Leibniz Gemeinschaft

Zwischenruf

Water: beware!

The secondary effects of climate change on water

Including contributions from ecology, geophysics, climatology, spatial planning, agricultural und business sciences, medicine and technology

Issue 1/2011

Editorial

Dear Reader,

There are a number of terms that have been exhausted due to their excessive use in recent decades. Two such terms will be focused upon in this issue of Zwischenruf "Water: beware!" They are: holistic and sustainable.

When we discuss water in terms of its use and protection, we are concerned with sustainability. Future generations will require sufficient quantities of clean water, just like we do. And we do not need to look at the regions of the world with risk of drought to become anxious about shortages. Even Germany is facing problems caused by global climate change, problems which have so far received little attention by politicians and the media. How, for instance, should more biomass be cultivated for generating energy and resources if the increased drought during summer months prevails together with the increased frequency of extreme weather events? Although the initial impact of global climate change has already become firmly anchored in the public consciousness, behind this lie less obvious reactions and unexpected side effects – and it is these secondary phenomena that this issue of Zwischenruf seeks to highlight.

The particular strength of the research institutes within the Leibniz Association is the range of topics that they cover, especially when tackling the major challenges facing society. The topic of the "secondary effects of climate change on water" is one such challenge. It is not just a matter of fresh water and biodiversity in rivers and lakes. It also concerns new pathogens, securing food supplies and flood control. It involves altered framework conditions for insurance companies and industrial production, as well as the coordination of spatial planning and water management. These challenges necessitate a new approach and, above all, a holistic view of the matter.

The "Zwischenruf" series is aimed primarily at political decision-makers in central and local government. At the same time, I am convinced that both the research results and the recommendations to politicians derived from them will also be of great interest to a wider audience.

With this in mind, I wish you an enthralling read!

Kind regards,
Karl Ulrich Mayer
President of the Leibniz Association

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Water: beware!

Climate change, disappearing lakes and why mosquitoes are turning into globetrotters

Hubert Wiggering (ZALF), Klement Tockner (IGB), Gunnar Lischeid (ZALF), Aranka Podhora (ZALF)

Water as a resource and habitat

Water represents life on this planet like no other element. As an environmental commodity, just like soil and air, it is a resource which deserves particular protection. Only 3.5 % of the earth's water is fresh water, usually bound as ice in the poles, glaciers and in permafrost, where it fulfils crucial functions, but cannot be directly exploited. Of the 118,000 km3 of water theoretically available across the globe each year (by way of comparison: the Rhine has an annual runoff of 60 km3), 49 % flows into the sea, 50 % is used by forests, steppes and wetlands as ecosystems, 0.9 % is used for irrigation, and only 0.1 % is actually available to cover humans' basic needs and to support industry. According to these statistics, there are sufficient quantities of water, albeit, unfortunately, not always in the right place or at the right time.

There are a number of global problems concerning water, most significantly, access to hygienic, clean fresh water, adequate water for agriculture and industrial production and the application of water management. Flood control, waterborne pathogens and the preservation of biological diversity also constitute global challenges. Each year, around 500 billion euros are currently being invested in the water sector, the majority of which goes towards the supply and disposal of water in industrial nations. Less than 20 billion euros are ring-fenced for global water protection.

It is a well-known fact that water constitutes an essential and often scarce resource for humans, the economy and for ecosystems. Because of the major role it plays, the central issues are discussed again and again: is water a tradeable commodity, just like food, or should water be given a special protection status for economic development? Should water be privatised or should it be regulated by the state?

Further complexities arise from the polarity of the problem in that climate change can bring both water shortages and excesses as a result of flooding. Although these primary effects of climate change have now become firmly anchored in the consciences of most decision-makers, they are regrettably marginalised or even neglected in legislation. In addition, many of the water protection measures currently called for are inadequate to the complexity of these diverse interrelations in a confined world.

Natural protective mechanisms against water pollution, flooding, and so on, are often underestimated. Due to the secondary effects of climate change on the water budget, it is increasingly the case that critical situations are worsened or that completely new problems arise. And, finally, adaptation measures can also lead to underestimated side effects. For this reason, devising concepts to adapt to climate change in favour of protecting this essential natural resource necessitates a broad, inter- and transdisciplinary approach, which this issue of Zwischenruf intends to demonstrate.

How climate change has a direct effect on water

Water is particularly affected by climate change. The known primary effects include glaciers melting and crop failure following periods of drought and flooding.

Floods are the most expensive and destructive natural disasters in the world. In the period from 1900 to 2004, 2.9 billion people were affected by flooding, over 130 million were made homeless, and nearly three million lost their lives. This trend continues. Bangladesh, for instance, is a massive flood area. Himalayan rivers "feed" the most densely populated country in the world. Around 30 years ago, however, flooding and drought started to increase as a consequence of land use change in the catchment areas and as a result of climate change.

The quality of water is also becoming increasingly impaired by climate change. For instance, our inland waters are (for the time being) centres of biological diversity, comparable to coral reefs or tropical rainforests. Although lakes and rivers cover only 0.8 % of the earth's surface, they are home to 10 % of all known species of animals and a third of all vertebrates. This diversity is decreasing dramatically, more so than in any other ecosystem.

In addition, the energy and climate crises are increasing the pressure on bodies of water as ecosystems, and on water as a resource. This phenomenon can be seen in the increasing conflict between the production of renewable energies and water scarcity, bioenergy production and the rapid increase in the use of hydropower whilst, at the same time, water scarcity is becoming more frequent. A further tension is that dams, especially those in the tropics, often create more greenhouse gases than is saved by compensating for fossil fuels.

The increasing demands placed on biomass for use in industry or as energy also necessitate new solutions for the water cycle, in connection with climate change, in particular in the event of declining precipitation.

Wherever biomass is required, the need for artificial irrigation in agriculture rises. If the irrigation water is taken from groundwater, the quantity of groundwater will further decline, or rivers and lakes will disappear. If the irrigation water is absorbed by the plants and released into the atmosphere by transpiration, the quantity of water in the atmosphere is increased, leading to greater quantities of precipitation at a greater distance. The irrigation water that seeps into the ground returns to the groundwater, and the cycle commences anew. Due to such circulation, solutes and harmful substances accumulate in the topsoil, and the cycle affecting the quality of groundwater begins again.

Indirect effects – or secondary effects of climate change

With each disaster, the press, the public and politicians are reminded of the impact of climate change. Unfortunately, there is not a similar raised awareness about the secondary effects of climate change on the protective good – water. Secondary effects add to the primary effects, often intensifying them, and our aim is to highlight this in this issue of Zwischenruf.

It can clearly be seen, for instance, that different regions and sectors react to climate-induced water fluctuations in different ways. In order to deliver a coordinated approach, individual legal and conceptual provisions need to be devised involving close, integrated consultation between water management and spatial planning, as well as adapted institutional framework conditions. Climate change can be counteracted, even in droughty regions, by professional water management with targeted retention in rural and groundwater replenishment, as in Brandenburg, or by closed-loop recycling. In addition, so-called virtual water, as a partial aspect of production, should be factored into the equation. One of the aims is to stabilise the economy by providing adequate solutions, since industries are already suffering from climate-induced water shortages. On the other hand, statutory provisions, for example concerning flood insurance, could play a central role in creating uniform regulations on certain water-related issues.

It is also crucial to look beyond the borders of Germany, and to consider the global nature of the topic. For instance, tropical pathogens and their vectors are spreading in Germany, for which special monitoring and purification systems need to be created. According to the World Health Organization (WHO), 2.3 billion people fall ill each year because of contaminated water, and 3.5 million people die from waterborne diseases. Clean fresh water, adequate waste water purification, improved hygiene conditions and waterborne diseases are inextricably linked.

In addition, parallels between German and the international experience become apparent if we take the example of salt water intrusion on small islands. Such parallels enable us to learn from one another, in an international exchange of experience.

Water – a national and international topic of discussion

In Germany, legislators have protected water and regulated its use since 1957, with the implementation of the Federal Water Act. The United Nations has declared 22 March as World Day for Water, to draw attention to the significance of this resource. In 2010, the General Assembly of the United Nations (UN) declared access to clean fresh water and sanitation a human right. However, as a human right, it is not enforceable under international law, meaning that no legal consequences can initially arise from this. If, however, clean water and sanitation are viewed as conducive to a decent standard of living, they may become enforceable[1].

At the United Nations Conference on Environment and Development in 1992 in Rio de Janeiro, the "Earth Summit", environmental commodities were less prominent in the Rio Declaration on Environment and Development; nonetheless, numerous states signed the Framework Convention on Climate Change there. In 2002, the Johannesburg Declaration on Sustainable Development underscored more clearly the significance of water: "air, water and marine pollution continue to rob millions of a decent life." One of the demands was "to speedily increase access to such basic requirements as clean water." International foundations have therefore been laid to enable the topic of water to be dealt with again at the forthcoming United Nations conference in 2012 in Rio de Janeiro (Rio +20). This issue of Zwischenruf highlights the necessity of concentrating not only on the primary effects, but increasingly on the secondary effects of climate change.

As a result of the obvious primary consequences of climate change on water taking centre stage, both scientific research and political demands concerning secondary effects have until now often been overlooked. Particularly in view of "Rio+20", scientific findings and associated political demands are more important than ever.

The expertise of the Leibniz institutions – whether singly or in collaboration – enable answers to be given to these questions, and aims to help close these gaps with regard to secondary effects.

You can already guess why mosquitoes are turning into globetrotters. But you can ultimately find out what lies behind disappearing lakes in this edition of Zwischenruf. Furthermore, if you have any questions, please feel free to contact the research institutes of the Leibniz Association, which deal intensively with research into water.

[1]Cf. http://www.redglobe.de/nordamerika usa/3896-wasser-ist-ein-menschenrecht

Fig.: A. Prochnow (ATB)

Winter barley with intercepted water

In search of suitable institutions

Climate change poses a challenge at all political levels

Insa Theesfeld (IAMO), Katrin Drastig (ATB)

The significance of water in agriculture

In the future, an increasing number of people with a growing per capita food energy demand will have to be fed from agricultural products grown on a shrinking area of cultivated land. Irrigation farming will have a crucial role to play here: in the future, for every litre of water used, a higher yield of agricultural products will be needed. Further difficulties are anticipated such as increased aridity during the most important vegetation phases, as well as singular extreme events, such as late frost and intense rainfall, together with a general shift in the vegetation period.

In addition to so- called primary plant cultivation adaptation strategies which focus on water efficiency by way of technical progress and improved control of irrigation techniques, secondary institutional adaptation strategies are required. In other words, regulations and coordination mechanisms concerning the use of the resource water must be adapted.

Adaptation strategies

Plants require the most water during the phase of maximum leaf formation and the highest growth in mass. In Germany, for example, local beet stocks require one third of their total annual water demand in July and August.

Due to selection and breeding strategies, opportunities now exist to produce drought-resistant cultivars or even to control when the blossom and fruit should develop. Another way to enhance water efficiency is to use modern irrigation techniques in which particular attention must be paid to the control of the process. After all, irrespective of the irrigation technique, the control system has a greater effect on water conservation than the actual irrigation technique.

In addition to these primary strategies, secondary adaptation strategies also exist, particularly institutional innovations in the agricultural water sector. Here it is a matter of adapting regulations and coordination mechanisms when dealing with the resource water: how can organisations and authorities in the agricultural water sector react to the impending change? In seeking answers to this question, forecasts on climate change need to be considered, in addition to numerous other socio-economic and political drivers.

Together with the German Development Institute in Bonn, IAMO has conducted studies in the Federal State of Brandenburg, the Ebro river basin in Spain and the US State of California. These studies demonstrate how water authorities at different administrative levels have managed to introduce a range of institutional innovations to adapt agricultural water management to climate change.

The most important trends can be summarised as follows: in addition to horizontal collaboration between authorities, for example, cooperation between agricultural and water authorities, it is becoming increasingly popular to collaborate vertically, for instance, by including interest groups. The three countries participating in the study recognised the need for broad social participation, which is necessary to cope with the diverse aspects and consequences of climate change. In addition, climate change adaptation strategies are increasingly being drawn on as a criterion for financial funding mechanisms.

In the process, however, problems also arise, such as the ill-defined allocation of responsibilities, when authorities cooperate within the political and administrative hierarchy at national, federal state or community level.

Water utilisation calls for not only technical, but also innovative institutional adaptation strategies to cope with the rising demand for agricultural products and climate-induced impacts.

With the rising demand for agricultural products and climate-induced changed impacts, not only technical but also innovative institutional adaptation strategies must be devised for water utilisation.

Fig.: H. Foltan (ATB)

Providing crops with water may constitute a growing challenge to agriculturalists.

The situation is similar for horizontal interaction between different sectors and organisations. Likewise, bureaucratic inertia impedes institutional change. If, for example, in the past central authorities exclusively decided who may extract water from rivers and wells and under which conditions, it will be difficult to implement a regulation that transfers responsibility to the local level. Yet, the knowledge of the local conditions is often crucial, particularly when dealing with the resource of water.

Recommendations for action in policy-making

Farm-related plant cultivation strategies

Water is the limiting factor in many field crop systems. It is not appropriate to apply a blanket policy of primary plant cultivation adaptation measures to all farms in a certain region. It is not possible to assert whether individual measures to improve water efficiency are simply "good" or "bad". The entire 'farm system' must be taken into consideration.

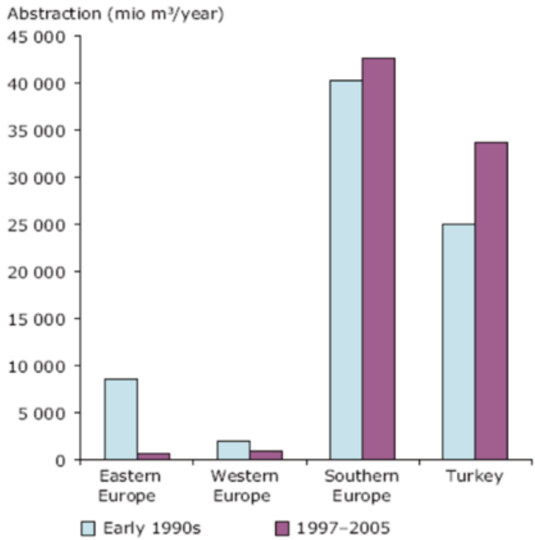
Both the farmers and authority officials should be familiarised with the latest research results, in a comprehensive manner, to enable them to derive the best adaptation measures for their particular local conditions.

For instance, soil management and soil tillage, sowing, crop species, crop rotation and irrigation must be adapted to the soil type, groundwater conditions and the weather, as well as to the current state of the market.

In this context, the quantification of water utilisation by individual measures as well as the evaluation of potential efficiency improvements are a novelty. This is one of the topics being explored by the Young researcher group `AgroHyd´ (http://www.atb-potsdam.de/agrohyd), recently established at ATB.

Current research has led to the following recommendations for action:

- **Create a supportive institutional environment for agriculturalists:** Agriculturalists require a certain degree of planning reliability to invest in new technology or cultivation strategies. Such planning reliability includes support by multi-risk insurance as well as a drought relief programme, which is already being applied today. Politicians and authorities help by providing information and transparency.



Water abstraction for irrigation

Fig.: EEA Core Set Indicator CSI 18, based on data from Eurostat data table: Annual water abstraction by source and by sector.

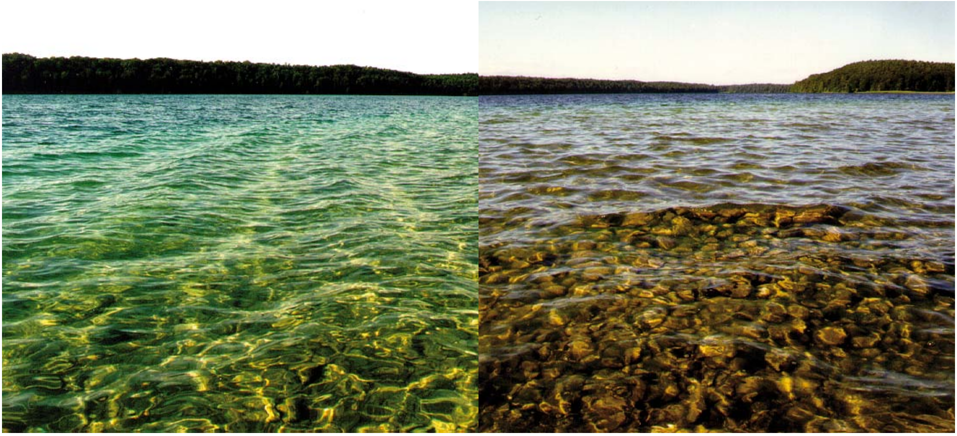
- **Ensure a supportive institutional environment for organisations and authorities in the agricultural water sector:** The changes previously implemented by agricultural water authorities are viewed as secondary adjustment to climate change. It is important to identify bureaucratic inertia at an early stage, and to counteract it. Financial incentive schemes and training programmes help to motivate employees by familiarising them with new procedures and processes.

- **New coordination mechanisms in the agricultural water sector are required:** Adaptations by the agricultural water sector cannot be made by them in isolation. An integrated approach and management across various sectors are required. Integrated Water Resources Management (IWRM), as the current paradigm of water management, and the implementation of the European Water Framework Directive are paths being taken in this direction. One key aspect of both concepts is the participation of local actors and water users in water management decisions. Politicians play an important role here in creating a framework that fosters real participation beyond the mere dissemination of information. Participation forums must remain in place long term to have a real impact on designing measures and programmes. Trust can be created if developed proposals are actually implemented in policy measures and programmes. A requirement for this is that the mechanism enables contributions to be given to decision-makers.


Fig.: EEA Report, 2009, page 37

Irrigated olives on Crete

Fig.: T. Gonsiorczyk (IGB)



Clean water – an increasingly scarce resource globally

Freshwater ecosystems under climate stress – What can be done?

Peter Kasprzak, Michael Hupfer,
Peter Casper, Mark Gessner,
Hans-Peter Grossart (IGB)

"An abundance of bodies of water – but a lack of water"

These few words give a climatological/hydrological description of the Northeast German Lowlands, particularly the federal states of Brandenburg and Mecklenburg-West Pomerania. Precipitation rates in Germany are declining from the southwest to the northeast. This decline results in a strain on the water balance in the north-eastern regions, particularly during the summer months. In the Lake Stechlin area, around 75 km north of Berlin, the average annual precipitation rate is 634 litres per square metre (L/m^2). The evaporation rate is 549 L/m^2. More water evaporates from the open lake surfaces than is replaced by precipitation. Only the positive balance of the land surfaces – around 85 L/m^2 – ensures groundwater recharge, securing the existence of numerous lakes and streams.

Climate change has a negative impact on anthropogenically influenced freshwater ecosystems. This is particularly the case for the northeast of Germany, which experiences little rainfall.

Efforts must be made to achieve targeted water retention in the landscape and enhanced groundwater replenishment to stabilise aquatic ecosystems in the region in the face of the effects of climate change.


Fig.: M. Schrumpf

Fig. 1: Swimming jetty at Kleiner Kronsee, a nature reserve near Lychen (Brandenburg, April 2011). The dried algae coating on the pillars are a clear indication of the water loss (approximately 1.70 m).

For around 30 years, water scarcity has been exacerbated by the now noticeable effects of climate change. The consequences are declining water levels in lakes, reduced groundwater recharge, increased evaporation from lake surfaces and a shift of precipitation from summer to winter. According to model-based forecasts, precipitation will decrease by around 50 to 60 L/m^2 by 2050, exacerbating water shortages. Economic consequences will follow: the increasing demand for irrigation water to cultivate high-grade agricultural crops in the lowland region is expected to exceed the available quantity of water in around ten years. This forecast necessitates a rethink, now!

Cause and effects

The close inter-relationship of human impact and the effects of climate change intensify the consequences of water scarcity even further. This is particularly true for extensive draining systems linking moors, wetlands, and inland drainage areas to rivers but also for extracting groundwater at locations with low supplies or poor recharge. Although it is often very difficult to differentiate between anthropogenic impact on the landscape water balance and the effects of climate change, one thing is certain: the water levels of a number of lakes in the Northeast German Lowlands have fallen by up to 3 metres in recent decades (see Figure 1).

Water loss and rising temperatures already have a far-reaching impact on the entire lake ecosystem. Thermal stratification, the light climate of lakes, the duration of ice coverage and the input of substances from catchment areas have been especially hard hit. The spread of exotic animal and plant species to the area is facilitated, leading to the creation of new biocoenoses comprising native and exotic forms. These new biological communities have no common life history, and may therefore have a considerable impact on the ecological conditions of affected lakes.

In other words, together, climate change and direct anthropogenic impact on the landscape impairs the function and use of lakes. If, however, man's impact exacerbates the effects of climate change on inland waters, it ought also to be possible to ameliorate them by introducing appropriate protective measures.

Fig.: calculated by IGB

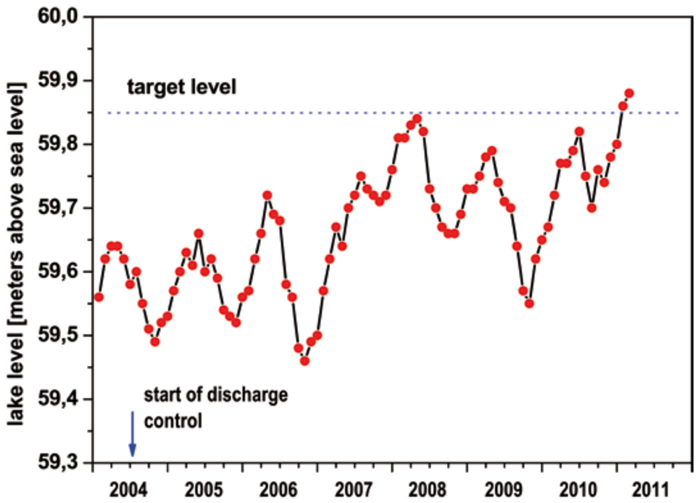


Fig. 2: Time series of water levels at Lake Stechlin. The start of impoundment in September 2004 and the long-term target level of storage water of 59.85 m above sea level are shown.

Lakes undergoing change: the example of Stechlin

Lake Stechlin (with an area of 4.23 km^2 and a maximum depth of 69.5 m) is one of the deepest oligotrophic lakes of the Northeast German Lowlands. Two lasting interventions in the lake's water balance have occurred in the past 300 years: between 1745 and 1750, it was linked up to the river system of the Havel, and in 1960 the cooling water cycle for Rheinsberg nuclear power station was constructed. As a result, the lake level fell by around 1.25 m. By raising an existing weir in 2004, runoff was reduced, damming the lake again. Aided by a number of wetter years, the targeted level of storage water of 59.85 m above sea level was realised within a short space of time (see Figure 2). Although the historic lake level will not be achieved by the damming measures, in its current state, Lake Stechlin no longer suffers from acute water scarcity.

Nevertheless, it continues to be negatively affected by the interaction between climate change and anthropogenic impact. In addition to the problems of water scarcity, other changes have become evident, particularly in the past 15 years: rising water temperatures at the surface, extended thermal stratification in summer and an increased availability of plant nutrients.

Lake Stechlin under climate stress

The effects of these changes have included a displacement of the species spectrum and increasing quantities of planktonic algae. The ecologically valuable “underwater meadows”, formed primarily by stoneworts, have already declined dramatically. In the shallow areas of the lake, stands have shrunk by around 90 per cent since the 1960s. Another critical change is the oxygen concentration of the lake's deep water that has been declining since the mid 1990s. Global warming may be one of the causes of this phenomenon. After all, global warming has led to the prolongation of the time of oxygen consumption in the lower layers of water, due to the extension of the thermal stratification, before deficits can be compensated for in late autumn by the input of atmospheric oxygen (see Figure 3).

Recommendations for action in policy-making

Advancing climate change makes it essential to further reduce anthropogenic impact on inland waters, to buffer negative effects to the greatest possible extent.

The negative effects of climate change can be alleviated by measures to promote groundwater recharge and to retain water in the landscape:

- Above all, such measures include the consistent **renaturation of lakes and streams**, and the r**ehydration of**

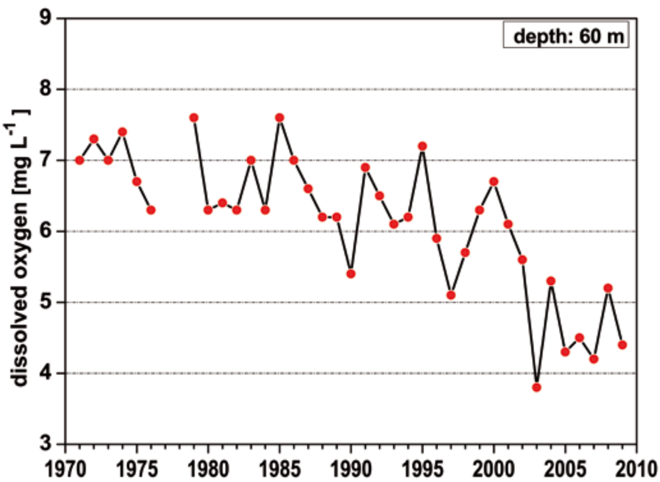


Fig.: calculated by IGB

Fig. 3: Time series of the oxygen concentration in the deep water of Lake Stechlin. The annual minimal concentrations at a depth of 60 m in the months of November or December are portrayed.

wetlands. Such measures decelerate run-off from the area, helping bodies of water to react less negatively to fluctuating precipitation. **Areas suitable** for such measures need to be set aside on a large scale for **adapted usage, if necessary, by restricting use**.

- **Groundwater recharge** can be enhanced by **converting coniferous forests into broad-leaved stands**. Averaged over the year, less water is evaporated from broad-leaved trees than from conifers, which also helps to stabilise the water balance of lakes. In carefully selected cases, scarce groundwater supplies can be supplemented by the artificial infiltration of river water or by well-purified waste water. The same applies to mitigating water shortages in lakes by connecting them up to streams.

- In addition, as a result of **climate change**, increasing **nutrient enrichment** (eutrophication) can be expected in many cases, which fosters the growth of planktonic algae, making lakes turbid. For this reason, there must be sustained endeavours to **capture and eliminate external sources of nutrients**. The EU Water Framework Directive offers an important legal basis to achieve this end.

Fig.: © petrabarz – Fotolia.com

Around 10,000 litres of water are required to produce one kilogramme of lamb. By comparison, it takes only 6.5 litres to grow half a tomato.

Virtual water – think about it!

Interview with Marianela Fader (PIK)

Around ten thousand litres of water are consumed to produce one kilogramme of lamb; thirty thousand litres are required to make a computer, and half a million litres to produce a tonne of paper. Thus, international trade implies always water trade. However, since the water is not physically embedded in the products, we refer to this as "virtual water." The agricultural sector is one of the world's largest water consumers. Marianela Fader carries out research into the topic of virtual water at the Potsdam Institute for Climate Impact Research.

Ms. Fader, what role does virtual water play in the climate debate?

As an adaptation strategy, a country suffering from water scarcity could import virtual water and use its own water resources for higher-level economic purposes, such as in tourism and industry. From a global perspective, the efficiency of water use could be improved by shifting agricultural land to water-efficient regions.

How is virtual water measured?

Usually in cubic metres consumed to produce one kilogramme of a commodity, then it is a measure of efficiency. But also often in the quantity of imported and exported water, and sometimes as the "water footprint" in the per capita quantity consumed by a country's population.

What problems can we expect to see in the future?

Demand for water will continue to rise in all sectors, whilst water will become scarcer in many regions, primarily (but not only) as a result of population growth. Together with the expansion of agricultural areas, the extension of irrigation and the improvement of land and water productivities, virtual water trade constitutes a potential adaptation strategy. However, trade is determined by many other factors – water is rarely the main criterion. And many governments will be afraid of taking too high a risk by putting the food security of their own people into the hands of other countries.

Is there a need for political action with respect to this topic?

Research needs to be carried out into this subject. Firstly, we know very little about the impact climate change and the CO_2 fertilisation will have on the water productivity of plants. The net effect may even vary considerably from region to region. Secondly, we need to know where each country consumes which resources, also indirectly, to be able to link a society's level of consumption to environmental consequences. Thirdly, it is extremely important for each country to find out the extent to which national food security is dependent on external resources. These topics ought to be considered in many political decisions, such as with regard to agricultural subsidies, international environmental and trade agreements, and the control of demographic development.

Fig.: Andreas Röhring (IRS)

The Große Dhünntalsperre, the largest drinking water dam in western Germany, is surrounded by a water protection area to prevent the water from becoming contaminated.

More space for water!

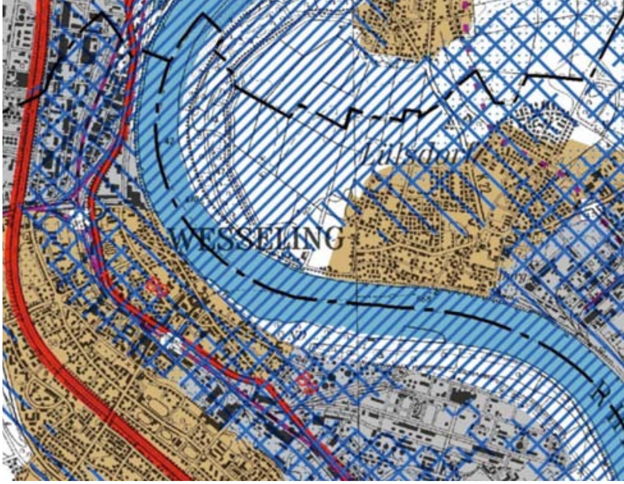
Carolin Galler (Institute of Environmental Planning, Leibniz Universität Hannover), Peter Müller (ARL), Gregor Prinzensing (IRS), Katlen Trautmann (IÖR)

Comprehensive cooperation required

Comprehensive cooperation between water management and spatial planning can enhance water and spatial management, mitigating the effects of climate change. The call for such cooperation is rooted in the element itself: the natural resource of water meets not only humans' basic needs, but also those of nature. Having adequate quantities of sufficiently high-quality water is a central requirement for meeting many social and natural functions. Any change in the water balance caused by water usage or climate change has an effect on space utilisation. Vice versa, any type of space utilisation changes the water balance.

As a result of climate change, demographic change, new EU directives and other "drivers" of change affecting the water balance and space utilisation, managers of water and spatial planners are faced with new challenges, necessitating considerably greater cooperation between these two areas. In combination with economic and technological change, this signifies drastically altered framework conditions for the integrated management of the water balance. Within this process, sustainable spatial development needs to accommodate uncertainties surrounding the future course of climate change and social change.

Against this backdrop, an interdisciplinary team of scientists and practitioners in the research group "Water and spatial planning" at the Academy for Spatial Research and Planning – Leibniz Forum for Spatial Sciences (ARL) has been engaged in exploring the tasks, Fig.: Regional plan for the administrative district of Cologne (2006): section preventive flood control (detail)



Flood control through spatial planning

framework conditions and options for action in water management and spatial planning. The Leibniz institutions ARL, IÖR and IRS, amongst others, have collaborated on this topic and have drafted recommendations for the sustainable use of water with regard to space.

Benefit from synergies

Water resources management involves the supply of water, the protection of water and the protection of the population against damage from water. In recent years, European directives have had a crucial impact on this area of activity. The EU's Water Framework Directive (WFD) requires that by 2015 all waters have to achieve good ecological and chemical status and, for groundwater, good quantitative and chemical status. However, the water management sector is unable to achieve these environmental targets single-handedly.

With regard to multidisciplinary planning on the organisation and development of space, spatial planning traditionally pursues an integrative approach by combining, coordinating and assessing spatially-relevant issues. With its own objectives, tasks, tools and skills, spatial planning operates in the same fields as sectoral planning like water management.

By coordinating space utilisation, spatial planning can support river basin management pursuant to the WFD and make a considerable contribution to flood risk management as set out in the EU Flood Directive (FD).

Particular support needs to be given to the activities related to water protection in river catchment areas by nature conservation, agriculture, forestry and spatial planning.

Similarly, to implement the FD, spatial planning, shipping and nature conservation should be included, in addition to water management. After all, the spectrum of measures for appropriate flood protection ranges from dykes and protective barriers at the bodies of water to adapted agricultural use and the location and type of buildings.

Close cooperation between water management and spatial planning can lessen climate-induced effects on the water balance, and counteract them.

The political objectives and legal requirements of water management can be implemented effectively by coordinated spatial planning.

The integrated planning and implementation of multifunctional measures requires environmental information that needs to be brought together in an information system and updated by coordinated monitoring.

Fig.: Andreas Röhring (IRS)

Industrial river landscape of the Rhine near Cologne

Example: flood risk management
Using the example of flood control, we can see how different interests intertwine. After all, on the one hand:

- the creation of large flood polders decreases peak discharge values, and hence water levels, in areas prone to flooding which, in an emergency, may lead to a considerable reduction of the damage caused;

- a shift of dykes creates the conditions for restoring the typical biological diversity found in the alluvial landscape.

However, such measures are often implemented only sluggishly. After all, on the other hand:

- "waterfront living" is still, and increasingly so, considered to be a premium location, and this fact often hinders the availability of the areas required to implement such measures;

- the consistent reservation or recovery of areas requires the participation of many stakeholders and planning levels, making the planning process more cumbersome.

Attempting to solve spatial planning and management tasks has gained considerably in complexity.

An approach based purely on the perspective of managing bodies of water is insufficient. Various factors need to be taken into account, namely the development of a sustainable use of surface water and groundwater in times of climate change, achieving the "good status" target and the focused management of flood risk. In addition, all of these need to be combined with other spatial planning objectives.

Recommendations for action in policy-making

The recommendations put forward by the ARL research group "Water and spatial planning" aim primarily to utilise the effectiveness and efficiency potential of a coordinated approach between spatial planning, water management and sectoral planning. In this respect, it is important to coordinate the planning processes, to develop a joint strategy and to combine tools and measures.

- Realistic environmental information systems are the key to the success of the transition to integrated, preventive environmental and spatial development. As an important and promising step forward in cooperation between spatial planning, water management and sectoral planning, all spatial environmental data should be consistently stored and exchanged with an appropriate level of detail. The methods used to capture and evaluate the data should be synchronised across disciplines.

- At the same time, environmental information systems form the basis for continuous monitoring in all scopes of duties. In this way, conflicts and synergies between different water-related tasks can be identified and the efficiency potential of multifunctional measures can be realised.

- Those involved in spatial planning can initiate and moderate joint strategy development between the various departments of sectoral planning. They are considered to be "impartial", and have a great deal of experience in moderating conflicts of interest. The objectives of water protection and flood prevention can then be integrated into sustainable spatial development. To this end, spatial planning has the legal instruments and planning tools at its disposal, such as declarations, representations and designations. By following an integrated planning approach, conflicts or synergies between water-related measures, for instance, by means of climate or nature conservation can be identified and constructive multifunctional solutions can be implemented.

- Greater attention should be given in spatial planning to the function of water infrastructure systems as hubs for spatial development and water uses or wastewater disposal. In particular, aspects of infrastructure should be integrated in regional planning and municipal urban land use planning at an earlier stage than is presently the case.

- New investment projects for water infrastructure and the distribution of funding should be tested for "demographic sustainability."

Fig.: in the public domain / Alexander Bock

Flooding at Lake Werder in Bremen in April 2008 as a result of a hurricane

- Flood protection can be considerably enhanced and secured from a spatial planning perspective by designating flood generation areas and areas for flood retention in floodplains, by the large-scale introduction of decentralised storm water leaching and the construction of emergency water routes. Spatial planning is in the unique position of having the resources and expertise for delivering this at its disposal. Here, spatial planning can operate in a multi-disciplinary manner, unlike sectoral planning such as water management which is very important, particularly in light of climate change.
- A joint estimate of the financial requirements for realising the objectives of the WFD and the FD and their comparison with the objectives and measures of nature conservation (in particular for the Natura 2000 network) are important prerequisites for calculating the efficient use of funds. There will be certain circumstances where the impact of spatial planning can work efficiently by achieving results in multiple areas, and this should be exploited to the greatest possible extent.

Too dry or too wet?

Christoph Jeßberger (ifo), Tim Mennel (ZEW), Daniel Osberghaus (ZEW), Markus Zimmer (ifo)

It can no longer be denied that Germany is experiencing changes to its water cycles which have been induced by climate change. There is a fundamental need to adapt to the changed environmental conditions. This is particularly the case for industrial production, the most important user of water resources in Germany. The insurance industry is also affected by the increase in extreme events (above all, flooding and intense rain), the occurrence and impact of which are very difficult to predict, making the situation fraught with uncertainties. To keep the resulting macroeconomic effects to a minimum, a careful regulation of industrial water usage – adapted to local conditions – is required. In addition, with regard to the increased danger of flooding, the possibility of compulsory insurance in the area of natural hazards ought to be considered.

Germany is a country with an abundance of water

Between the years 1961 to 1990, the average water yield from renewable water resources was around 188 bn m³ per year, only 15 to 20 % of which was actually used. Figure 1 shows the main users' percentage share in 2007.

In the low rainfall year of 2003, however, the water yield from renewable water resources was only around 99 bn m³, compared to a demand between 38.0 (2001) and 35.5 bn m³ (2004). Bearing in mind that German glaciers are expected to disappear sometime between 2035 and 2045 and the snow cover duration will be 30 to 60 days shorter, a large proportion of the current inflow from upstream feeder rivers must be considered uncertain. Without upstreams, only 44 bn m³ would have remained as the so-called internal water resource (difference between precipitation and evapotranspiration) in 2003.

Regulated "self service" – a sustainable and economically sound use of water?!

It is incumbent upon water authorities to secure the sustainable use of water resources by industry. Within the process, the legal requirements of the Federal Water Act are transferred to the regional level of the "Bundesländer" (states in

Climatic effects on the water cycle vary from region to region, necessitating individual local regulations.

Even today, production in water-intensive production sites is already subject to climate-change induced regional water shortages in Germany.

Under certain circumstances, more severe and frequent flooding could require government intervention in the insurance market. Compulsory insurance or a disaster relief fund could be a solution.

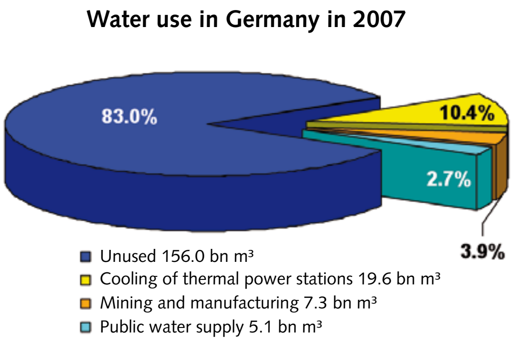


Fig. 1: Percentage shares of different uses of the water resources in Germany in 2007

Fig.: Umweltbundesamt (2009) "Wasserwirtschaft"

Germany) in relevant statutory regulations and ordinances. These specifications are typically implemented by way of water allocations. Compliance with these allocations is overseen by the upper and lower local water authorities, as well as by the supreme water authorities, which usually equate to the ministries of environment in the federal states. Because of the regional responsibility created by this structure, not only ecological but also social and economic aspects can be taken into consideration in the course of regulating the allocation of water. To assess the use of water resources, it is useful to illustrate a number of facts on water usage:

- Water-intensive production processes are primarily understood to be water users and not water consumers, since they treat used and polluted water and return it to the regional water cycle. The main water-intensive sectors are energy generation, the chemical industry, cement and metal production, quarrying and mining (for example, coal production), the food industry and paper production.

- Water consumers (where water is evaporated or bound in capital goods) are particularly thermal power stations and companies in the food and beverage industry, as well as certain processes in metal production and the chemical industry.

- For cost efficiency reasons, water-intensive production facilities pump their own water, whereby they are regulated by water authorities via individual water allocations. In fact, 94.9 % of the water used in industry is self-supplied. In most water-intensive production processes, it is possible– at an acceptable additional cost –to manage production with hardly any use of fresh water.

- Water allocations regulate abstraction rates, temperatures (the difference between abstracted and drained water) and pollutant loads on a daily, hourly or annual basis.

- Intense rainfall leads to increased water pollution due to sediments

Too dry or too wet?

and, therefore, under certain circumstances, to a reduction in the quantity of usable water. For example, dirt particles may damage the turbines in hydro-electric power plants.

The need to change the existing state regulations, and consequently, also the allocations, arises if the existing framework conditions are no longer able to secure the ecologically, socially and economically sustainable use of water. As part of the process, the demand for the use of the resource water must be adapted to the movement in the level of availability of this resource brought about by climate change.

Water-intensive production without water?

Figure 2 shows the expected change in industrial water usage from 2012 to 2025. The results were simulated using the interdisciplinary computer-aided decision support system DANUBIA, which takes into account the interactions between the natural and anthropogenic impact on climate, ecology and the economy. Strong regional differences are revealed in the generally declining use of water. Between 1991 and 2007 alone, water usage for public supply and in thermal power stations, mining and manufacturing industries fell by over 30 % in all. This trend is due to efficiency improvements in water usage, which will continue to be raised. In the future, the impending population decrease, in particular in eastern Germany, will have a negative impact on industrial production, reducing water usage even further.

On average, water usage in Germany is expected to decline by around 10.6 % by 2025 because of further efficiency improvements and demographic change, and by a further 0.4 % due to adaptations to climate change-induced local shortages of available water supplies.

Following the extremely hot summer in 2003, the Ifo Institute held numerous discussions with experts and then developed case studies within a representative survey of water-intensive enterprises in Germany. The problems that occurred were captured and conclusions drawn regarding the advance of climate change.

In summary, the following statements can be made:

- In summer 2003, only 2.6 % of the water-intensive production sites experienced a temporary drop in production due to the climatic conditions, which was usually compensated for in the course of the year.

- 39 % of the companies that expect water availability problems in the future ascribe this to the quantity of water; around 21 % ascribed

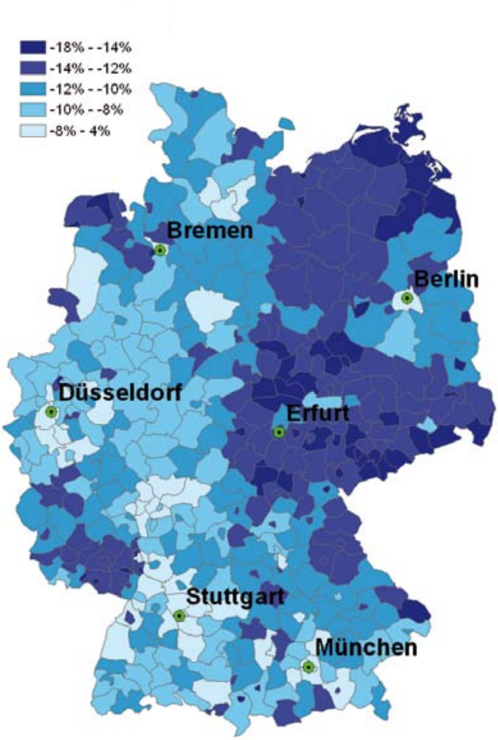


Fig. 2: Expected change in industrial water usage 2012-2025 (expressed as a percentage)

Fig.: Authors' design Industrial water demand Percentage change between 2012 and 2025

it to the quality of water and only 4 % to the water temperature. A future shortage of utilisable water is therefore most likely to be based on a decrease in the water yield due to drought. A poorer quality of water, that is the contamination of existing quantities of water, which usually occurs as a result of intense rainfall or flooding, must also be considered.

- 5.2% of the companies claimed that they would consider relocating production sites in the event of a distinct change in climatic conditions. In general, however, the production sites are based in locations unlikely to encounter serious problems in the event of climate change.

Taking climate change into account, Germany will continue to offer good conditions for existing water-intensive industrial enterprises in the future. As potential locations are already highly developed and as resource utilisation is tightly regulated, the siting of additional production facilities will, however, become increasingly difficult. Large-scale climate-change induced relocations of production from abroad into Germany are therefore not to be expected. However, changes in precipitation patterns will have other implications for industry and consumers.

Flooding – is compulsory insurance necessary?

According to the findings of climate researchers, flooding that might be expected once in a hundred years, such as the flooding of the River Elbe in 2002, could well occur more frequently in the future. According to research, even intense rainfall events could cause damage to homes and businesses more frequently in the future. From an economic perspective, insurance markets essentially offer the most obvious solution to cope with this risk. In Germany, however, only a relatively small number of households are insured against natural hazards: the insur-

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ance density was 26 % of all residential building insurance policies in 2009. For this reason, politicians in Germany tend to regularly compensate non-insured households and companies that have been hit particularly hard. In fact, such government support has been provided in recent years in various forms by both the national and federal state governments, whereby there are no a-priori set rules or procedures. From an economic perspective, this approach is considered to be inefficient: each situation where there has been state support can lead to a deterioration of precaution, in particular a drop in demand from the private sector for insurance ("charity hazard"). As a remedy, the introduction of compulsory insurance for natural hazards has repeatedly been the subject of political debate. Although some lawyers voice their concerns about such interference in the freedom of contract, from an economic perspective, there are also arguments in favour of this proposal, for example, ad-hoc state aid would no longer be required. Instead, property owners would be obliged to make their own provision. Furthermore, macroeconomic studies have revealed that economies with high insurance densities are able to absorb external shocks, such as natural disasters, more rapidly. These are just some of the reasons why there is compulsory coverage in the area of natural hazards in many European countries.

However, there are a number of arguments against compulsory insurance. Firstly, there are the costs and administrative effort involved in implementing compulsory coverage. More significantly, however, there is the question concerning the distortion of incentives with regard to settlement – how should areas with a high risk of flooding be dealt with? Compulsory coverage generally involves an obligation to contract for insurance companies, as well as a partially regulated tariff which, in the case of insurance against natural hazards, would lead to a distortion of actuarially fair premiums. Premiums would then no longer be based on actual risk. Such a socialisation of the costs of high-risk properties, such as those near a river, harbours economic risks: affected residential areas that, in the face of climate change, ought to be abandoned would be regularly reconstructed with compulsory insurance funding. Zoning into risk classes (such as with the existing ZÜRS system) and differentiated premiums could ameliorate the problem, but what would happen if the owner of a house at risk were unable to pay a high risk premium?

In cases such as these, the government would presumably have to intervene in the market in order to maintain social equality. This might be achieved through public reinsurance, as in France, which has compulsory coverage with a standard tariff, or via a regulated dis-

In addition to river flooding, intense rainfall events can also cause economic damage.

aster relief fund for non-insureds, as in Austria, which does not have compulsory coverage. It goes without saying that both approaches make more sense than the practice of German ad-hoc aid. However, this does not resolve the question of which system is more efficient. Comparative empirical studies using data from the 1990s suggest that compulsory insurance offers economic advantages with regard to premium levels, the efficiency of insurance companies and damage prevention.

Admittedly, the market for insurance against natural hazards in Germany was underdeveloped back then. In the current market environment, the insurance density is increasing – albeit at a low level – meaning that the far-reaching intervention in the free market tends to become less important. However, no robust, empirically substantiated statement on the efficiency of the German insurance market has been put forward to date.

Recommendations for action in policy-making

What are the consequences of the climate-induced changed precipitation structure for legislators?

- Both water scarcity and risk of flooding have economically perceptible effects, justifying intensified endeavours in the area of water regulation.

- Tradable allowances, as expedient in the case of globally impacting carbon emissions, for instance, are unsuitable for avoiding the strongly localised effects of water use. To ensure the sustainable use of water resources, individual regulations tailored towards local conditions are therefore indispensable. Supranational guidelines often fail to take into account local needs and conditions to a sufficient extent. For this reason, the state should primarily aim to create stronger regional institutions that are committed to the objective of achieving the sustainable use of water resources. At the same time, these institutions should have considerable freedom in completing this task.

With regard to the insurance sector, above all, standard regulation is required – only empirical studies on cost efficiency, distribution effects and preventive effects will be able to show whether it should consist of compulsory insurance or a disaster relief fund.

Until sound evidence is presented on this matter, it makes sense from an economic point of view to effectively inform households and companies about existing and increasing flood risks and possible countermeasures (building measures, private insurance), to draw up reliable, standardised rules for compensation payments, and to possibly carry out spatial planning changes in high-risk areas.

Culex mosquitoes are known to transmit such viruses as the West Nile virus. The Sindbis virus, which can cause fever with rheumatic disorders, was discovered for the first time in Germany in 2010.

Base of life and risk of infection

Jürgen May (BNITM)

Water: essential for life and the origin for the spread of infectious diseases

Worldwide, many people still do not have access to clean water. People suffer from epidemics of infectious diseases, particularly in countries with low levels of hygiene and poor medical care such as developing and emerging countries, but also in case of natural disasters. Climate change may worsen this situation.

In tropical regions, incidences of respiratory infections and infections of the gastrointestinal tract increase in the rainy season. This is partly caused by the direct ingestion of contaminated water, as is the case with typhoid fever, cholera and other viral diseases. On the other hand, mosquito larvae develop in water and are able – as adult vectors – to transmit pathogens such as malaria parasites and arboviruses. Since mosquitoes are able to breed in even small water holes, it can be difficult to eliminate the breeding sites by conventional control measures.

Waterborne infections can spread rapidly in new areas if the appropriate conditions for the pathogens or vectors are present. By this means, the construction of dams, canals and irrigation systems have led to a spread of specific infections.

Such anthropogenic environmental changes have led, for instance, to the increased prevalence of:

- schistosomiasis (helminth infection) due to an increase in water snails as intermediate hosts
- onchocerciasis (river blindness) due to an increase in breeding sites of the vector blackfly
- helminths infections of the gut due to increased contacts to larvae, which live in wet grounds

The spread of infections with parasites and viruses is also affected by environmental changes. Intensive farming enhances the expansion of malaria by changing the breeding sites of Anopheles mosquitoes. Urbanisation intensifies the spread of cholera through water contamination and of dengue fever through artificial water holes in which larvae of Aedes vectors can grow.

Climate change may have an additional impact on the proliferation of pathogenic agents: extreme weather conditions can lead to flooding, which contaminates drinking water, and can, on the other side, lead to drought conditions with a concentration of pathogens in the remaining water. In general, the larger the water surface as a result of flooding, the greater the variety of potential breeding sites. Moreover, rising water temperatures often shorten the reproductive cycle of pathogens and vectors, and can prolong their lifespan.

In Germany for every one degree rise in the weekly average temperature there is a five to ten per cent increase in notifications of salmonella infections. It is assumed that one third of salmonella infections can be associated with temperature changes.

Tropical diseases emerging in Germany

For several years the BNITM in Hamburg has been investigating the effect of seasonal fluctuations of rain on malaria and other diseases in Ghana. The researchers created a model with locally compiled data in order to predict the incidence of malaria nine weeks after precipitation peaks. The occurrences of diarrhoeal diseases, such as salmonellosis and rotavirus infections, are dependent on weather-related fluctuations as well.

Studies using satellite imageries have demonstrated that changes of land use and the associated distribution of water have a major impact on the incidence of malaria: the risk for the

Environmental changes may introduce pathogens and vectors of tropical diseases to Germany, or enable them to become autochthonous to the country.

We need an international monitoring system for emerging infectious diseases.

In places at risk, the disinfection of drinking water can help. Some promising solutions have emerged from Germany.

Fig: BNITM

Clean drinking water from drilled wells reduces the risk of infectious diseases.

disease decreases with the proportion of wooded areas around villages. The risk increases, in contrast, if villages are surrounded mainly by plantations. Reasons for this could be the accumulation of water in the axils of some plants or altered soil conditions. It also became apparent that the further a household is located from the centre of a village, and hence the closer it is to agricultural areas, the higher the risk for the children of the household for malaria.

Altered precipitation and the quality of water are important factors affecting health in tropical areas. Nevertheless, the spread of waterborne pathogenic agents can also pose a threat in our latitudes:

- Malaria was diagnosed in people who have never visited the tropics. Six different Anopheles species are present in Germany, but it has not yet been investigated in detail for all of the species whether they can transmit malaria parasites and, if so, how effectively.

- Several years ago, for the first time eggs of the tiger mosquito, which can transmit dengue viruses and other pathogens, were found in Germany.

- Sandflies, which transmit leishmaniasis, have also been discovered in Germany.

- The yellow fever mosquito was seen recently in Madeira, and will most likely reach the European mainland soon.

- In France, Italy, Hungary and other Eastern European countries, there were repeated occurrences of the West Nile virus, which is spread over long distances by birds and is then transmitted from mosquitoes to humans. The presence of the birds is also very much dependent on water resources.

- Scientists from the BNITM and the University of Heidelberg recently published a study reporting a new mosquito species that had migrated from Japan and three novel viruses had been identified in mosquitoes: the Sindbis (Ockelbo disease, fever with rheumatic disorders), the Batai (Calovo fever) and the Usutu virus (Usutu fever).

Fig.: BNITM

Examination of an open body of water for pathogens and mosquito larvae

According to the World Health Organization, climate change is the greatest global risk to health of the 21st century. The differences between rich and poor will become even greater, and the consequences will be felt the most in the already disadvantaged areas of Sub-Saharan Africa. The distribution, warming and quality of water is a major factor for the spread of infectious diseases in endemic countries and their introduction to new areas.

Recommendations for action in policy-making

- In the future, it will be necessary not only to provide a national surveillance of infectious diseases, but also to monitor them in endemic areas. Such an international early warning system ought to comprise the mapping of vector mosquitoes in Germany and the epidemiological investigation of tropical pathogens that may be introduced.
- Politicians should help to improve networking between national and international institutions for the epidemiological investigation and registration of emerging waterborne diseases and transmission vectors.
- In addition, further research is required to clarify how, and how efficiently native vectors can transmit certain pathogens.

A technical approach

Fig.: FBH/schurian.com

Prototype for drinking water purification

Johannes Glaab, Michael Kneissl (FBH)

Mobile water disinfection using new UV LED radiation sources

Scientists at FBH and the Technische Universität Berlin have developed a module to disinfect water on the basis of ultraviolet light-emitting diodes (UV LEDs), creating the technological basis for an energy-efficient solution applicable decentrally. Water disinfection by means of UV radiation is already an established, widespread solution in the centralised supply of water. Currently, low-pressure gas discharge lamps are used as radiation sources. However, these lamps have serious disadvantages, such as a short operating life, a high operating voltage and toxic quicksilver as the illuminant – these features limit their use in decentralised water disinfection solutions considerably.

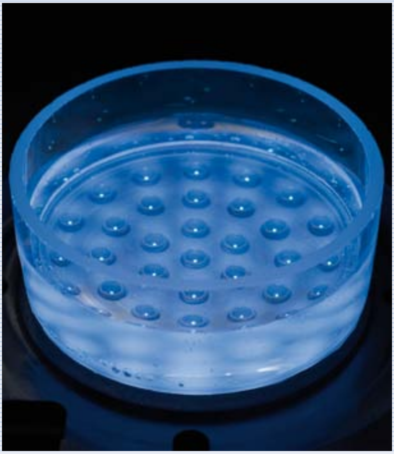
UV LEDs, on the other hand, are semiconductor devices built on specially grown crystal layers. They offer numerous advantages, making them attractive for use in mobile, self-powered apparatus for water disinfection. They are particularly characterised by their long operating life and low operating voltage. The latter, in turn, enables energy to be supplied by batteries and solar cells – an important requirement for use in regions without constant power supplies. In addition, by varying the composition of the crystal layers, theoretically any wavelength in the UV spectrum (200 to 400 nanometres) can be set and therefore adjusted to the respective needs. Wavelengths of around 265 nm are specifically required for water disinfection.

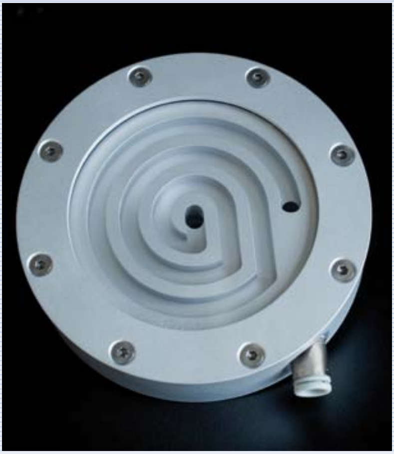
In initial experiments with standing water, scientists have proved the germicidal effect of radiation from UV LEDs (wavelengths 268 nm and 283 nm) using the new UV module. It is evident that the disinfection efficacy is at least equally as good as the use of conventional gas discharge lamps.

Building on these findings, a prototype was developed that is able to disinfect small quantities of flowing water. At a flow rate of 11 millilitres per minute, a reduction of the bacterial count by a factor of a thousand was achieved.

Scientists are now working on considerably enhancing the performance of the UV LEDs which, at the same time, is the requirement for their ability to disinfect higher flow rates and to become a commercially viable application.

Fig.: FBH/schurian.com





Disinfection tests of standing (left) and flowing (right)

Recycled water

Recirculating water use: both opportunity and risk

Fig.: T. Hohenbrink (ZALF)

Intensive crop farming (wheat) in the North China Plain near Shijiazhuang

Gunnar Lischeid (ZALF), Peter Langendörfer (IHP)

The ideal type of water usage takes place within closed recirculation. As a result of the shortages that already exist today, "used" water, such as rainwater, should be returned to the landscape water balance, rather than being drained off into receiving waters. This recirculation would contribute to groundwater recharge and to the stabilisation of the water balance. For example, purified waste water could be used for irrigation in agricultural areas. It is also now technically and economically viable to recover nutrients from waste water. Particularly against the backdrop of climate change and its associated dry periods, this approach is gaining in importance.

However, the consistent application of closed-loop recycling repeatedly presents a challenge. Moreover, the proper handling of recirculated water is crucial to its success. Equally important is the connection between closed-loop recycling and the interplay of the intensive use of groundwater and climate change. This aspect results in a series of frequently underestimated secondary effects, as the following examples show:

- The example of China: The high yields of the breadbasket in the North China Plain (Hebei Province) can only be achieved by intensive irrigation and fertilisation. Some of the irrigation water leaches, however, leading to an accumulation of nitrogen and pesticides in the topsoil, which eventually reaches groundwater. This water is subsequently used for irrigation again and a disastrous circulation of pollutant enrichment begins.

- The example of the Uckermark: The increasingly dry and hot summers cause small streams to dry out in summer. Since groundwater then has to cover greater flow distances

Fig.: T. Hohenbrink (ZALF)

Flood irrigation with pumped groundwater in the North China Plain

to the next water-bearing river, harmful substances contained in groundwater can be retained better in the subsurface, perceptibly improving the quality of water in larger rivers. In this case, an interruption of the natural circulation would have a positive impact on the environment.

- The example of the northeast of Germany: Due to increased evaporation, groundwater levels in the northeast of Germany having been falling for thirty years, increasingly causing small lakes and wetlands to dry up. The organic components of the sediments are decomposed, and the carbon which may have been stored within them for centuries is released, exacerbating the greenhouse effect. Since, however, many aquatic and bog plants require large quantities of water, i.e. are very wasteful users of water, when shallow lakes and wetlands dry up, this leads to a considerable reduction of transpiration, which again is beneficial to groundwater. In this case, the interruption of the natural circulation between soil and the atmosphere has a negative impact on lakes and wetlands, but a positive impact on groundwater.

Closed-loop recycling can make a crucial contribution to counteracting water shortages induced by climate change.

To apply closed-loop recycling more efficiently and successfully, there is a necessity for technical innovation, improved data availability and an adaptation of the legal foundations.

However, intensified closed-loop recycling also creates new risks and previously underestimated secondary effects, which necessitate intensive interdisciplinary scientific collaboration.

Parched stream bed in the Uckermark, 2 September 2008

- In general: Finally, a crucial factor for consideration, but the scale of which is difficult to assess, is the impact of meteorological and hydrological extreme events, such as intense rain and drought, with regard to the leaching of nutrients and harmful substances into groundwater, or the long-terms effects on ecosystems. If these events increase in intensity and frequency in the future, as predicted, there is reason to fear serious long-term effects.

Scientists are expected to interpret the effects of climate change and the associated socio-economic change, and to develop appropriate adaptation strategies. However, the secondary effects of these adaptation strategies have been given little consideration to date, because they necessitate intensive interdisciplinary networking. In turn, they cause completely new risks. On the other hand, surprisingly, under certain circumstances, new opportunities may also be created. For this reason, one of the focal areas of the investigations carried out at ZALF explicitly addresses unexpected effects, non-linear interactions and feedbacks.

However, such effects can only be captured using a well-developed meteorological network. To this end, as part of the IQLevel project, water level probes to monitor groundwater without infrastructure are being developed at IHP. The probes, integrated in the water level gauge pipe, measure the water level, the water temperature, the pH value, the salt content or the sulphate concentration of groundwater at any temporal resolution. The individual probes independently create a radio network to forward the data. An ad-hoc network between individual sensor nodes is automatically established to bridge greater distances. Therefore no infrastructure measures, such as the construction of cable trays, are necessary, enabling such meteorological networks to be constructed and changed speedily and flexibly.

Recommendations for action in policy-making

- Instead of discharging purified waste water into rivers and streams, it could be used to irrigate agricultural areas or to support the water balance of wetlands. The nutrients remaining in the purified waste water could be converted into plant biomass and organic harmful substances in the soil could be degraded, reducing the contamination of rivers. It would be important for this to be supported by amendments to the legal framework.

- There are sometimes surprising secondary and tertiary effects resulting from the inextricably linked climate and socio-economic change. In this setting, appropriately adapted management strategies need to be devised for intensively used landscapes, which have diverse and competing uses for water. The combination of an in-depth expert knowledge of closed-loop recycling, technical innovation and the use of interdisciplinary approaches has led to a situation where qualified statements can give insights upon which to base decisions necessary as a result of these changes. The legal framework conditions will again have to be adapted to enable these management strategies to be implemented. To this end, politicians will have to work in close collaboration with scientists.

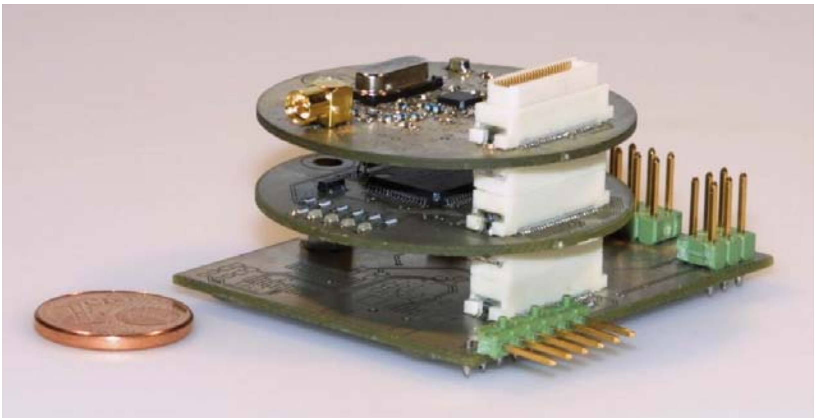


Fig.: IHP

Modular construction of a sensor node developed within the IQLevel project, consisting of a motherboard, a processor board and a radio circuit board

Danger from below

Groundwater protection on small islands – its importance must not be underestimated

Kathleen Schwerdtner Máñez, Marion Glaser, Sebastian Ferse (ZMT), Helga Wiederhold, Hans Sulzbacher (LIAG)

Supplying small islands with fresh water

Supplying islands with fresh water has always played a crucial role with regard to their settlement and cultivation. Islands of at least 1.5 ha in size have a freshwater lens, fed entirely by the seepage of precipitation. Since the specific weight of the precipitation water is lower, a higher pressure level is established at more elevated parts of the island. This creates a body of fresh water that floats like an iceberg on the saline groundwater in the deeper bedrock of the island. If less rain falls and if fresh water extraction for drinking water continues, so-called saltwater intrusion occurs: the salt water displaces the already low quantities of fresh water.

There is no doubt that salt water intrusion, and the associated scarcity of fresh water, poses a central problem in coastal areas and islands across the globe. In Germany, for example, the East and North Frisian Islands are affected; and so are the islands and atolls of the Spermonde Archipelago in Indonesia. The freshwater lenses of small islands are vulnerable to natural events, such as flooding, erosion or changes in groundwater recharge – processes that will be exacerbated by changed climate conditions. This is compounded by anthropogenic threats, such as the overexploitation of wells, the emission of pollutants from the earth's surface and the destruction of dune belts. Without the careful coordination of groundwater usage and groundwater protection, it will be very difficult to secure basic human needs.

Secondary consequences of climate change threaten fresh water supply on small islands

Of the roughly 120 small islands and atolls of the Spermonde Archipelago in Indonesia (see aerial image on the right), scarcely more than 50 have a freshwater lens. Settlements are concentrated almost exclusively on these islands. Investigations carried out by the Leibniz Centre

On small islands, climate change exacerbates the phenomenon of salt water intrusion, which leads to the quality of groundwater being affected by salt water.

We require detailed knowledge of the bedrock of islands and of the freshwater lens that acts as groundwater to be able to counteract the effect of saltwater intrusion efficiently and at an early stage.

Geophysical measurements are the backbone of the investigations; in combination with social- and health-policy measures, the experience of German researchers on Borkum may be applied effectively in many tropical island environments.

Fig.: M. Glaser (ZMT)

A well in Spermonde that is drying up

for Tropical Marine Ecology (ZMT) show, however, that the livelihood basis of the approximately 45,000 residents of Spermonde is at risk. Secondary effects of climate change, such as the rise in sea level and more severe extreme weather events, exacerbate shore erosion on the islands, jeopardising the fresh water lenses, which are directly linked to the island surfaces. Islanders are reporting the increasing salinisation of the water and the drying up of many wells (see cover photo on page 42). On some of the islands, freshwater quality and availability have become so poor that drinking water has to be purchased from the mainland. Nonetheless, little attention is currently being paid in the political debate in Indonesia to the freshwater supply of small islands.

The example of Borkum

To develop strategies for dealing with the consequences of climate change, geophysical data on islands are of crucial importance. As part of the EU project "CLIWAT Climate & Water," the Leibniz Institute for Applied Geophysics (LIAG) is conducting relevant investigations and data acquisition along the North Sea coast and its offshore barrier islands. Amongst other things, scientists are investigating the bedrock of Borkum to model the freshwater lens and to be able to assess the impact of future climate change and its consequences, such as salt water intrusion. Freshwater lenses, easily definable because of the different electric conductivity of fresh and salt water, are mapped from a helicopter (see map on page 46). The numeric simulation models derived from this data show it may take several hundreds of years for a stable lens to form. If the boundary between fresh and salt water is changed by the excessive pumping of drinking water or by the construction of wells at unsuitable sites, the regeneration process may take a similar length of time – meaning that the freshwater lens is at risk. To identify changes to the fresh/salt water boundary, continuous measurements are taken on Borkum by two vertical electrode chains installed at a depth of 45-65 m. Well sites and water management are optimised, thanks to monitoring and modelling, ensuring the sustainable supply of drinking water.

International transfer of knowledge

Precisely such knowledge is also required for the Spermonde Islands. Until now, the islanders have hardly received any outside assistance in coping with the scarcity of fresh water. The high settlement density and population growth exacerbate the problem. Although, on the one hand, households reduce their consumption by using freshwater exclusively for drinking water, on the other hand, well water, which is increasingly salinated, is often still used for cooking. It is only a matter of time before the health

Fig.: S. Ferse (ZMT)

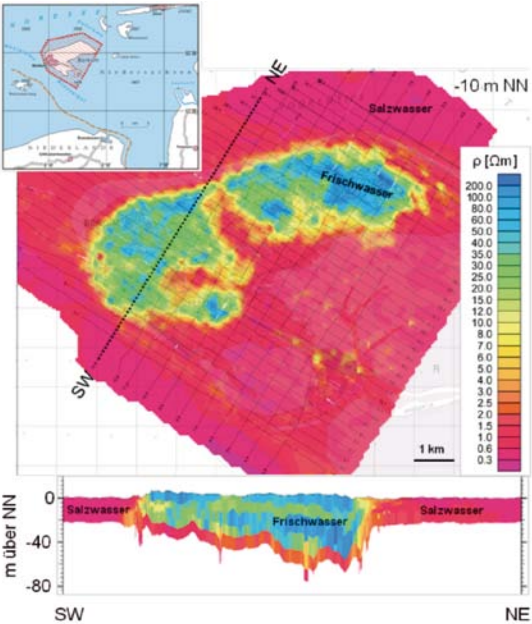
Aerial image of the Island of Barrang Caddi in the Spermonde Archipelago in front of the Indonesian island Sulawesi. Virtually every available square metre of the island is developed, restricting the growth of plants to a few front gardens. This has a negative effect on evaporation rates and groundwater recharge. Increasing coastal erosion, which has already led to the loss of several houses on the island edge, exacerbates the shortage of groundwater.

of the islanders will be affected. Rainwater tanks used on many Pacific Islands to collect rainwater on rooftops are not yet widespread in Spermonde. Some islands already purchase their drinking water externally. The water trade is organised by professional sellers who benefit from the scarcity of fresh water in the archipelago. In the longer term, it makes sense to construct desalination plants, but even this option harbours conflict potential. A plant constructed by a Japanese development aid agency was considered to be competition by the regional water distributors. Due to a lack of regular maintenance, insufficient spare parts and shore erosion, the plant was soon defunct. Islanders report that efforts to start it up again were undermined by the water distributors.

Recommendations for action in policy-making

- Intensified by secondary effects of climate change, salt water intrusion will increasingly threaten the quality of groundwater in coastal areas and islands in the decades to come. It is essential to address the advancing scarcity of drinking water.

- It is essential to gain greater knowledge of island bedrock to ensure the sustainable use of groundwater resources to reduce the danger of



Map of the specific electrical resistivity for 10 m below sea level underneath the North Sea island Borkum, and vertical section. The circumference of the fresh water lens (green/blue) stands out clearly against the surrounding salt water (red).

Fig.: BGR/LIAG

Danger from below

increasing salt water intrusion efficiently and at an early stage. Thanks to the targeted use of geophysical methods, such as those employed on Borkum, the freshwater lens can be explored non-destructively from the earth's surface. Well sites and the water management of the salt/fresh water boundary can be optimised based on simulation models and monitoring.

- Also, special attention needs to be paid to the more efficient use of rainwater, the satisfaction of basic water needs, and the health implications of drinking water shortages and quality problems.

- Recognition and knowledge of the problems surrounding groundwater protection and salt water intrusion must also be anchored more firmly in the consciousness of islanders.

GREENPILOT

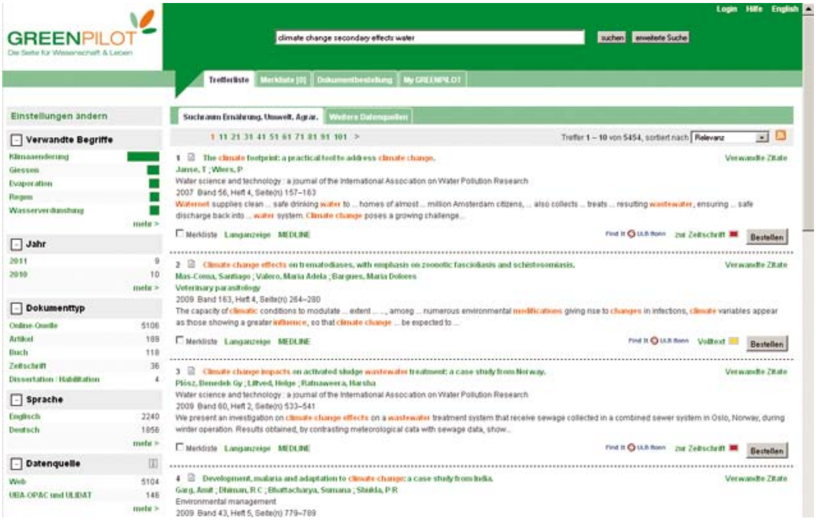


Fig.: www.greenpilot.de

An example of a literature search in GREENPILOT

Luciana Zedda, Tanja Meyer, Heike Grelka (ZB MED)

The search portal GREENPILOT (www.greenpilot.de) by the German National Library of Medicine. Health. Nutrition. Environment. Agriculture. (ZB MED) offers researchers access to scientific information. The search results originate from over 20 national and international scientific databases, catalogues, full texts in freely available journals and knowledge embedded deeply in relevant websites. The aim of GREENPILOT is to offer users direct access to the full text of a publication or to enable documents to be ordered.

Literature research in English on "climate change, secondary effects, water" yields more than 5,400 results (as of 12 July 2011) on the secondary effects of climate change on aquatic and terrestrial ecosystems. In addition, related terms are also researched.

Individual settings and filter options offer optimum conditions for delimitation of hits, for example, by refining the search through a related term such as "evaporation." In this case, there are considerably fewer hits (477), 92% of which are freely available online.

The literature search is supported by the semantic search tool Morphosaurus, and also by two multilingual specialist thesauri, which can search in up to 19 different languages. All in all, there are numerous publications on the influence of climate change on biodiversity and human health. These publications provide scientists with a wide range of technically sound information which cannot be found via conventional scientific journal portals or standard internet searches.

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GNM	Germanisches Nationalmuseum, Nuremberg
HI	Herder-Institut – Centre for Historical Research on East Central Europe, Marburg
IDS	Institute for the German Language, Mannheim
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ifo	Ifo Leibniz Institute for Economic Research at the University of Munich
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IPK	Leibniz Institute of Plant Genetics and Crop Plant Research, Gatersleben

IUF Leibniz Research Institute for Environmental Medicine, Düsseldorf

IZW Leibniz Institute for Zoo and Wildlife Research, Berlin

LIFA Leibniz Institute of Arteriosclerosis Research, Münster

LIN Leibniz Institute for Neurobiology – Center for Learning and Memory Research, Magdeburg

MfN Museum für Naturkunde - Leibniz Institute for Research on Evolution and Biodiversity at the Humboldt University Berlin

SGN Senckenberg Gesellschaft für Naturforschung, Frankfurt/Main

ZB MED German National Library of Medicine, Cologne and Bonn

ZFMK Alexander Koenig Research Museum – Leibniz Institute for Animal Biodiversity, Bonn

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FIZ KA FIZ Karlsruhe – Leibniz Institute for Information Infrastructure

IAP Leibniz-Institut für Atmosphärenphysik an der Universität Rostock, Kühlungsborn

IFW Leibniz Institute for Solid State and Materials Research, Dresden

IHP IHP GmbH - Innovations for High Performance Microelectronics, Frankfurt (Oder)

IKZ Leibniz Institute for Crystal Growth, Berlin

INM Leibniz Institute for New Materials, Saarbrücken

INP Leibniz Institute for Plasma Science and Technology, Greifswald

IOM Leibniz Institute of Surface Modification, Leipzig

IPF Leibniz Institute of Polymer Research, Dresden

ISAS Leibniz Institute for Analytical Sciences, Dortmund / Berlin

KIS Kiepenheuer-Institut für Sonnenphysik, Freiburg

LIKAT Leibniz Institute for Catalysis at the University of Rostock

LCI Schloss Dagstuhl - Leibniz Center for Informatics

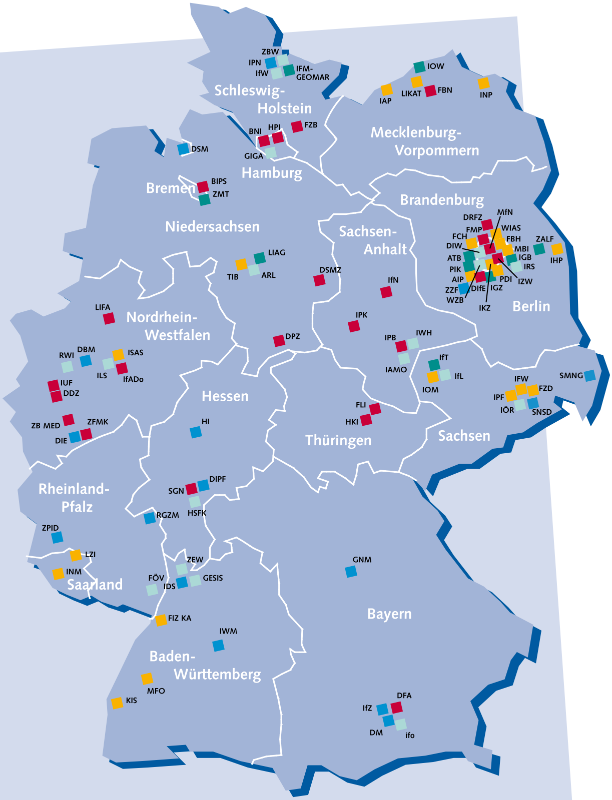
MBI Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy, Berlin

MFO Mathematisches Forschungsinstitut, Oberwolfach

PDI Paul Drude Institute for Solid State Electronics, Berlin

TIB German National Library of Science and Technology, Hanover

WIAS Weierstrass Institute for Applied Analysis and Stochastics, Berlin



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