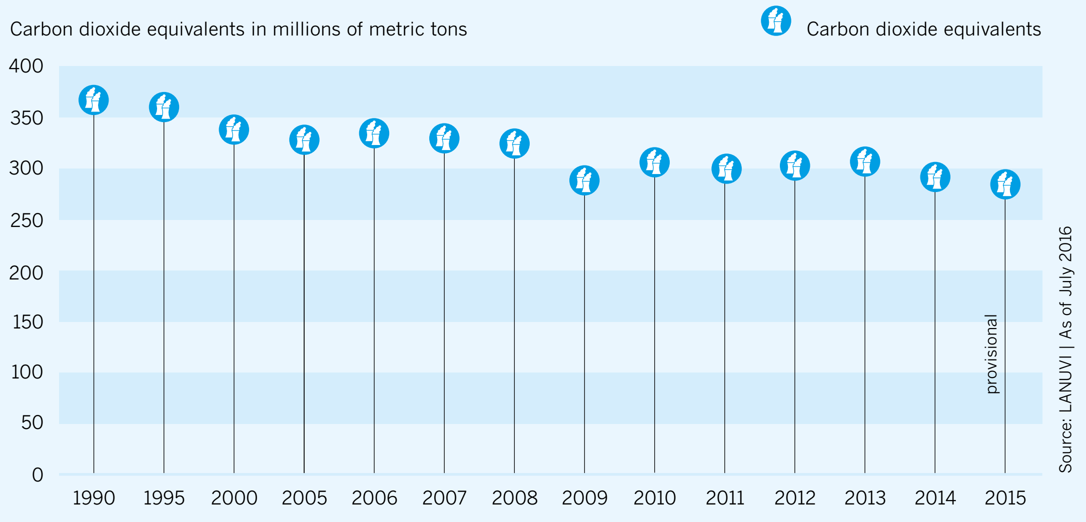
The climate, climate protection and humanity's hunger for energy are closely connected. At the turn of the millennium, the Nobel Prize-winner Paul Crutzen contributed the term "Anthropocene" to the scientific discussion: a new epoch characterized by humanity's influence on geologically significant processes – including the chemical composition of the soils, the oceans and the atmosphere. Most consider the starting point for this age to be the industrial revolution and the use of fossil fuels to generate power on an industrial scale. For around 200 years, power generation has been based in large part on the burning of fossil energy sources such as coal, natural gas and crude oil. As a result, the amount of greenhouse gases in the atmosphere causing climate change has grown significantly. In order to reach the objective set at the climate conference in Paris at the end of 2015 of limiting the increase in the average global temperature to less than 2 °C above the preindustrial temperature level, we will need to keep expanding our use of low-carbon future energies. Furthermore, it also requires the introduction and widespread use of efficient, innovative technologies. Only when we significantly reduce greenhouse gas emissions will we be able to keep climate change and its consequences within a manageable scope. As Germany's number-one industrial state, North Rhine-Westphalia has a particular responsibility in this regard. As the seventh-largest emitter of greenhouse gases in the European Union – with 50% of its CO_2 emissions coming from the energy sector – if North Rhine-Westphalia does not make a significant contribution, neither Germany nor the European Union will be able to reach their climate change mitigation objectives.

Figure 19 Greenhouse gas emissions in the European Union in 2014



In 2014, the 28 states of the EU emitted a total of 4.3 billion metric tons of CO_2 equivalents (around 8.5 metric tons of CO_2 equivalents per capita, primary energy sources). Germany emitted more than one fifth of this overall amount and, with 900 billion metric tons of CO_2 equivalents, was the largest EU emitter (around 11.1 metric tons of CO_2 equivalents per capita). North Rhine-Westphalia accounted for around 292 million metric tons of CO_2 equivalents (roughly 16.6 metric tons per capita), which means that the state is one of the seven largest emitters of greenhouse gases in the EU. In 2014, the US emitted about 6.9 billion metric tons of CO_2 equivalents (about 21.5 metric tons per capita); the most current available figures for China have recorded around 11 billion metric tons of CO_2 equivalents for the year 2012 (roughly 8.1 metric tons per capita).

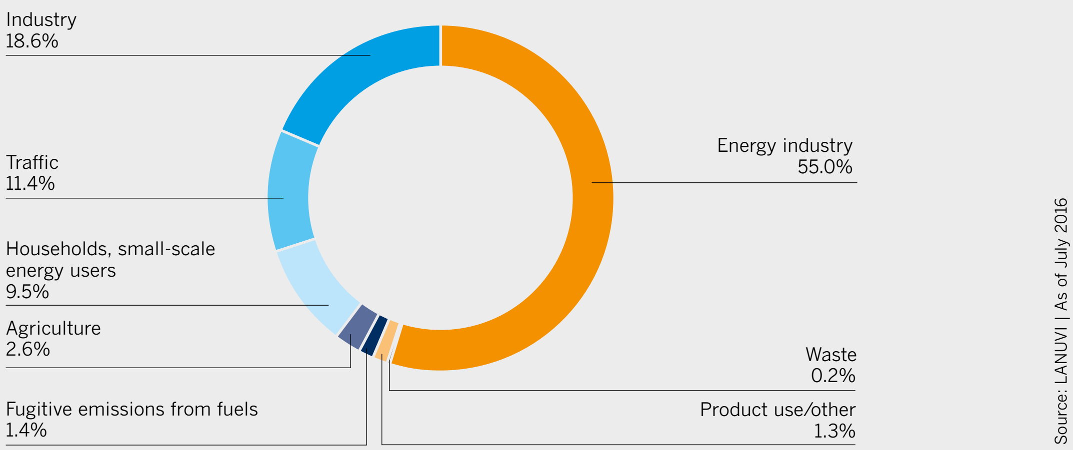
Figure 20 Environmental indicator: greenhouse gas emissions in NRW



In 2014, North Rhine-Westphalia emitted roughly 292.3 million metric tons (converted into CO_2 equivalents) of climate-damaging emissions; in 2015 emissions totalled roughly 284.5 million metric tons (provisional value). Emissions decreased by 20.4% (2014) and 22.6% (2015) respectively compared with the reference year 1990. In the last ten years, there has been a significant downward trend in the amount of emitted greenhouse gases. More substantial efforts are required to achieve the objectives set out in NRW's Climate Protection Act (Klimaschutzgesetz): a reduction in greenhouse emissions of at least 25% by 2020 and a reduction of at least 80% compared with the 367 million metric tons emitted in 1990 by 2050 (this would mean a maximum of 275 million metric tons being emitted by 2020 and a maximum of 73 million metric tons of CO_2 equivalents per year from 2050).

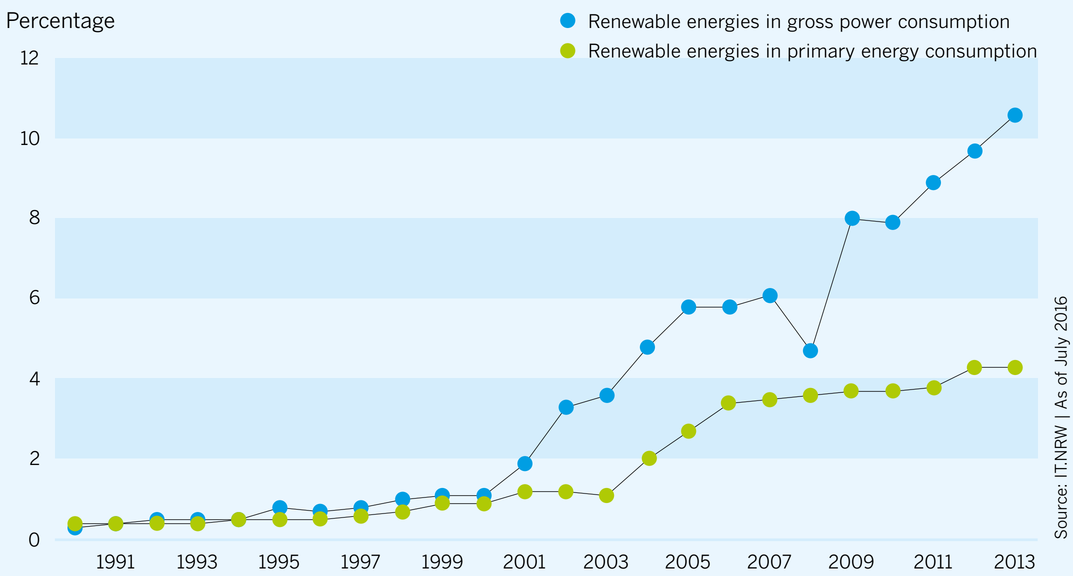
Environmental indicator: greenhouse gas emissions
www.umwelt2016.nrw.de/028

Figure 21 Distribution of greenhouse gas emissions in NRW in 2014



The energy sector – lignite and coal-based power generation in particular – has consistently been one of the major sources of greenhouse gas emissions. In 2014, 55% of the state's emissions came from this sector; it is the only sector in which emissions have not dropped below 1990 levels (there are currently 1.5 million metric tons or roughly 1% more emissions than in 1990). Other significant sectors in 2013 were industry with around 18%, traffic with around 11% and households and small-scale consumers with around 10% of total emissions. Agriculture was responsible for 2.6% of local greenhouse gas emissions. Fugitive emissions from fuels, for example, from coal mines and the oil and gas industries, accounted for 1.4% of emissions. The use of products such as the refrigerants in air-conditioning units generated about 1.3% of emissions, while waste only had a share of 0.2%.

Figure 22 Environmental indicator: renewable energies in gross power consumption and primary energy consumption in NRW



In 2013, renewable energies made up 10.6% of gross power consumption and 4.3% of primary energy consumption (consumption of unconverted primary energy sources). Both shares have displayed a significant positive trend over the last 10 years. However, major efforts are required to reach the objectives set on both state and federal levels. The NRW Climate Protection Plan (Klimaschutzplan) envisages at least 30% of electricity being generated from renewable energies in 2025, and the federal government's energy concept aims to increase the share of renewable energies in Germany's gross energy consumption to 30% by 2030.

Environmental indicator: renewable energies in gross power consumption and primary energy consumption
www.umwelt2016.nrw.de/031

Energy and resource efficiency

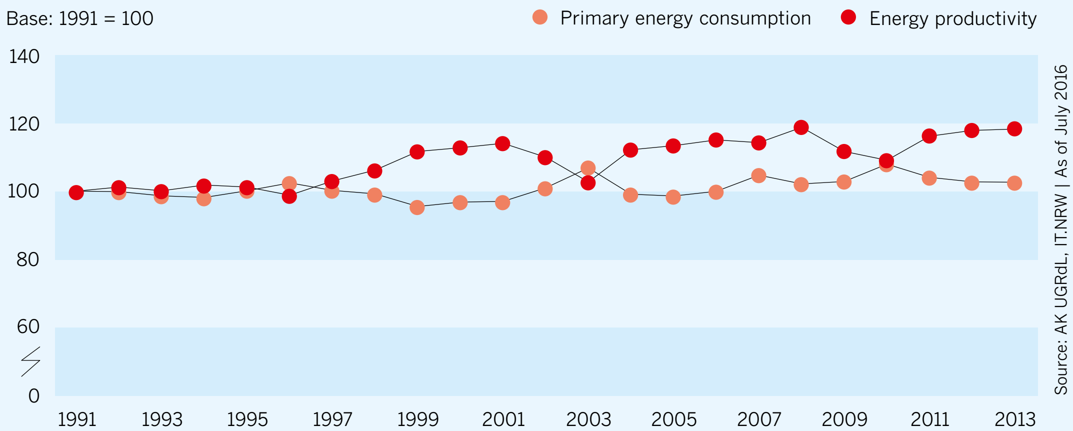
It holds true on both a small and a large scale, for households, public institutions, companies and for entire national economies: The economical, efficient management of natural resources – especially fossil energy sources and non-renewable resources – is a yardstick for sustainability. This is because the exploitation of (finite) resource reserves results in direct environmental damage as well as indirect consequences for the climate. Moreover, the economic and ecological cost of using non-renewable resources increases in the long term. This is why we urgently need to increase resource and energy efficiency, to improve resource conservation by implementing circular economy measures and, finally, to reduce resource and energy consumption levels. It is against this backdrop that efficiency has become one of the guiding principles of North Rhine-Westphalia's sustainability strategy, which also has to do with the fact that North Rhine-Westphalia is a center for many energy and resource-intensive industries: This is where about one third of German power is produced and where one quarter is consumed. Overall, about one third of Germany's greenhouse gas emissions come from North Rhine-Westphalia. The state's climate change mitigation policy in this context follows an industrial policy strategy that puts its trust in North Rhine-Westphalia's potential for innovation as a center of business, science and research. The cornerstones of NRW's first Climate Protection Plan and NRW's Green Economy Strategy are the consistent use of existing efficiency technologies as well as strengthened efforts to develop and research new low-carbon technologies. The latter could contribute to a decoupling of economic growth and resource consumption in the future. This means that North Rhine-Westphalia has the opportunity to become a trailblazer in an ecological and industrial transformation.

Figure 23 Environmental indicator: resource productivity and resource consumption in NRW

Resource productivity – the relationship between the gross domestic product and the consumption of abiotic, non-renewable resources – amounted to a value of 128 in 2014. A trend analysis of the last 10 years has shown a significantly positive trend. In contrast, the resource consumption indicated here as an index stagnated statistically at an undesirably high level. However, the beginnings of a decoupling of the gross domestic product – the measure of economic performance – and resource consumption have been observed. Up until the adoption of a new edition of the 2016 German Strategy for Sustainable Development, the national objective is to increase resource productivity to twice the level of the baseline year 1994 by 2020.

Environmental indicator: resource productivity and resource consumption
www.umwelt2016.nrw.de/038

Figure 24 Environmental indicator: energy productivity and primary energy consumption in NRW



Energy productivity, the gross domestic product achieved in relation to primary energy consumption, is a measure of the efficiency of energy use. The value 100 designates the level reached in the baseline year 1991. In 2013, local energy productivity was 118 and thus only 18% higher than at the beginning of the time series. The result of the trend analysis for the years 2004 to 2013 was a significant trend toward stagnation. Primary energy consumption over the last 10 years, displayed here as an index, also stagnated (primary energy requirements were 4,194 petajoules or about 239 gigajoules per capita in 2013). The clear decoupling desired between the gross domestic product and primary energy consumption has not yet been observed. The federal government's energy concept includes the goal of increasing energy productivity to twice its 1990 level by 2020. North Rhine-Westphalia's Climate Protection Plan strives to increase final energy productivity by 1.5% to 1.8% per year.

Environmental indicator: energy productivity
www.umwelt2016.nrw.de/047

Environmental indicator: primary and final energy consumption
www.umwelt2016.nrw.de/037

Environment and health in North Rhine-Westphalia

Nitrogen dioxide concentration at urban background sites

NO_2 23 µg/m³

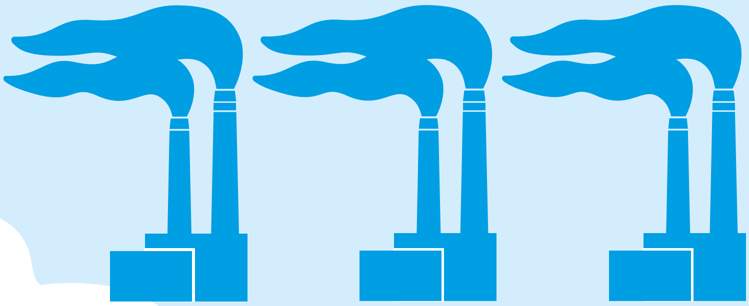
Mean annual value 2015

Nitrogen oxide emissions NO_x

294,000 t in 2012

Top 3 mercury emitters 2012[2]

Lignite-fired power plants



Weisweiler	Niederaußem	Neurath
299 kg	497 kg	497 kg

Concentrations of particulate matter at urban background sites

PM_{10} 18 µg/m³

Mean annual value 2015

Master Plan on Environment and Health
for North Rhine-Westphalia

Municipalities with air quality plans[3]

1 Source: IT.NRW | As of January 2016 ▪ 2 Source: Ökopol | As of 2016 ▪ 3 Source: LANUV | As of June 2016 ▪ 4 Source: MWEIMH | As of October 2016 ▪ 5 Source: KBA | As of January 2016 ▪ 6 Source:

Population[1]

17.7 million

people

Length of roads in interstate traffic[6]

Autobahn, federal, state and district roads

29,554 km

Night-time noise pollution over 55 decibels

1.4 million

people affected

Number of motor vehicles[5]

11.3 million

of those 3.8 million vehicles with diesel engines and 5,618 electric cars

Nuclear facilities[4]

3 interim storage/ enrichment technology

3 decommissioned/being dismantled/ in "secure containment"

Selection of important airports

6

Plants being monitored pursuant to the Industrial Emissions Directive

Around 3,200

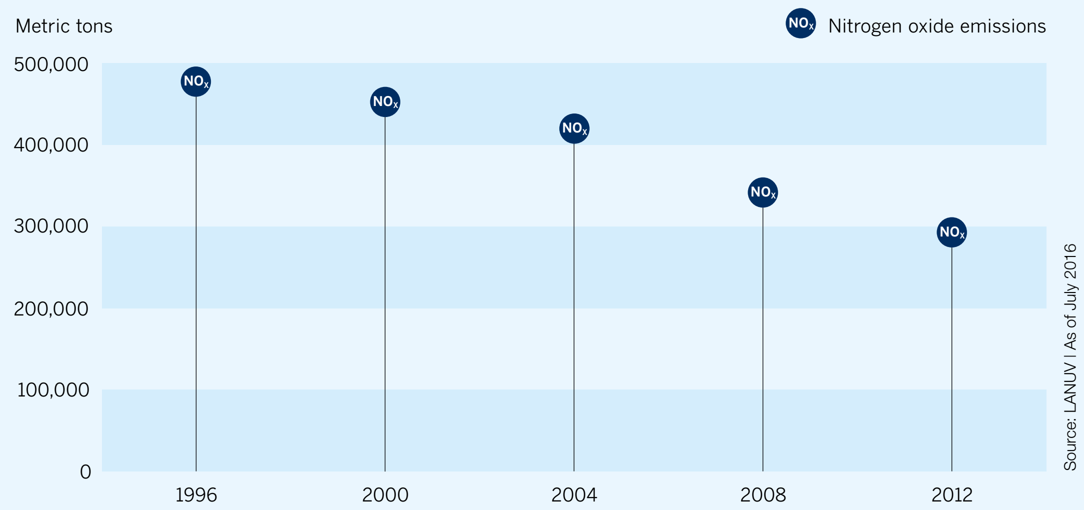
Straßen.NRW | As of January 2016 ▪ Map: Artalis Kartographie und Design, Jacqueline Böttcher

Air pollutants and other environmental contaminants

A network of monitoring stations continuously monitors North Rhine-Westphalia's air quality. Among the particularly harmful substances that they record are nitrogen dioxide and particulate matter. People who inhale these air pollutants regularly are more frequently afflicted by respiratory and cardiovascular diseases and cancer than people who are exposed to lower levels of pollution. Road traffic is one of the main sources of nitrogen oxides and particulate matter. These pollutants, which also pose a danger to health in just small amounts, concentrate in cities. This pollution primarily affects people who live on busy roads.

Organochlorides such as dioxins and polychlorinated biphenyls (PCBs) are some of the air pollutants which can pass into the food chain and contaminate the food we eat. The concentrations of dioxins and PCBs measured in the air are now in decline, although the long-life contaminant PCB remains a part of background pollution for decades. So there is no reason to sound the all-clear signal yet. Moreover, attention today is being directed toward pollution like mercury emissions from large-scale power plants, as emissions like these can accumulate in fish and find their way into our food as a result. For this reason, protecting the environment also means protecting human health – this is the guiding principle of the Master Plan on Environment and Health (Masterplan Umwelt und Gesundheit) that the State Government is now implementing. Its goal is to improve the framework for healthy environmental and living conditions in North Rhine-Westphalia. It also describes fields of action where approaches that transcend specialties and departments could provide added value for environmental health protection.

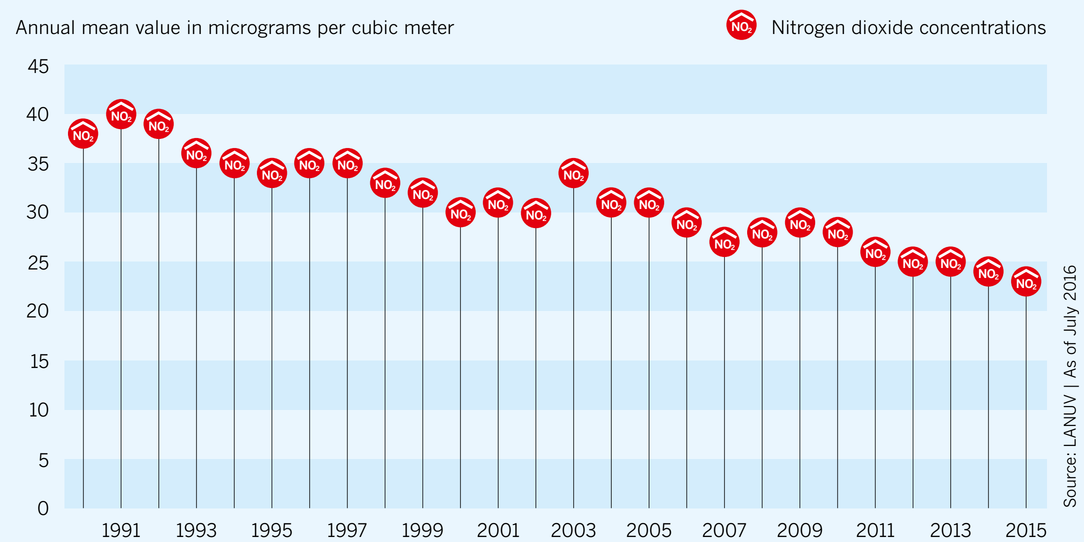
Figure 25 Environmental indicator: nitrogen oxide emissions in NRW



From the first observations 20 years ago to 2012, North Rhine-Westphalia's nitrogen oxide emissions dropped by 38% to 294,000 metric tons. The main emitters were industrial plants with 163,000 metric tons and road traffic with 84,000 metric tons. North Rhine-Westphalia's contribution comprised 28% of the total volume of 1,051,000 metric tons permitted for Germany by an EU directive, or 23% of the 1,274,000 metric tons actually emitted by Germany in 2012. The next data collection for North Rhine-Westphalia took place in 2016 and was not available at the time of publication.

Environmental indicator: nitrogen oxide emissions
www.umwelt2016.nrw.de/061

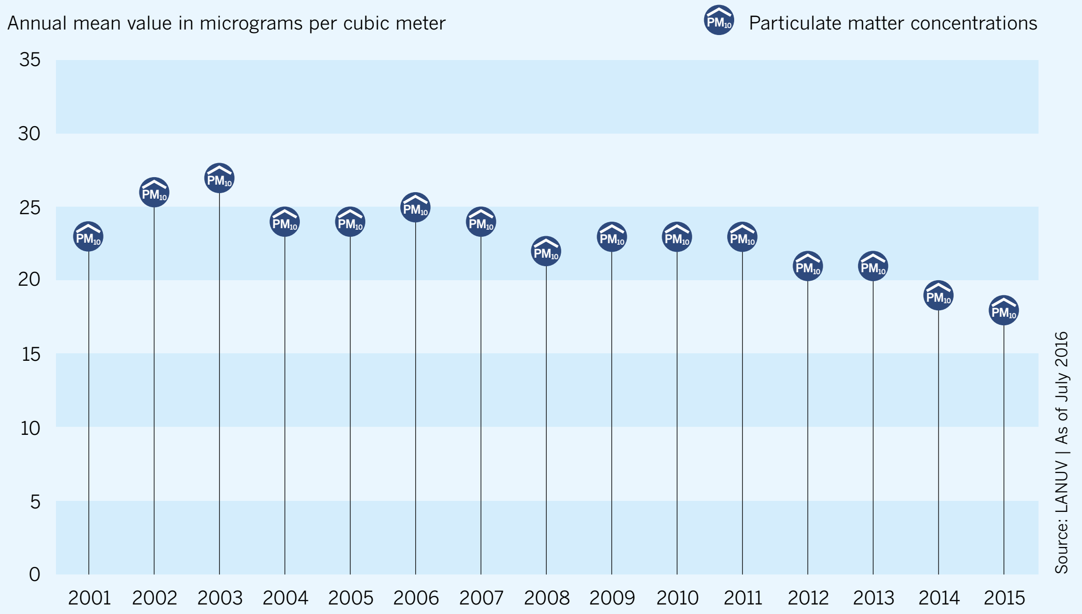
Figure 26 Environmental indicator: nitrogen dioxide concentrations at urban background sites in NRW



In 2015, the mean annual value for nitrogen dioxide concentrations at urban background sites calculated from data collected from 23 monitoring stations was 23 micrograms per cubic meter. This means that the nitrogen dioxide concentrations in residential areas away from very busy roads and industrial plants fell short of the statutory, EU-wide annual limit value of 40 micrograms per cubic meter. A trend analysis of the last 10 years has shown that nitrogen dioxide concentrations are dropping significantly. Nevertheless, the annual EU limit value for nitrogen dioxide concentrations on roads in urban agglomerations is still frequently exceeded.

Environmental indicator: nitrogen dioxide concentrations at urban background sites
www.umwelt2016.nrw.de/063

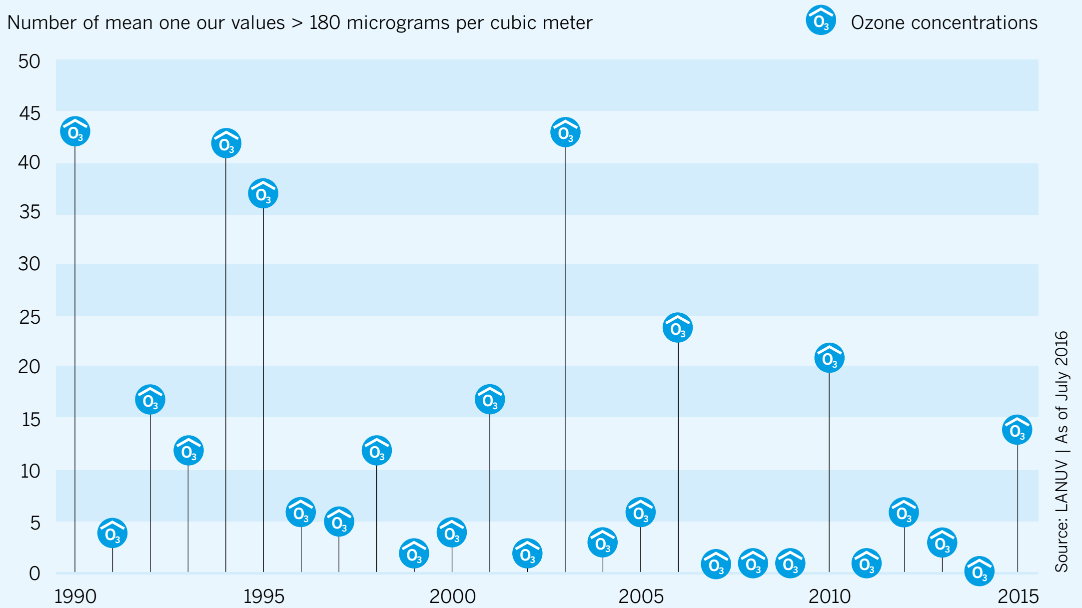
Figure 27 Environmental indicator: particulate matter concentrations at urban background sites in NRW



Urban background pollution with particulate matter smaller than 10 micrometers was below the annual EU limit value of 40 micrograms per cubic meter. A trend analysis of the last 10 years has shown a downward trend. This indicator comprises the annual means of PM_{10} pollution from 25 monitoring stations in urban residential areas. The State Government's goal is to reduce particulate matter concentrations to below 20 micrograms per cubic meter by 2030 at the latest – in compliance with the guideline values of the World Health Organization (WHO). This goal was reached at urban background sites in 2014 and 2015, aided by the absence of longer periods of atmospheric inversion.

Environmental indicator: particulate matter at urban background sites
www.umwelt2016.nrw.de/066

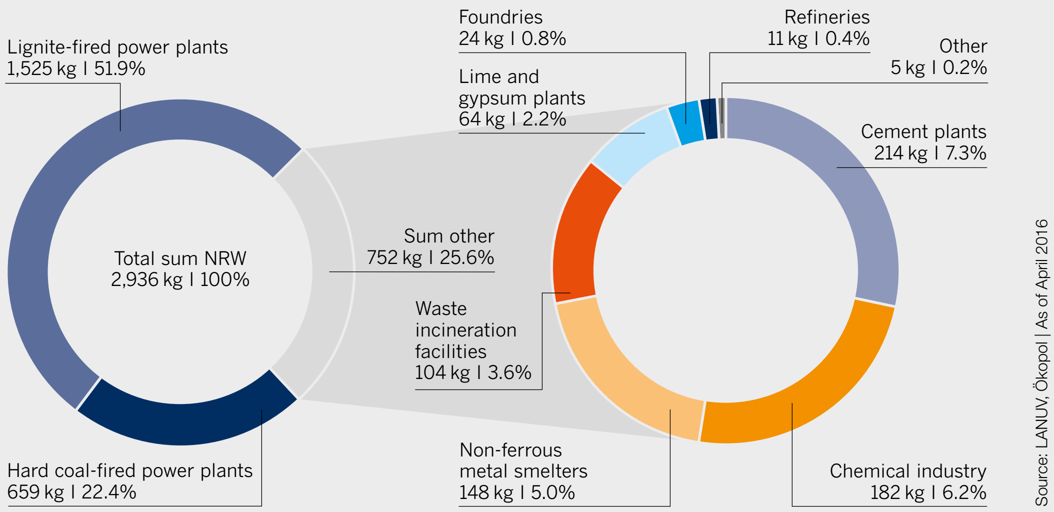
Figure 28 Environmental indicator: ozone concentrations at urban background sites in NRW



During the hot, sunny summer of 2015, the information threshold value of 180 micrograms per cubic meter was exceeded 14 times at the 21 monitoring stations, and the alarm threshold value of 240 micrograms per cubic meter was exceeded twice. However, there has been no discernible trend for ozone concentrations in the last 10 years, possibly because the incidence of high ozone values is coupled with (occasionally absent) midsummer periods of fine weather. This has been observed, for example, in values from the years 2003, 2006 and 2010 with their "summers of the century." The increased incidence of hot spells due to climate change could change this trend in the future.

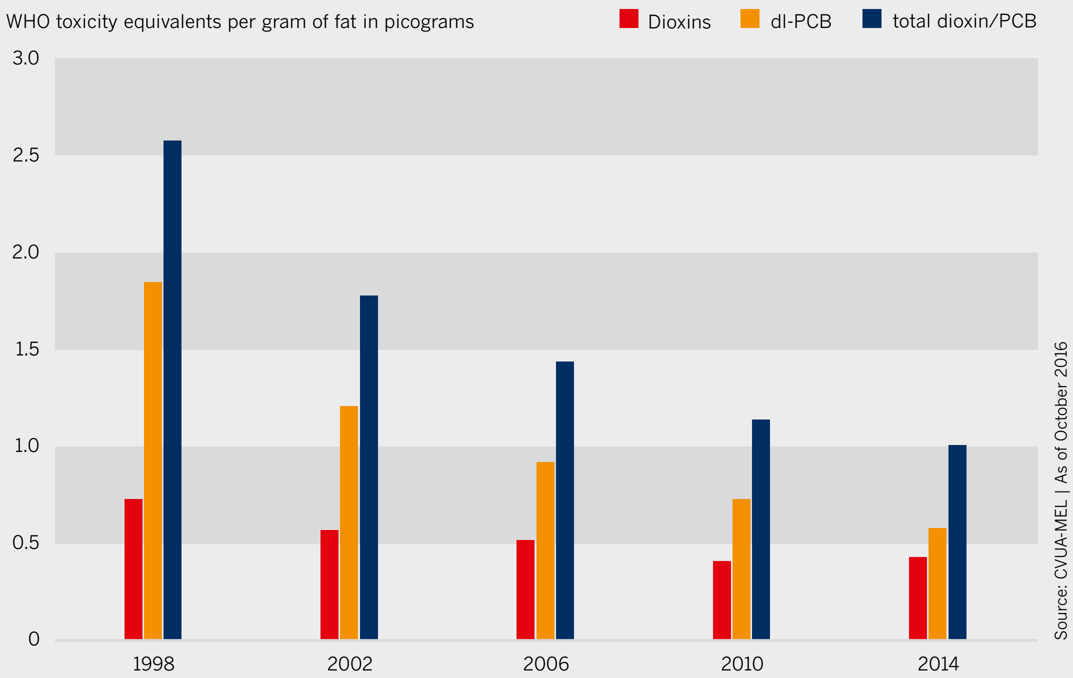
Environmental indicator: ozone concentrations at urban background sites
www.umwelt2016.nrw.de/069

Figure 29 Industrial mercury emissions in NRW in 2012



Lignite-fired power plants were responsible for more than half and coal-fired power plants for almost one quarter of the almost three metric tons of the state's highly toxic, harmful mercury emissions in 2012. The remaining quarter of the state's mercury emissions were accounted for by cement plants, the chemical industry, metalworking plants and waste incineration plants.

Figure 30 Dioxins and dioxin-like PCBs in raw milk from NRW



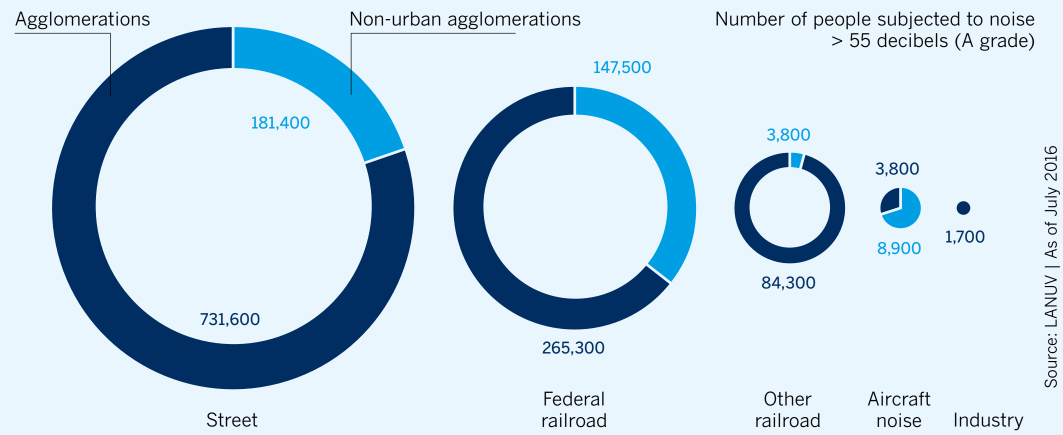
The results from 2014 show that the dioxin contamination of raw milk decreased by 75% and levels of dioxin-like PCB dropped by about 70% compared to 1998. Since 1990, a decrease of 90% has been observed for the sum of the six marker PCBs (dl-PCB), which account for half of the marker PCBs in food and animal feed. All of these values are significantly lower than the maximum EU limits laid down for dioxins, marker PCBs and the sum of dioxins/marker PCBs.

Noise pollution, radioactivity, electromagnetic fields

Like radioactivity and electromagnetic radiation, noise pollution is one of the physical phenomena that can have a negative impact on our health. According to the WHO, environmental noise is the second most significant environmental factor negatively affecting human health behind air pollution. In North Rhine-Westphalia, around 1.4 million people are affected by harmful environmental noise. The noise reduction strategy adopted by the cabinet in 2015 and the “NRW wird leiser” (“NRW gets quieter”) action alliance aims to noticeably reduce this noise pollution. Electromagnetic radiation is a by-product of electrical facilities, for example broadcasting facilities and power supply stations. Unlike noise pollution, humans are unable to perceive electromagnetic radiation, although it does have an effect on the human body. For this reason, the Ministry for Climate Protection, Environment, Agriculture, Conservation and Consumer Protection of the State of North Rhine-Westphalia attaches great importance to prevention and health protection. In 2011, there was a severe nuclear disaster in Fukushima in Japan. However, fallout and radioactivity concentrations in the air were 10,000 times lower than those after the Chernobyl reactor catastrophe in 1986. In North Rhine-Westphalia itself, only a few nuclear facilities are in operation; former nuclear power plants such as Würgassen and Hamm-Uentrop have been decommissioned. In contrast, in neighboring Belgium, three reactors that went into operation in the mid-1970s in Doel and Tihange have had their operating periods extended by another decade to 50 years. These reactors’ susceptibility to malfunction has been a great cause of concern in neighboring regions. This is why the Ministry for Climate Protection, Environment, Agriculture, Conservation and Consumer Protection of the State of North Rhine-Westphalia is playing an active role in the political and legal examination of these facilities.

Figure 31 **Environmental indicator: noise pollution in NRW**

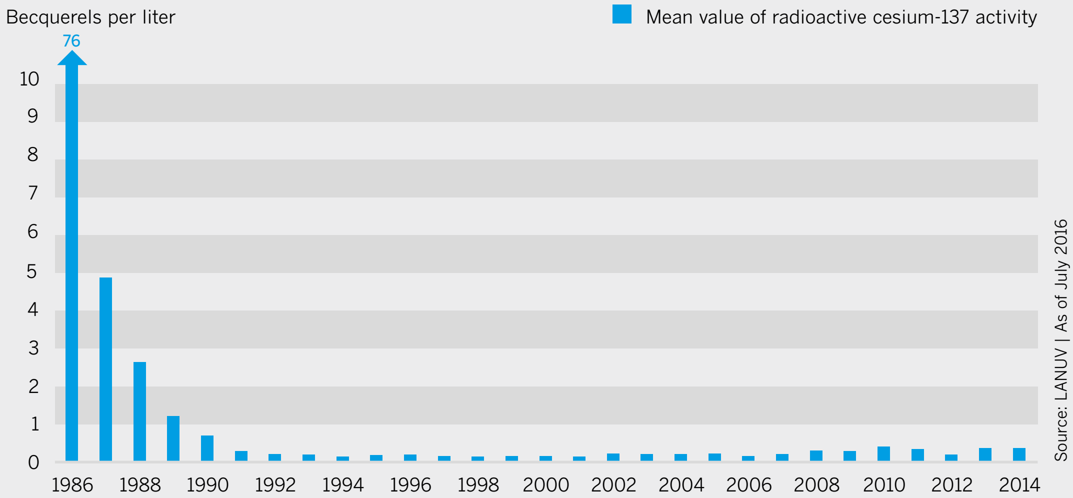
Partial indicator: night-time noise pollution



More than 1.4 million people or 8% of the population are subject to noise levels of over 55 decibels at night between 10 pm and 6 am. Three quaters of thoses affected – mainly by traffic noise and train noise – live in agglomerations. 55 decibels is the equivalent of the volume of a normal conversation; 60 decibels is the volume in an office. The WHO has set the threshold level for harmful noise at a level of 40 decibels; it has deemed night-time pollution above 55 decibels as hazardous to health. The State Government aims to significantly reduce overall noise pollution in residential areas by 2030 – while taking into account WHO recommendations.

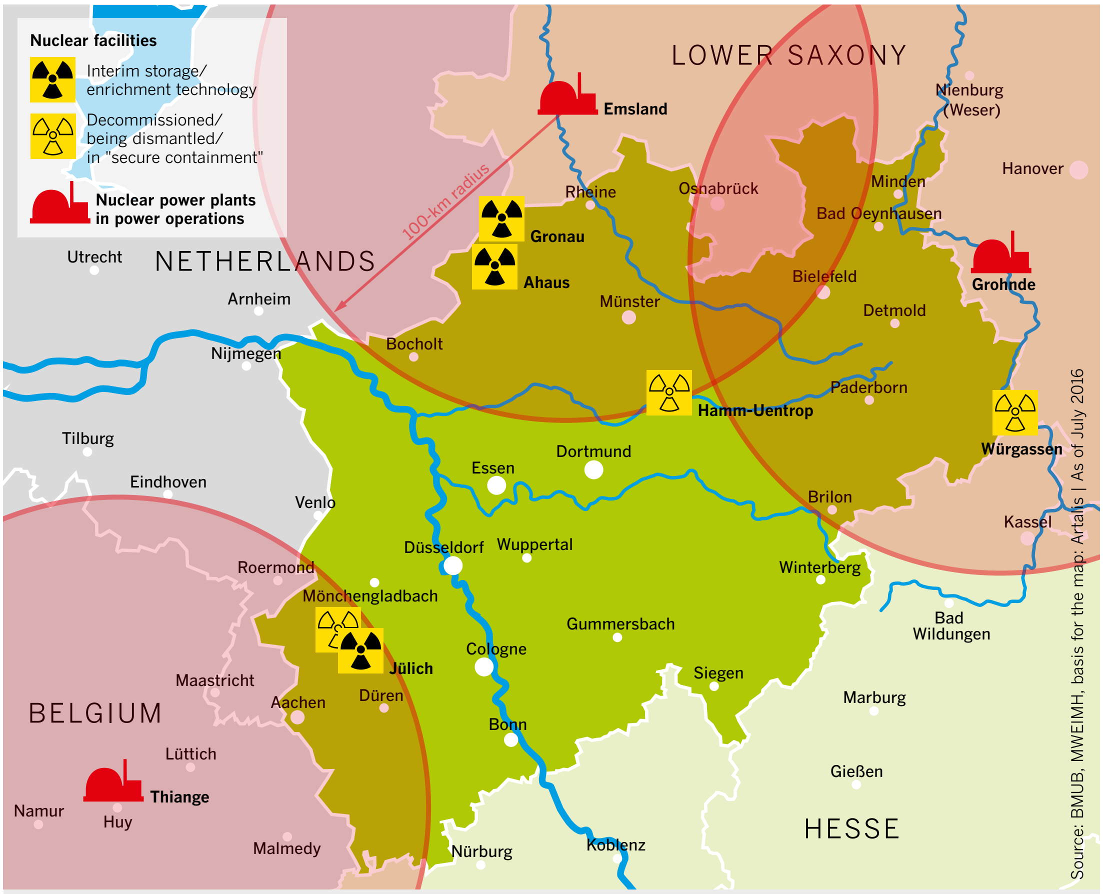
Environmental indicator: noise pollution
www.umwelt2016.nrw.de/071

Figure 32 **Average radioactive cesium-137 activity in milk samples in NRW**



Since the Chernobyl reactor catastrophe in 1986, radioactivity has been monitored in a number of media in line with the Precautionary Radiation Protection Act (Strahlenschutzvorsorgegesetz). After 1986, the radioactivity measured in North Rhine-Westphalia once again dropped significantly – exemplified here using the mean values of measurements of radioactive cesium-137 in milk. The limit for cesium-134 and cesium-137 in milk is currently 370 becquerels per liter. The Fukushima disaster in 2011 did not contribute to any radioactive contamination of the milk in NRW.

Figure 33 Nuclear facilities in and out of operation in NRW as well as nuclear power plants in power operations in the area surrounding NRW



The four formerly active reactors in North Rhine-Westphalia have now been decommissioned: The Würgassen nuclear power plant has been dismantled, the Hamm-Uentrop high-temperature reactor is in a state of "secure containment" after its fuel elements were discharged and removed, and the Jülich experimental atomic reactor and the research reactor Jülich 2 have been dismantled. Temporary storage is taking place at the Jülich container warehouse (spent fuel elements from the decommissioned Jülich experimental atomic reactor and the Hamm-Uentrop very-high-temperature reactor) and in the Ahaus Interim Storage Facility (mainly casks with fuel elements from German nuclear power plants). The Gronau uranium enrichment plant produces primary components for nuclear power plants. Protection radiuses (outer zone = 100 kilometers around a nuclear power plant in power operation) have been laid out around the nuclear power plants Tihange in Belgium and in Emsland and Grohnde in Lower Saxony, which reach all the way to NRW. Measures need to be prepared – based on the recommendations of the German Commission on Radiological Protection – for Germany to take in these zones in the event of a radiological disaster.

Facility-related environmental monitoring

Technical plants are the backbone of branches of industry such as the energy sector, the chemical industry, paper manufacturing and metal processing. They are subject to high duties of care and high levels of soil, air and water protection during planning, building and operations. Not only must they prevent any harmful effects or other hazards from occurring, but the general public and the surrounding neighbourhood cannot be expected to endure any considerable disadvantages or nuisances either. To achieve this objective, state-of-the-art preventative measures must be taken.

There is now a high level of monitoring for the roughly 18,000 industrial facilities in North Rhine-Westphalia. The facilities themselves are the ones first and foremost responsible for complying with these provisions with their own monitoring procedures. The environmental authorities – the regional governments and lower environmental authorities of administrative districts and independent towns – inspect them regularly and provide the general public with transparency about the facilities. These measures are supplemented by waste disposal monitoring and inspections in the event of complaints or after malfunctions and accidents.

Waste, soil and water in North Rhine-Westphalia

Settlement area

301 m² per capita

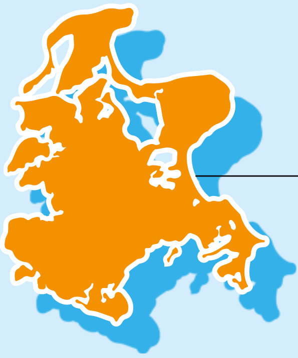
Land consumption

Increase in settlement and traffic areas

9.3 ha per day

At 921 km²

land consumption 1996–2015 was roughly the same size as the island of Rügen



Settlement and traffic areas

Proportion of state land area[2]

23%

Areas recorded with contaminated sites

Abandoned waste-disposal and industrial sites

Around 85,000

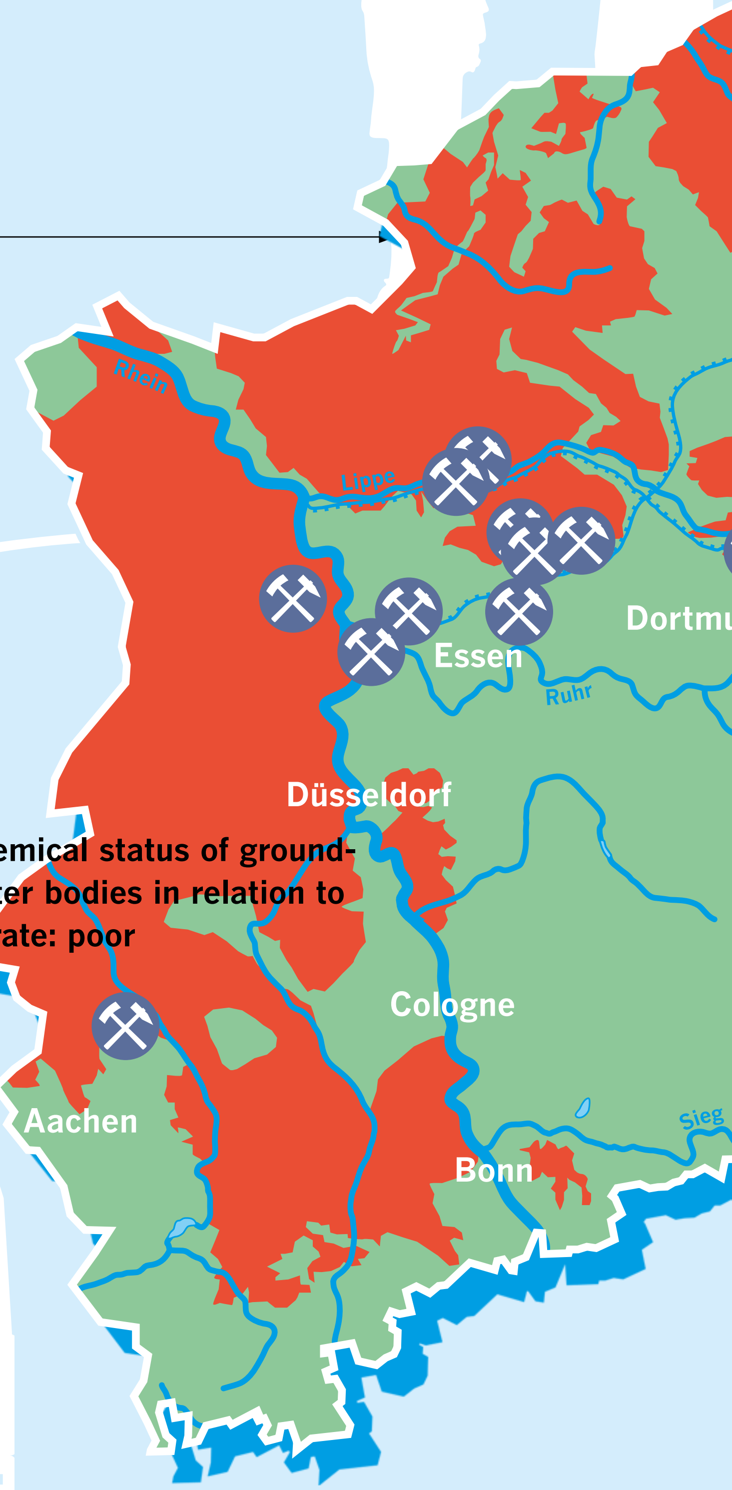
Household waste and recycling

per capita in 2014

480 kg

50%

recycling rate



Chemical status of ground-water bodies in relation to nitrate: poor

1 Source: IT.NRW | As of January 20 ▪ 2 Source: IT.NRW | As of May 2016 ▪ 3 Source: IT.NRW | As of June 2010 ▪ Source map: Artalis Kartographie und Design, Jacqueline Böttcher I LANUV,

Population density[1]

518

inhabitants/km²

Nitrate concentration in groundwater

Proportion of monitoring stations that record nitrate contamination > 50 mg/l

NO_3

14%

Water consumption of households/ small-scale commercial operationse[3]

135 liters

per inhabitant per day

Ecological condition of surface waters

Only 6%

have a very good/ good ecological status

Hazardous waste disposed of

6.7 million t

in 2014

Chemical quality of groundwater bodies

60%

in good condition

Mine filling and backfilling of in part hazardous waste

Mid-1980s to 2006

11

hard coal mines

Waste generated and disposed of at waste management facilities in NRW

46.7 million t

in 2013

Geobasis NRW | As of June 2014

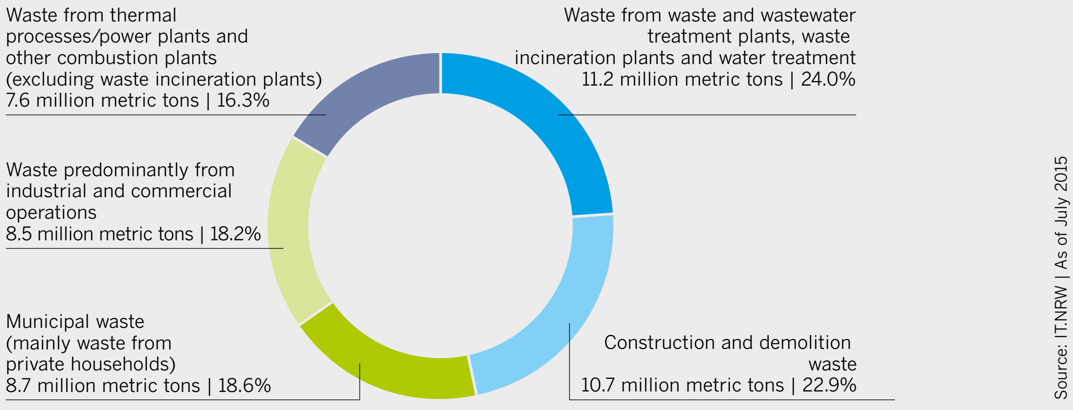
Waste management and the circular economy

The state of North Rhine-Westphalia aims to implement a system of ecological waste management. In accordance with the new five-step hierarchy, prevention, reuse and recycling take clear precedence over other forms of waste recovery and disposal.

In light of a starting situation shaped by waste disposal security, the priority of North Rhine-Westphalia's new Waste Management Plan for Municipal Waste (Abfallwirtschaftsplan für Siedlungsabfälle), which came into effect in April 2016, is regional self-sufficiency when it comes to waste disposal. This means disposing of municipal waste that accrues in North Rhine-Westphalia in the state itself and as close as possible to where it was generated (the proximity principle). The European legal principles of self-sufficiency and proximity relate to waste that is intended for disposal and to mixed municipal waste intended for recovery.

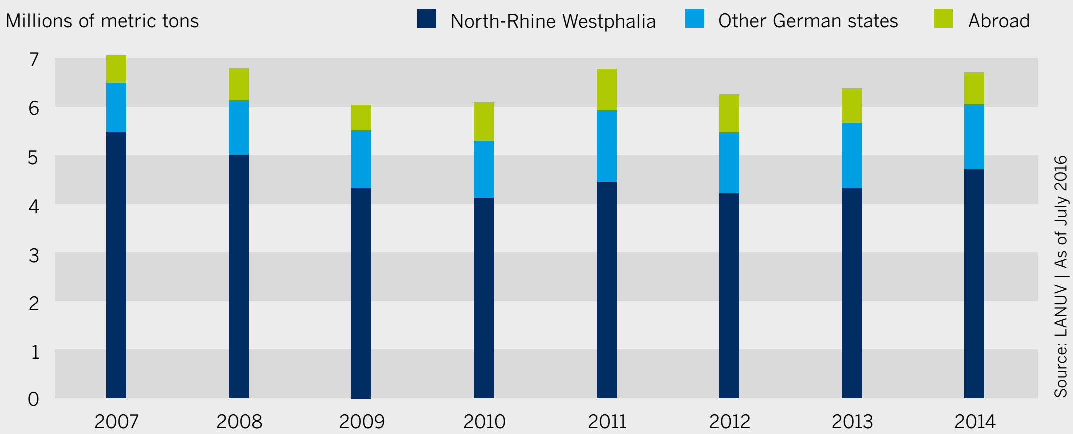
The new Waste Management Plan aims to provide significant momentum to the intensified utilization of municipal waste as a source of raw materials and as an energy supply. For this reason, the Waste Management Plan contains ambitious requirements for preventing, reusing and recycling waste. The state is helping municipalities to implement the plan by providing them with appropriate best practice recommendations.

Figure 34 Waste generated in NRW and delivered to waste management facilities in NRW in 2013



The roughly 46.7 million metric tons of waste delivered to waste management facilities in North Rhine-Westphalia are made up of the following: 11.2 million metric tons of waste from waste and wastewater treatment plants; 10.7 million metric tons of construction and demolition waste; 8.7 million metric tons of municipal waste (for the most part waste from private households and similar commercial waste); 8.5 million metric tons of waste from industrial and commercial operations, including process waste; and 7.6 million metric tons of waste from thermal processes or power plants, and other combustion plants.

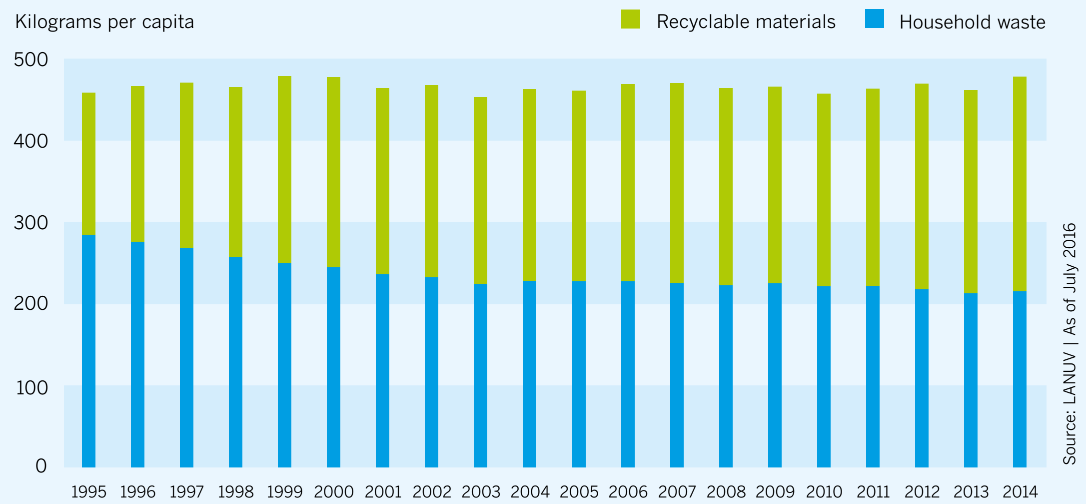
Figure 35 Hazardous waste disposed of in NRW by regional origin



From 2007 to 2009, the overall amount of hazardous waste disposed of in NRW was in steady decline. After relatively low amount in the years 2009 and 2010 due to lower production and less construction in a weakened economy, the overall amount increased significantly in 2011, bringing it back to its 2008 level. After the overall amount of hazardous waste disposed of dropped again in 2012, there was another increase from 2013. The result of an analysis of these eight years has shown a constant trend for the overall amount of hazardous waste disposed of.

Figure 36 **Environmental indicator: household waste and recycling in NRW**

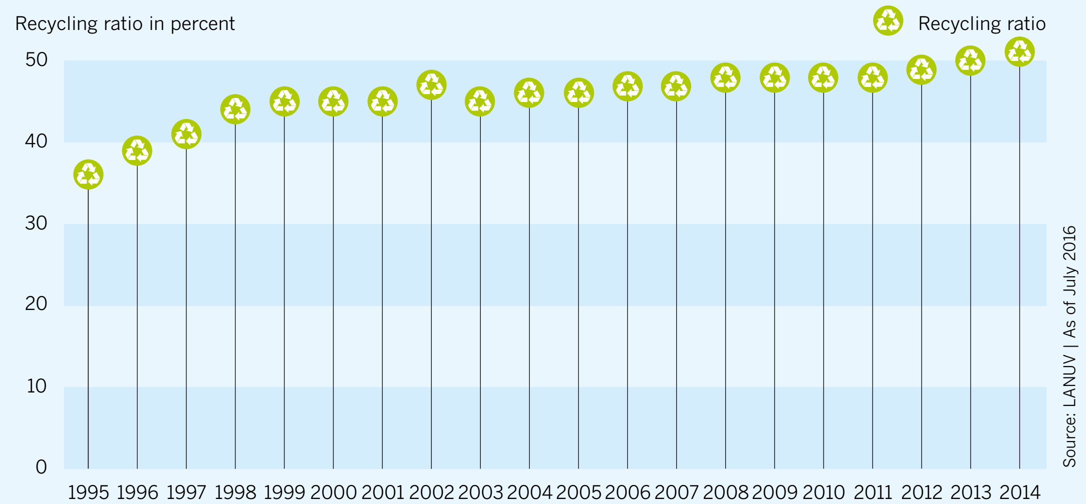
Partial indicator: household and bulky waste, and biodegradable waste, green waste and valuable waste



In 2014, a total of 480 kilograms of household waste was generated per capita in North Rhine-Westphalia; 216 kilograms of that comprised household and bulky waste, and 264 kilograms consisted of biodegradable waste, green waste and valuable waste. The per-capita amount of household waste remained significantly consistent in the period 2005 to 2014. A clear increase in the amount of separately collected biodegradable waste, green waste and valuable waste has been observed, while volumes of household waste that must be treated thermally or mechanically and biologically are continuously decreasing.

Environmental indicator: household waste and recycling
www.umwelt2016.nrw.de/100

Partial indicator: recycling ratio



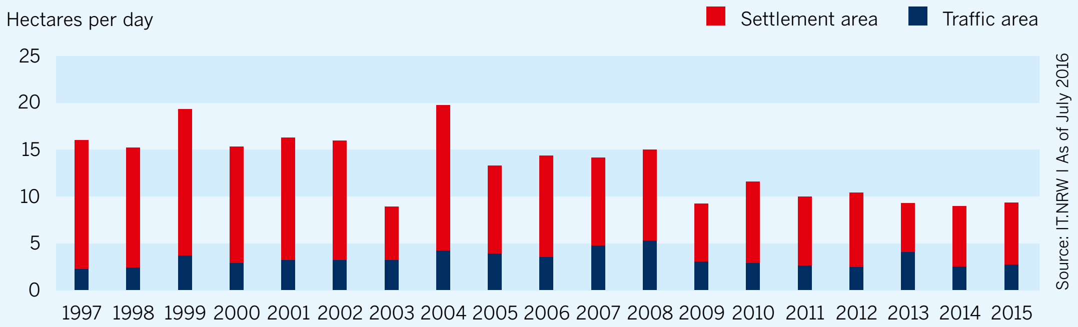
The recycling ratio is the percentage of household waste (biodegradable waste, green waste and valuable waste) that is supplied to plants or processes that aim to utilize these materials. A trend analysis of the last 10 years has shown a significantly positive trend. In 2014, the recycling ratio exceeded the 50% mark for the first time. The largest proportion of this was biodegradable waste and green waste, followed by paper, paperboard and cardboard, as well as lightweight packaging and glass. The State Government aims to achieve a recycling ratio of 65% by 2020. This will require an intensification and optimization of the separate collection and recovery of waste, especially for biodegradable waste and green waste.

Soil conservation and land consumption

Our soils are an undervalued resource. From unconsolidated rock to brown earths to peaty soils, each different soil has its own special, valuable characteristics, which give rise to specific soil functions. For example, soils determine the local ecological and water balance as filters and storage; are, in the true sense of the word, the foundation of our forestry and agriculture industries; have a decelerating effect on climate change; provide flood protection; and serve as habitats for fauna and flora. The multifaceted nature of North Rhine-Westphalia's landscapes are a reflection of the different soil types that shape this state. But our soils are in a state of permanent jeopardy. Once they are sealed or eroded, "consumed" as land or even contaminated with pollutants, these developments can only be reversed incompletely or at great effort. It takes a lot of effort to recycle or re-cultivate soils; they cannot just be relocated or replanted. Soils are the product of natural effects and human activity; they document natural and cultural history like an archive. Moreover, soils store about 80% of the organic carbon reserves that actively participate in the carbon cycle. This is why they are referred to as carbon sinks: They store enormous volumes of the climatically active gas CO_2. In the decades to come, climate change will also pose new challenges to many soils here in North Rhine-Westphalia. The frequency of extreme meteorological events such as heavy rainfall and long periods of drought is already increasing measurably. This means pure stress for our soils: Wind and water erode them, dry them out and muddy them. Only stable, humus-rich soils with a balance of nutrients and water suited to their location and sufficient plant cover will be able to endure this strain.

Figure 37 Environmental indicator: land consumption in NRW

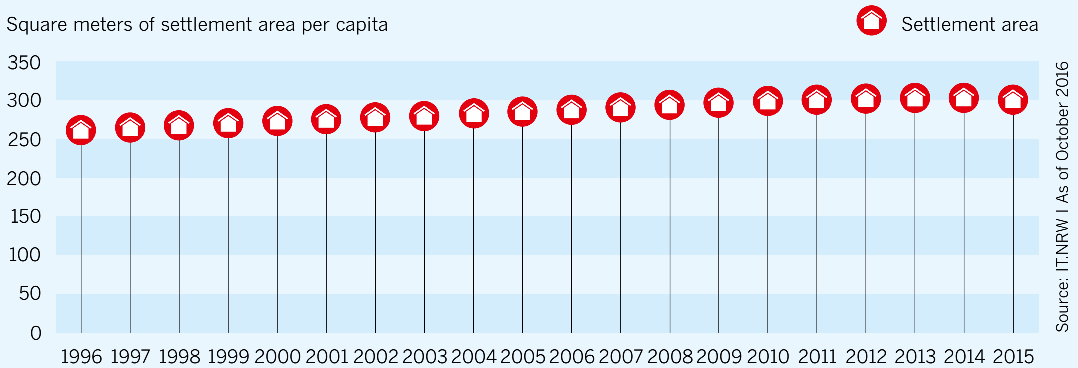
Partial indicator: settlement and traffic area growth



Land consumption in 2015 was around 34 square kilometers, or an average of 9.3 hectares per day. For the most part, it occurred to the detriment of agricultural land and fertile soils, and it comprised 6.7 hectares of land consumption per day for settlement areas and 2.4 hectares per day for traffic areas. There has been a significant trend towards a decrease in land consumption per day in the last ten years. The State Government aims to reduce land consumption to five hectares per day by 2020 and to net-zero in the long term.

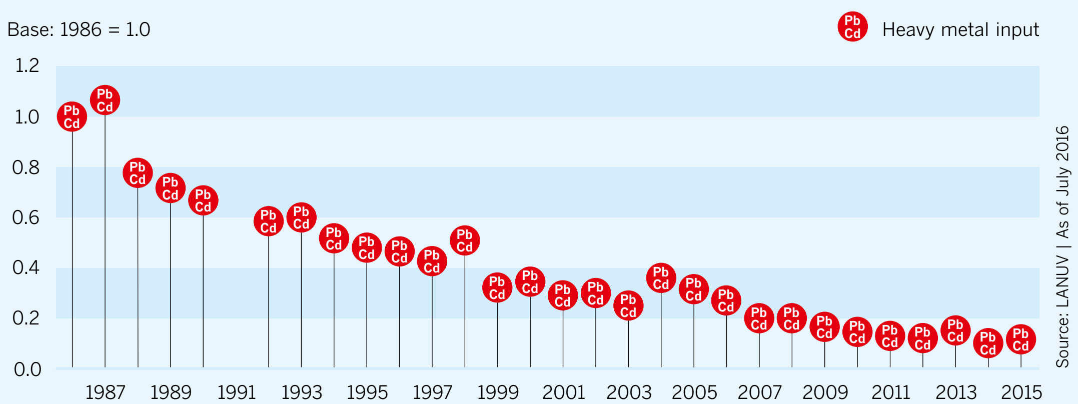
Environmental indicator: land consumption
www.umwelt2016.nrw.de/109

Partial indicator: settlement area per inhabitant



In 2015, there was around 301 square meters of settlement area per capita – which consists of the floor area and accompanying land for buildings, commercial areas (excluding mining land) and recreational areas. Overall, 17.7 million inhabitants shared 5,349 square kilometers (the equivalent of 16% of the state's land area). In the last 10 years, there has been a constant trend toward increasing urban sprawl, which is due to the state's most recent population growth.

Figure 38 Environmental indicator: heavy metal deposition at rural stations in NRW



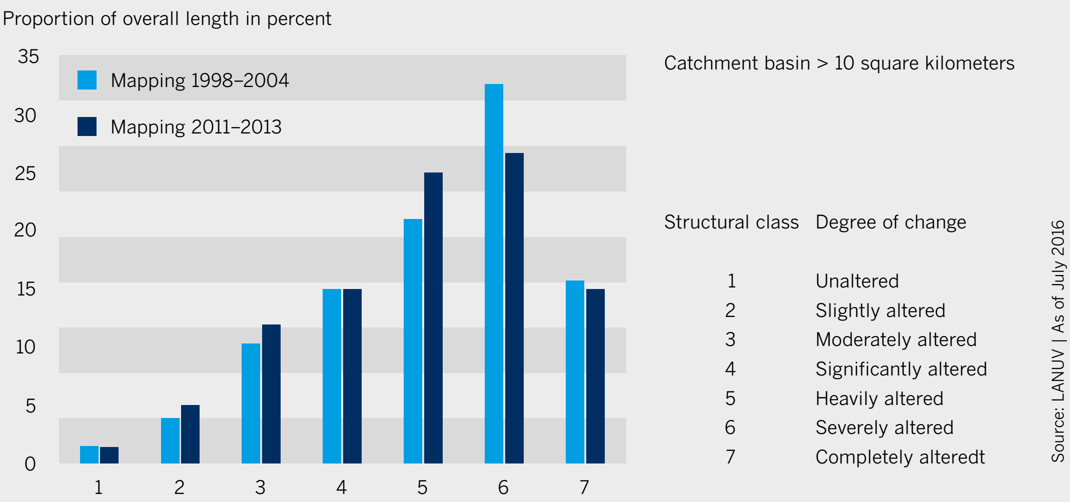
Lead and cadmium in dust deposition at a total of five rurally located background monitoring stations have decreased to about one eighth of their initial value in 1986. The trend over the last 10 years has shown a decrease in heavy metal depositions. The main reason for this welcome development has been the implementation of measures to minimize airborne particulate emissions – for example by utilizing debris removal systems and dust removal plants.

Environmental indicator: heavy metal deposits at rural stations in NRW
www.umwelt2016.nrw.de/112

Water management

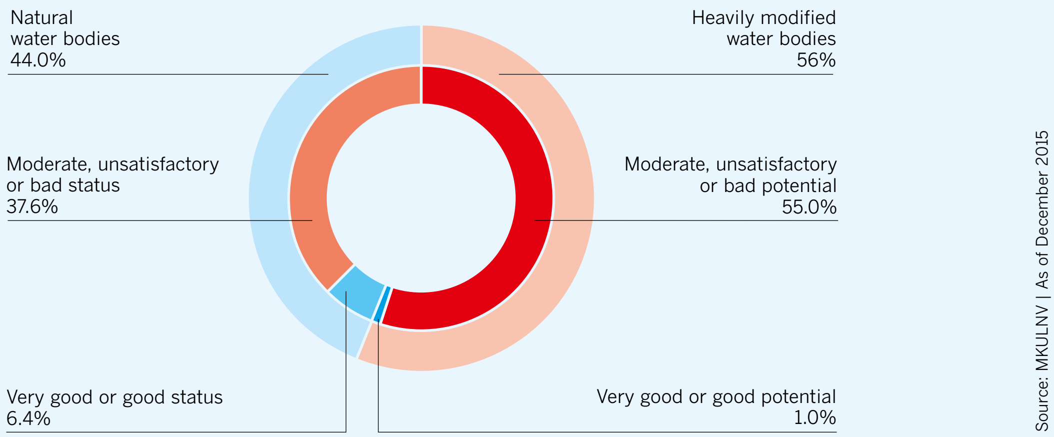
“Water is an inherited asset that must be protected and preserved.” Since 2000, this has been the guiding principle of the EU Water Framework Directive, which sets out how to deal with water as a resource. The mothers and fathers of European legislation coined the term “good status” in relation to water bodies and have set member states the objective of achieving this status for their bodies of water by 2027 at the latest. This is because they believe that the basis of life on earth – water – should continue to be available in the future, both in sufficient quantities of good-quality drinking water and in bodies of water that provide intact habitats. Two figures reveal the dimensions of this task: In North Rhine-Westphalia, this “good status” has only been achieved for 6% of natural running waters and – in terms of chemical quality – only 60% of groundwater. This shows that 17.7 million inhabitants – a very high population density with about 518 inhabitants per square kilometer – and vast swathes of industry, but also agriculture in North Rhine-Westphalia are leaving their trace. About 2% of the the state's land area is covered by water; running waters add up to a network 50,000 kilometers in length. But even if the state is rich in water: Our bodies of water are under heavy strain due to a range of different uses. Most rivers are regulated; many bodies of water such as canals, reservoirs and lakes leftover from former surface mines are of artificial origin. The dewatering measures taken by the coal mining industry have had far-reaching and lasting effects on both groundwater and surface water. Over 1,300 industrial plants discharge wastewater directly into the state’s bodies of water. In 2013, 2.5 billion cubic meters of water were used as coolant and 2.4 billion cubic meters of wastewater were treated in 636 public treatment plants. In addition to this, per-capita drinking water consumption was 133 liters per day. In the years to come, the state will have to continue to make a considerable effort to sustainably manage its water and bodies of water.

Figure 39 Degree of change in the water body structure of running waters in NRW



At the turn of the millennium, only 15% of running waters had an unaltered, or slightly or moderately changed water body structure (structural classes 1, 2 and 3) compared with natural bodies of water. According to most recent mapping, this proportion has grown to 18%. However, this still means that 82% of water bodies are significantly, heavily, severely or completely altered. For the latter group, only a limited improvement in water body structure is possible due to the water bodies' specific uses.

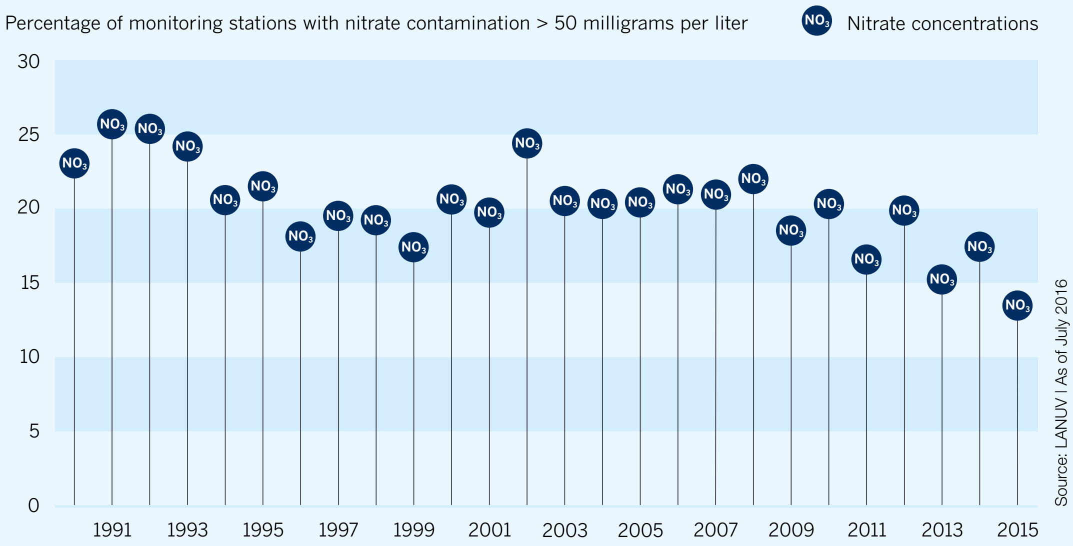
Figure 40 Environmental indicator: ecological status/ecological potential of surface waters in NRW in 2015



About 13,800 kilometers of the state's water bodies have been assessed; 44% of running waters have been classified as "natural" and 56% as "heavily modified": Only about 6% of surface running waters have a "good ecological status" – which includes a good chemical status – with a corresponding composition and frequency of aquatic species. 1% of water bodies at least have "good ecological potential." Around 93% of the water body kilometers assessed have a moderate to bad ecological status or moderate to bad potential. In line with the Water Framework Directive, the State Government aims to have achieved a "good ecological status" for all natural running waters and "good ecological potential" for all considerably altered or artificial waters by 2027.

Environmental indicator: ecological status/ecological potential of surface running waters
www.umwelt2016.nrw.de/119

Figure 41 **Environmental indicator: concentration of nitrates in groundwater in NRW**



Nitrate is an important parameter for groundwater quality and can have a negative effect on the human organism. At 50 milligrams per liter, the threshold value for drinking water is identical to the threshold value for achieving "good status" as prescribed by the German Groundwater Ordinance (Grundwasserverordnung). In 2015, almost 14% of the 100 groundwater monitoring stations spread throughout the state recorded values that exceeded this value (30% recorded values over 25 milligrams per liter). The Minden-Lübbecke district recorded the highest value at 281 milligrams of nitrate per liter. However, there has been a statistically significant trend toward lower nitrate concentrations. In accordance with the Water Framework Directive, the State Government aims to reduce nitrate levels in groundwater bodies to less than 50 milligrams per liter by 2027 at the latest.

Environmental indicator: nitrate concentrations in groundwater in NRW
www.umwelt2016.nrw.de/123

Nature and rural areas in North Rhine-Westphalia

The top 3 livestock species

1.5 million cattle[1]

7.4 million pigs[1]

11.5 million chickens[2]

These numbers are concentrated in the administrative district of Münster[3]:

Top 3 crops
Share of state land area[4]

4% winter barley

8% winter wheat

8% corn

High nature value farmland
Proportion of agricultural landscape

13%

Organic farming
Proportion of agricultural acreage

BIO 5%

Nitrogen surplus on agricultural land

N

93 kg/ha in 2014

Urban agglomerations/ settlement areas

28 **Special protection areas for birds[5]**

1 Source: Destatis | As of November 2015 ▪ 2 Source: IT.NRW | As of June 2014 ▪ 3 Source: IT.NRW | As of March 2010 ▪ 4 Source: IT.NRW | As of July 2015 ▪ 5 Source: LANUV | As of September 2016

Top 3 tree species in the forests

17% oak

19% beech

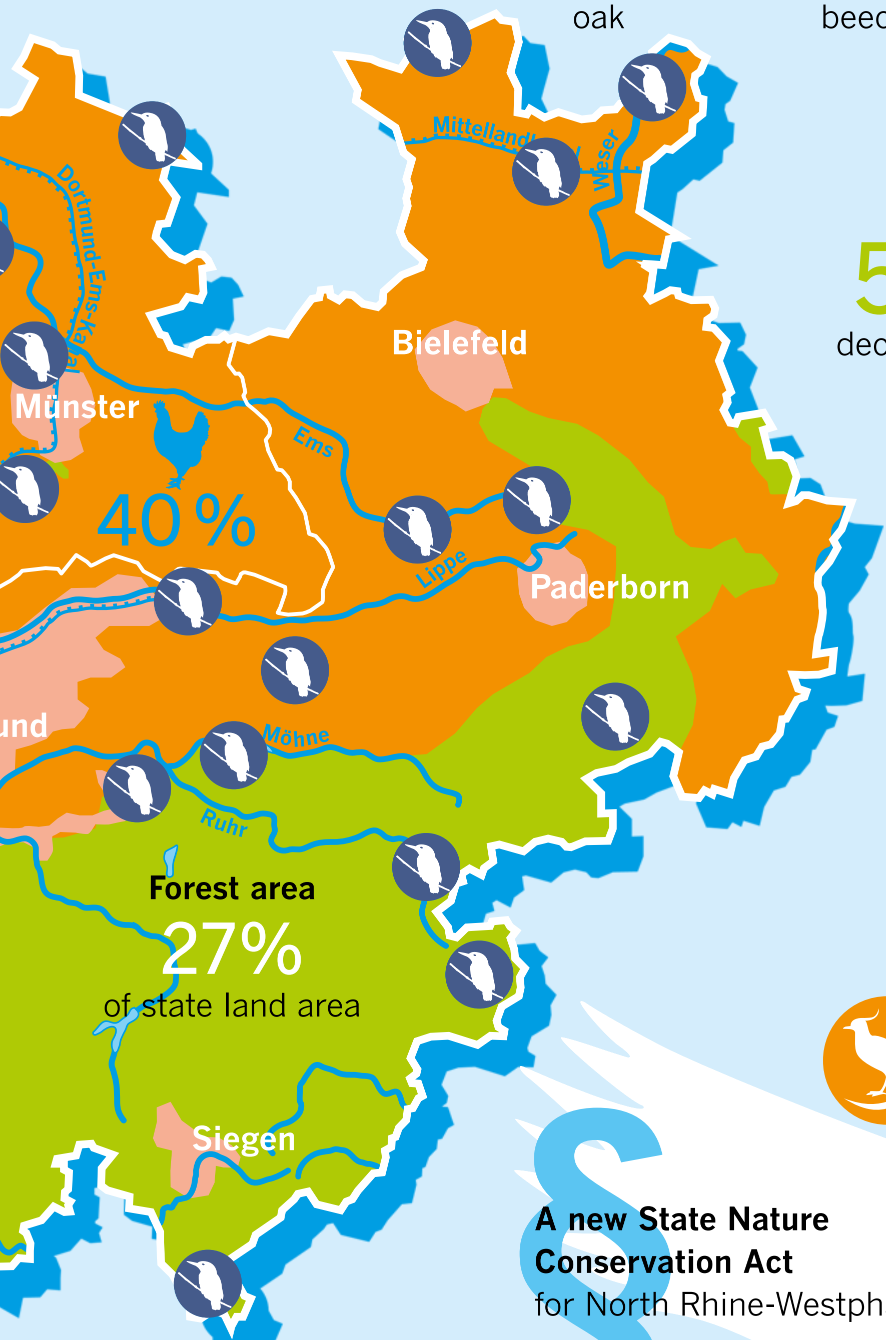
30% spruce

Proportion of deciduous and coniferous trees in the forests

55% deciduous trees

41% coniferous trees

4% temporarily unstocked areas



2016 State of the Forests Report[6]

28% with no crown damage

43% with slight crown damage

29% with significant crown damage

Species diversity and landscape quality

70% progress made

A new State Nature Conservation Act
for North Rhine-Westphalia

Nature conservation areas

8% of state land area

Endangered species

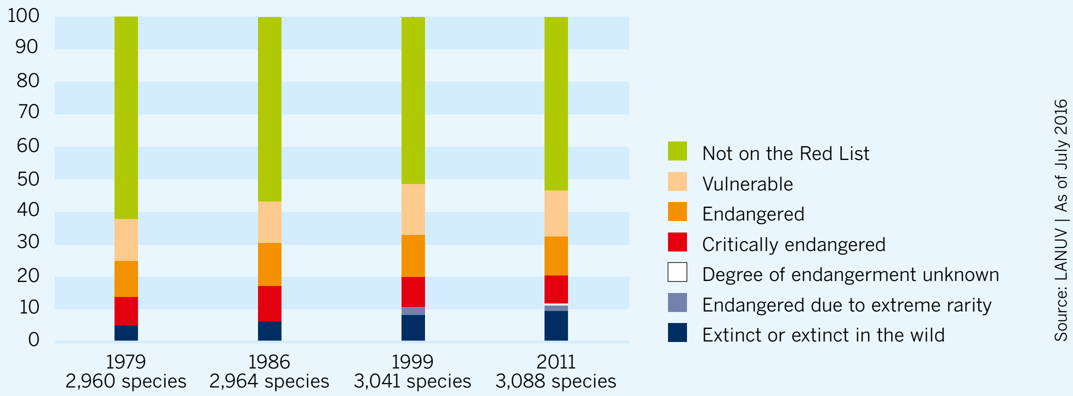
45% of plants, fungi and animal species are on the Red List

Biodiversity Strategy
for North Rhine-Westphalia

Natural heritage and nature conservation

North Rhine-Westphalia's environment is predominantly the result of human activity. This is because, alongside geographical and climatic conditions, agriculture and forestry above all, but also settlements, industry and traffic infrastructure all influence whether and how forests and open spaces can fulfill their function as habitats for animals and plants. This is where the active conservation of biodiversity and habitat diversity comes in. And it is more important than ever: In spite of encouraging progress, numerous species are on the "Red List of Endangered Animal and Plant Species in North Rhine-Westphalia," including popular species such as cuckoos, lapwings and nightingales. It is an intergenerational task to protect the forests, pastures, moors, heathland, meadows of wild flowers and field margins in their varying shapes and forms – so important for the ecological and water balance, for quality of life and natural scenery – as habitats for fauna and flora. In order to preserve them as natural heritage in the long term, they need to be developed, expanded and connected with one another.

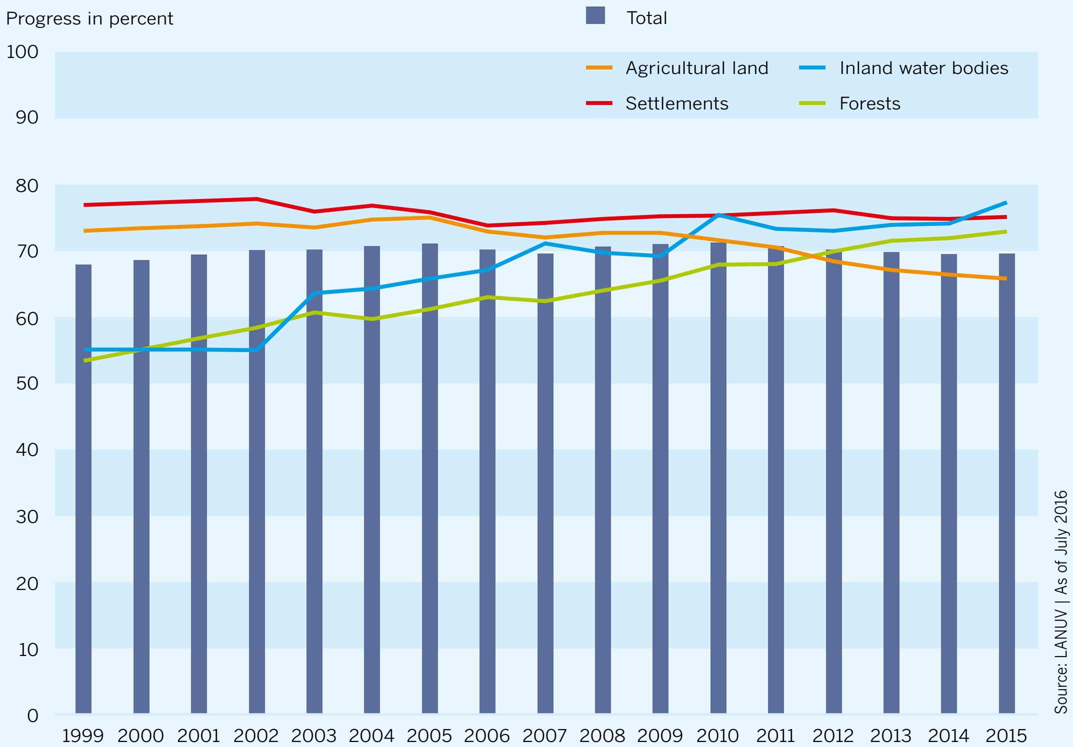
Figure 42 Environmental indicator: endangered species in NRW



The indicator "endangered species in NRW" is based on the "Red List of Endangered Plants, Fungi and Animals in North Rhine-Westphalia" and measures the percentage of Red List species among the total species assessed by the indicator, separated into endangerment category. The Red Lists have been published in regular cycles of about 10 years since 1979. This risk assessment is carried out by independent experts. The indicator includes species that have been assessed in all four Red Lists (about 3,000 species). For this reason, the indicator's percentages are not the same as the percentages in each of the individual Red Lists. In 2011, the proportion of Red List species in the indicator was 46.6%. The State Government aims to reduce the proportion of Red List species in the indicator to 40% by 2030.

Environmental indicator: endangered species
www.umwelt2016.nrw.de/142

Figure 43 Environmental indicator: species diversity and landscape quality in NRW



The indicator shows overall progress of 70% and stagnates at an unsatisfactory level. The important partial indicator "farmland" shows only 66% progress, with a statistically significant negative trend, whereas increased progress of 77% can be seen in the partial indicator "inland water bodies." The partial indicator "settlements" has made 75% progress with a stagnating trend, and the partial indicator "forests" shows progress of 73% with a positive trend. The State Government aims to achieve 100% progress by 2030 – i.e. what, since 1997, has been referred to as "maximum abundance" – for all landscape and habitats.

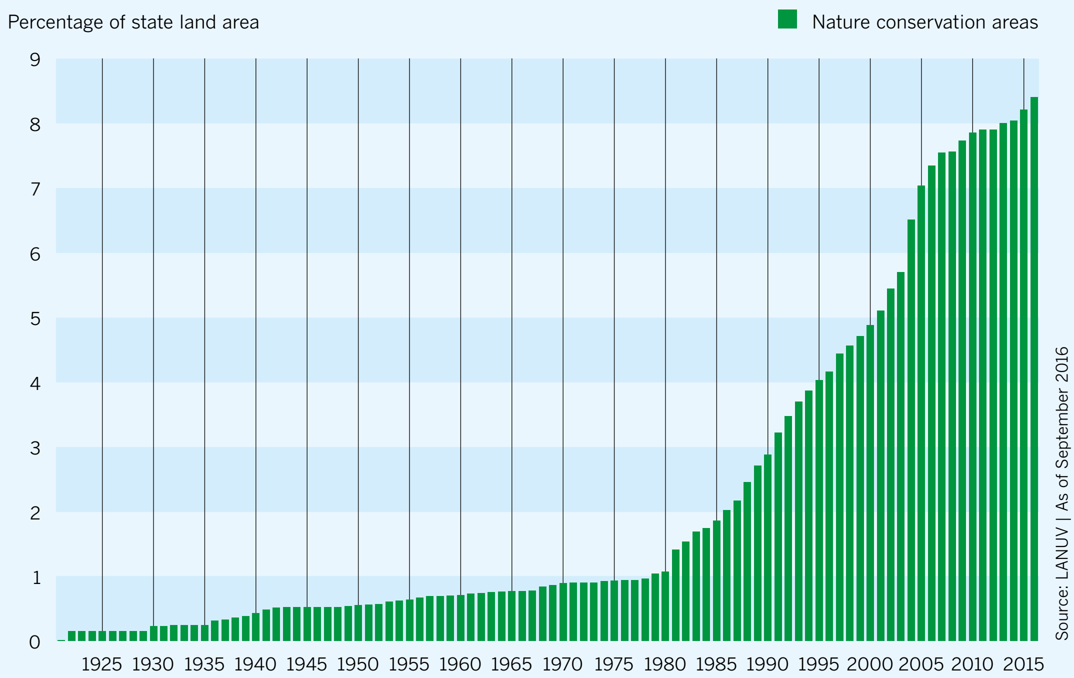
Environmental indicator: biodiversity and landscape quality
www.umwelt2016.nrw.de/145

Figure 44 Hierarchy of the most important conservation area categories in NRW

	Number	Area	Proportion of state land area
Nature conservation areas and Eifel National Park	3,237	285,231 ha	8.4%
Fauna-Flora-Habitat areas	517	185,000 ha	5.4 %
Special protection areas for birds	28	165,000 ha	4.8 %
Total distinct areas (areas that fall in several categories only count once)	–	397,707 ha	11.7 %

As of: September 2016

Figure 45 Environmental indicator: nature conservation areas in NRW



Nature conservation areas, including the Eifel National Park and the state's 3,200 nature conservation areas, are under the strictest protection. Large additions in the 1980s and 1990s can be explained by intensified efforts to designate nature conservation areas in landscape plans (Landschaftspläne). In the last 10 years, nature conservation areas have significantly increased to 8.4% of the state's land area, above all due to the implementation of the EU Habitats Directive. The goal of North Rhine-Westphalia's biodiversity strategy and one of the requirements of the new State Nature Conservation Act (Landesnaturschutzgesetz) is to expand the wildlife corridor to 15% of the state's land area, which means that the addition of further nature conservation areas can be expected.

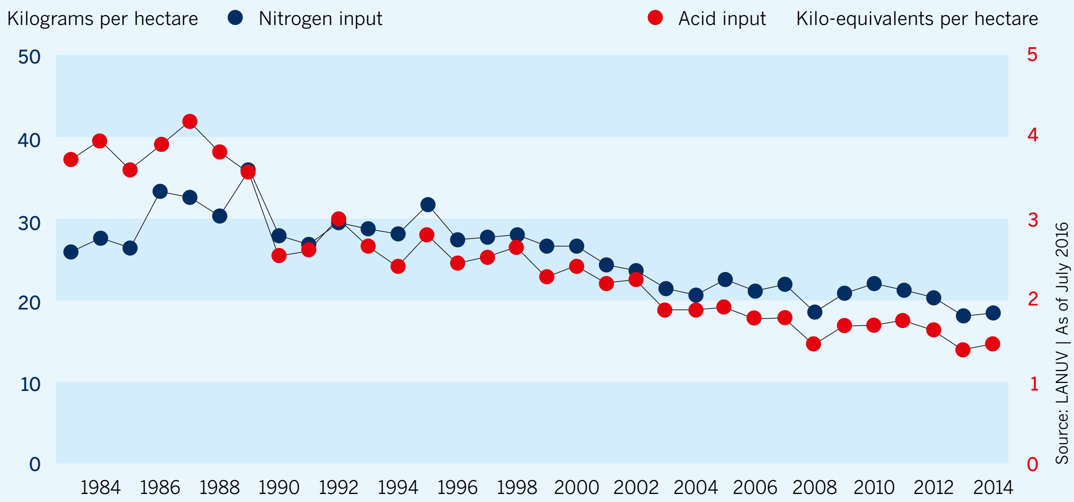
Environmental indicator: nature conservation areas
www.umwelt2016.nrw.de/150

Forests and forestry

Forests in North Rhine-Westphalia are popular recreation areas and habitats for fauna and flora, and play an important economic role. According to the State Forest Act (Landesforstgesetz), forests must be cared for and managed in a way that preserves their biological diversity, productivity, capability for regeneration and capability to fulfill important ecological, economic and social functions. But North Rhine-Westphalia's forests are also changing. In past years, they have aged and they are now more structurally diverse with a wider range of tree species. However, we must still view the current state of the forests as problematic. For example, only 28% of deciduous trees and conifers do not display signs of defoliation and can therefore be deemed healthy.

Forest conservation and management is not just a statutory obligation, but rather serves to protect endangered animal and plant species and is carried out in the interests of both the climate and the water balance. Due to a diverse range of complex interactions, forests perform important tasks almost in passing, such as producing oxygen and storing water and greenhouse gases. Moreover, forests are where the renewable resource timber is produced, which means they are the starting point for a value added chain that is gaining in significance in light of climate change. Native forests also provide important open spaces for citizens to relax, and make an essential contribution to healthcare, especially for urban populations. The importance of the forests' productive, protective and recreational functions cannot be overrated in Germany's most population-dense state.

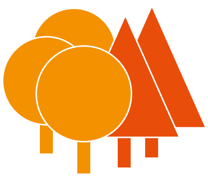
Figure 46 Environmental indicator: nitrogen and oxygen deposition in forest areas in NRW

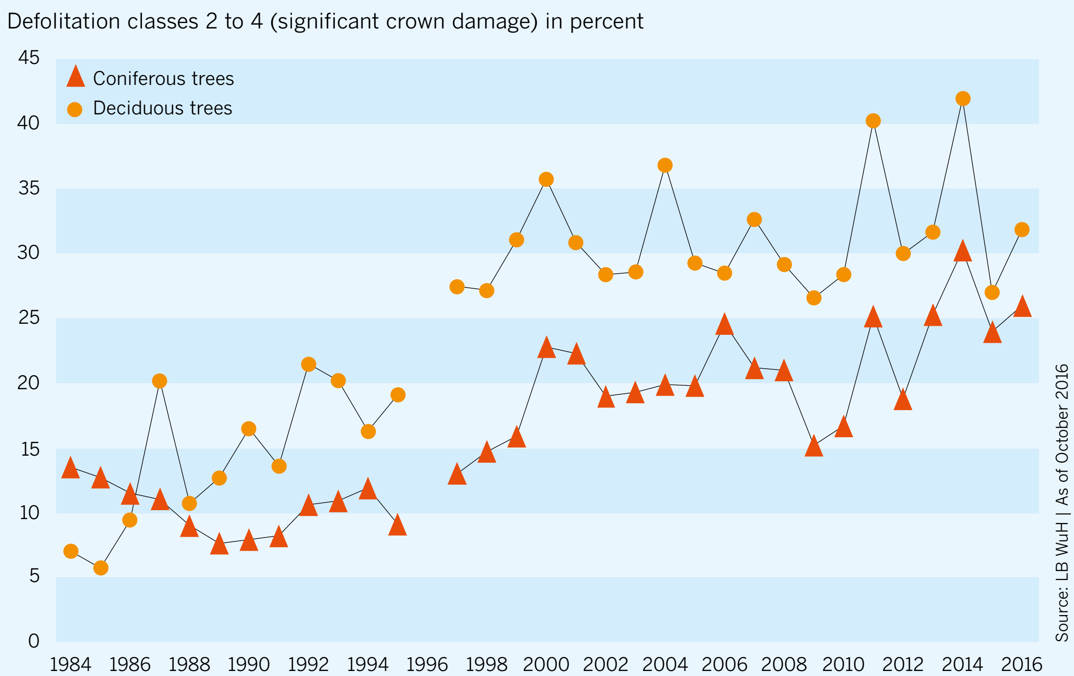


In forest areas, acid rain and wet nitrogen deposition in the form of nitrate and ammonia have been decreasing since the 1980s. There has also been a statistically significant decrease in nitrogen and acid deposition in the last 10 years. The five monitoring stations for this indicator, which are located in the state's large forest areas and in typical sites in the lowlands and hill country, recorded an average of 18.5 kilograms of nitrogen per hectare in 2014. Acid deposition ran to 1.5 kilogram equivalents of acid per hectare in 2014. In order to effectively relieve the strain on forest ecosystems, the state aims to keep reducing nitrogen and acid deposition in forest areas in the future to below the critical limit.

Environmental indicator: nitrogen and acid deposition
www.umwelt2016.nrw.de/158

Figure 47 Environmental indicator: condition of forests in NRW

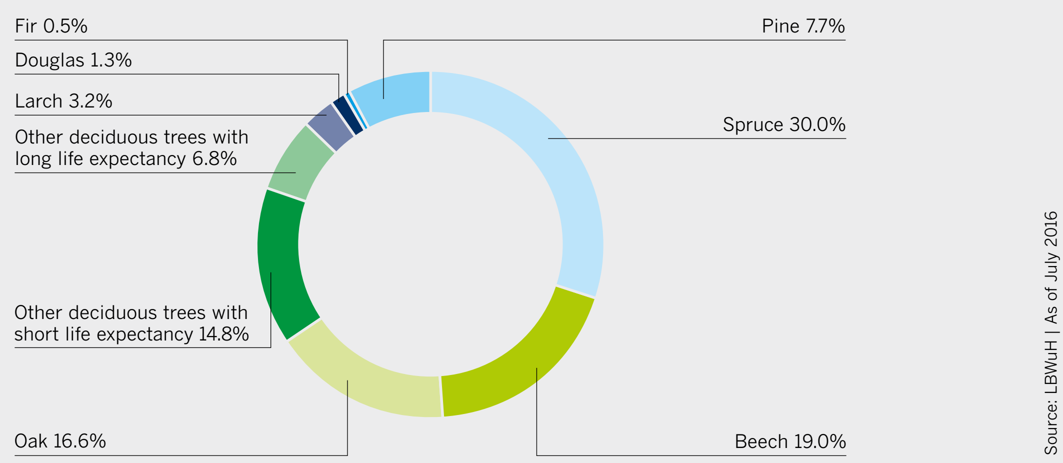




According to a trend analysis, the proportion of deciduous trees and conifers with significant crown damage has remained at a consistently high level over the last 10 years due to a range of different influences. A tree is said to have crown damage if it has lost at least a quarter of the leaf or needle mass typical for its species or if its crown has severe discoloration (defoliation classes 2 to 4). In 2016, 32% of deciduous trees and 26% of coniferous trees displayed this kind of damage. In order to attain more vital forests, climate change needs to be limited to less than 2 °C above preindustrial levels and a further consideration of climate change in forest management is required, as are further reductions in pollutant deposition.

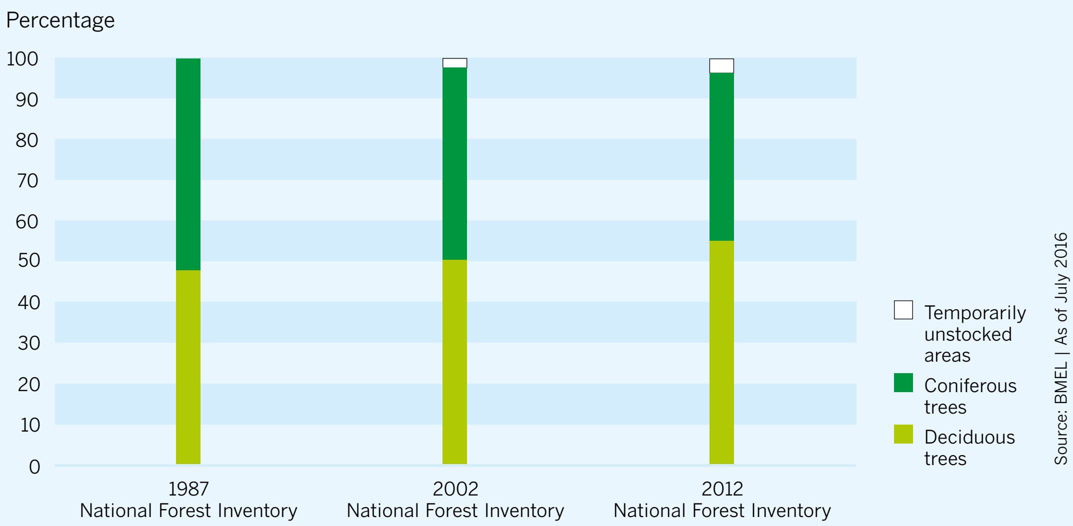
Environmental indicator: forest condition
www.umwelt2016.nrw.de/160

Figure 48 Proportion of tree species according to the 2012 NRW State Forest Inventory



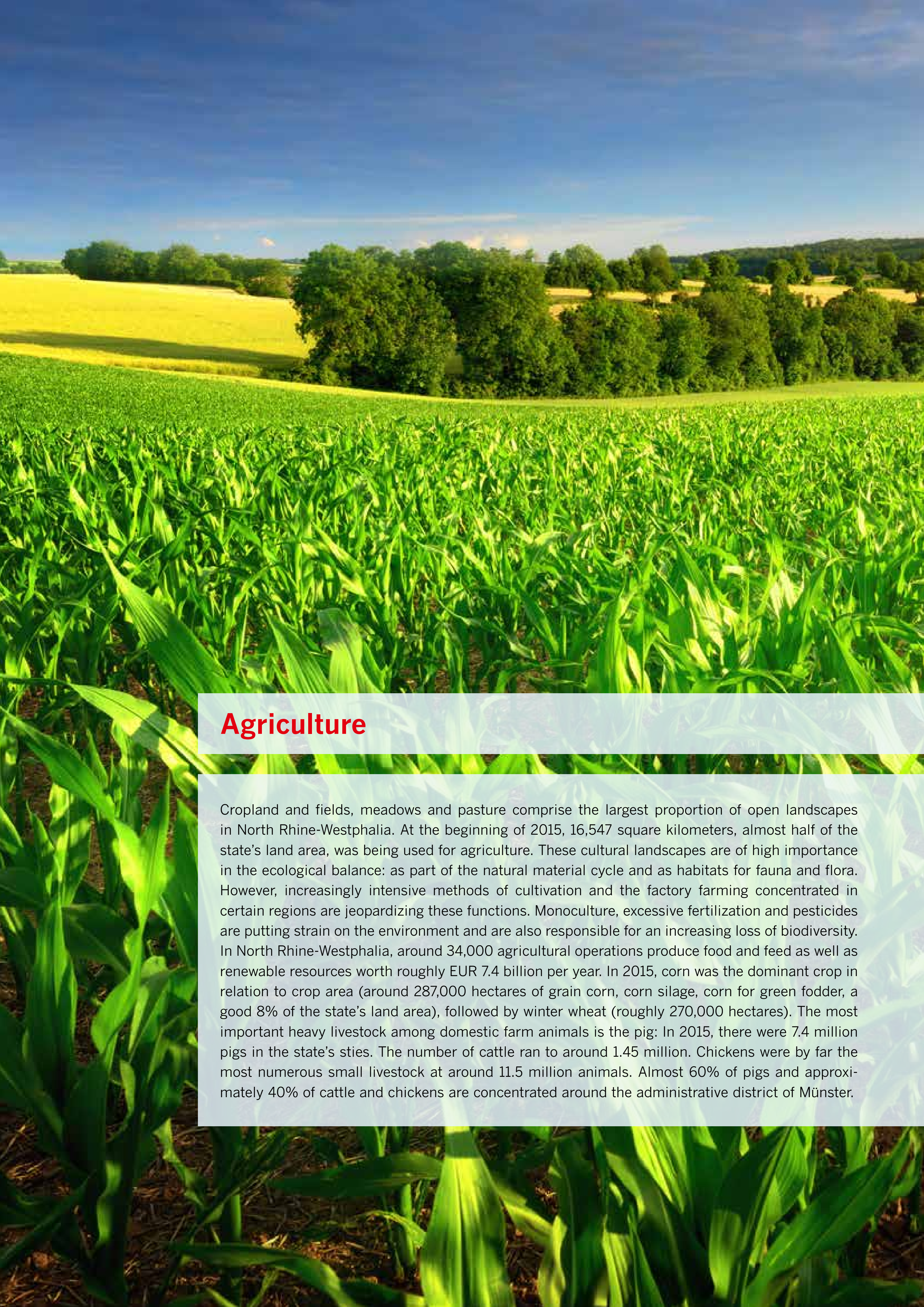
North Rhine-Westphalia's forests have become more structurally diverse with a wider range of tree species. Pure stands of conifers have shrunken by almost one quarter compared with the National Forest Inventory of 2002; more than half of forest stands consist of several tree layers. The spruce, still the dominant conifer, currently accounts for 30% of forest stands. It is followed by the deciduous tree species beech at 19%, oak at around 17%, and pine at about 8%.

Figure 49 Environmental indicator: proportion of deciduous trees and coniferous trees in NRW



From 1987, when the first National Forest Inventory was carried out, until 2012, the proportion of deciduous trees increased from 48% to 55% and the proportion of deciduous trees decreased from 52% to 41%. The decrease in the number of conifers has been, on the one hand, achieved by implementing silvicultural measures, but, on the other, is also a result of Kyrill, a storm that destroyed large stands of shallow-rooted spruces, especially in the Sauerland and the Siegerland, in 2007. The proportion of the temporarily unstocked areas has doubled to roughly 4% since 2002. The aim is to further reduce pure conifer stands in favor of increasing the percentage of deciduous trees.

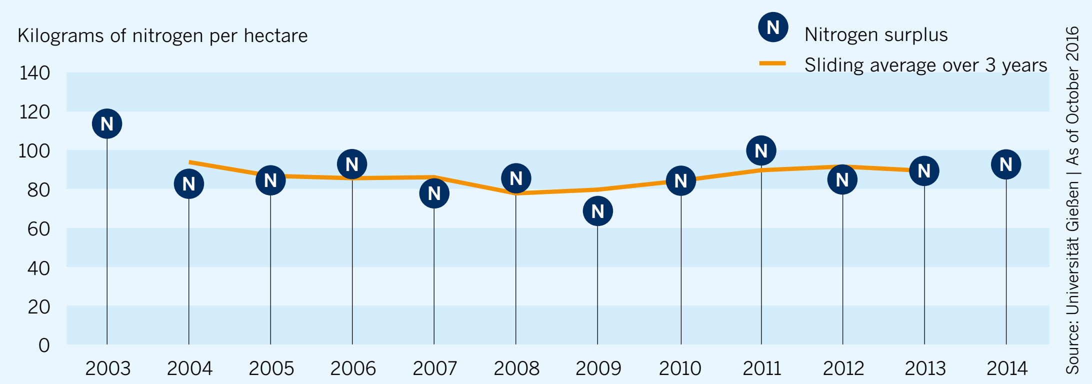
Environmental indicator: proportion of deciduous trees/conifers
www.umwelt2016.nrw.de/162



Agriculture

Cropland and fields, meadows and pasture comprise the largest proportion of open landscapes in North Rhine-Westphalia. At the beginning of 2015, 16,547 square kilometers, almost half of the state's land area, was being used for agriculture. These cultural landscapes are of high importance in the ecological balance: as part of the natural material cycle and as habitats for fauna and flora. However, increasingly intensive methods of cultivation and the factory farming concentrated in certain regions are jeopardizing these functions. Monoculture, excessive fertilization and pesticides are putting strain on the environment and are also responsible for an increasing loss of biodiversity. In North Rhine-Westphalia, around 34,000 agricultural operations produce food and feed as well as renewable resources worth roughly EUR 7.4 billion per year. In 2015, corn was the dominant crop in relation to crop area (around 287,000 hectares of grain corn, corn silage, corn for green fodder, a good 8% of the state's land area), followed by winter wheat (roughly 270,000 hectares). The most important heavy livestock among domestic farm animals is the pig: In 2015, there were 7.4 million pigs in the state's sties. The number of cattle ran to around 1.45 million. Chickens were by far the most numerous small livestock at around 11.5 million animals. Almost 60% of pigs and approximately 40% of cattle and chickens are concentrated around the administrative district of Münster.

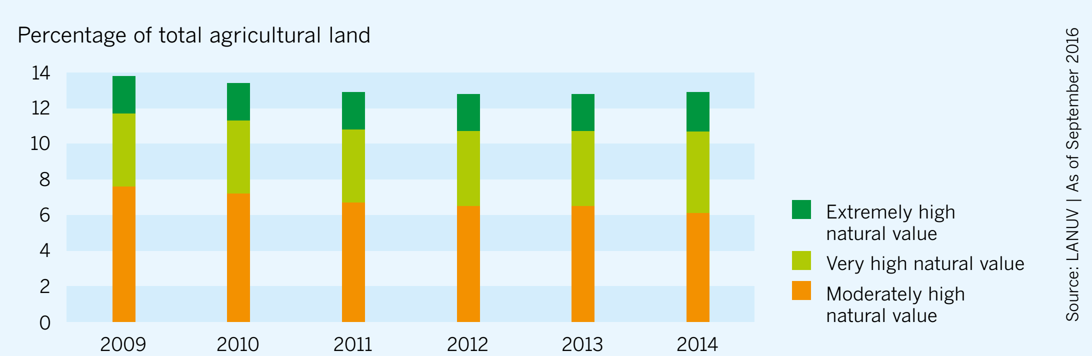
Figure 50 Environmental indicator: nitrogen surplus on agricultural land (land calculation) in NRW



If we balance the nitrogen input from farm fertilizers and mineral fertilizers against the nitrogen output during harvest, there is usually a surplus of nitrogen, as part of the nitrogen leaches into the soil or is contained in the humus, and nitrogen output cannot be precisely calculated beforehand. In 2014, the nitrogen surplus on agricultural land was 93 kilograms per hectare. A statistical analysis of the last 10 years has shown a constant trend. Critical nitrogen surpluses reflect regional livestock densities, which are very high in some areas. The State Government aims to reduce nitrogen surpluses to a maximum of 60 kilograms per hectare per annum by 2030.

Environmental indicator: surplus nitrogen on agricultural land
www.umwelt2016.nrw.de/169

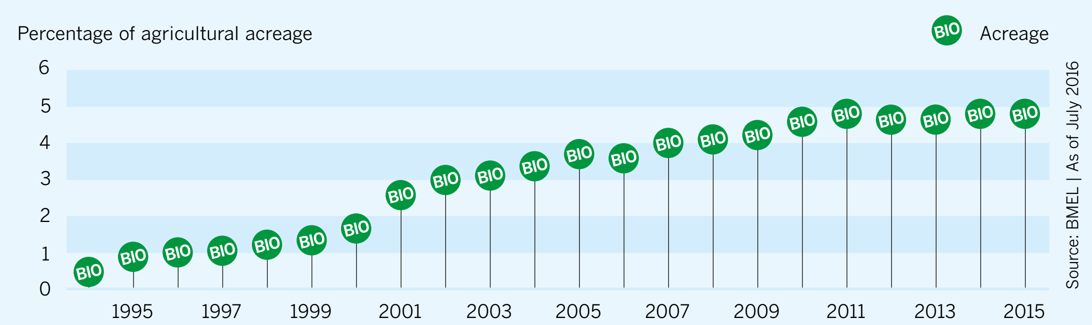
Figure 51 Environmental indicator: high nature value farmland in NRW



A mere 13% of the agricultural landscape is of high natural value (one third of this is located outside of farmed cropland and grassland). Agricultural areas of high natural value make a considerable contribution to biodiversity, with species-rich grassland, extensively used cropland, fallow land and linear structures such as hedges and near-natural stream courses. The State Government aims to preserve and expand agricultural land of high natural value.

Environmental indicator: agricultural land of high natural value
www.umwelt2016.nrw.de/172

Figure 52 Environmental indicator: organic farming in NRW



Even if the proportion of organic farms in the state's agricultural acreage has recorded a significantly positive trend in the last 10 years, this proportion has been stagnating at 4.8% since 2011. The State Government aims to increase the proportion of organic farms, because consistently foregoing certain substances such as chemical and synthetic pesticides or mineral nitrogen fertilizers protects the environment.

Environmental indicator: organic farms
www.umwelt2016.nrw.de/177

Glossary and list of abbreviations

>	greater-than symbol
%	percent
°C	degrees Celsius
⅞g	microgram
abiotic	relating to inanimate nature
AK UGRdL	Working Group on Environmental-Economic Accounting of the Länder
becquerel	unit of activity for a volume of a radio-active substance
BMEL	German Federal Ministry of Food and Agriculture
BMUB	German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
Cd	cadmium
CO_2	carbon dioxide
CVUA-MEL	Chemisches und Veterinäruntersuchungsamt Münsterland-Emscher-Lippe (Chemical and Veterinary Investigations Office Münsterland-Emscher-Lippe)
Destatis	German Federal Statistical Office
decibel	one tenth of a bel (a unit for measuring noise levels)
DGVN	United Nations Association of Germany
dl-PCB	dioxin-like polychlorinated biphenyl
DWD	Deutscher Wetterdienst (German Weather Service)
EEA	European Environment Agency
et al.	and others
EU	European Union
FC	field capacity
Footprint	ecological footprint
GDP	gross domestic product
Geobasis NRW	Division 7 of the Regional Government of Cologne
GFN	Global Footprint Network
gha	global hectare
gigajoule	1 billion joules
ha	hectare
i.e.	that is
IPCC	Intergovernmental Panel on Climate Change
IT.NRW	Landesbetrieb Information und Technik Nordrhein-Westfalen (State Agency Information and Technology North Rhine-Westphalia)
IWR	Institut für Regenerative Energie-wirtschaft (German Institute for Renewable Energy)
joule	unit of energy
KBA	German Federal Motor Transport Authority
kg	kilogram
km	kilometer
km^2	square kilometer
l	liter
LANUV	State Agency for Nature, Environment and Consumer Protection North Rhine-Westphalia
LB WuH	Forest and Timber State Enterprise
m	meter
m^2	square meter
m^3	cubic meter
mg	milligram
MKULNV	Ministry for Climate Protection, Environ-ment, Agriculture, Conservation and Consumer Protection of the State of North Rhine-Westphalia
MWEIMH	Ministry of Economic Affairs, Energy and Industry of the State of North Rhine-Westphalia
N	nitrogen
NH_4	ammonia
no.	number
NO_2	nitrogen dioxide
NO_3	nitrate
NOAA	National Oceanic and Atmospheric Administration
NO_x	nitrogen oxides
NRW	North Rhine-Westphalia
O_3	ozone
Ökopol	German Institute for Environmental Strategies
Pb	lead
PCB	polychlorinated biphenyl
percentile	statistical unit for dividing a data record into increments of 1% by size
petajoule	1 trillion joules
PFAS	fluorosurfactant
picogram	1 trillionth of a gram
PM	particulate matter
PM_{10}	particulate matter smaller than 10 micrometers
ppm	parts per million
RCM	regional climate model
RCP	Representative Concentration Pathway
Straßen.NRW	Landesbetrieb Straßenbau NRW (State Enterprise Road Building North Rhine-Westphalia)
t	metric ton
T	tesla (a unit for measuring the strength of a magnetic field)
UBA	German Environment Agency
USA	United States of America
W	watt
WHO	World Health Organization

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