Federal Ministry of Education and Research

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GRoW

WATER AS A GLOBAL RESOURCE

Water as a Global Resource (GRoW)

In the face of population growth, climate change and drinking water scarcity, one of the biggest challenges of the 21st century is ensuring the sustainable use of water resources. In a 2016 report leading representatives of the business world classified the uncertainties in the water sector as the biggest global risk of the coming decade. Two thirds of the global population currently live in regions that experience water shortages at least one month per year. This is due to natural stocks of clean water being depleted faster than they can be replenished. Such excessive use of global water resources results in conflicts. Therefore, efficient and sustainable use of available water resources can help to substantially improve living conditions in the affected regions and to resolve conflicts.

The United Nations' 2030 Agenda for Sustainable Development recognizes the global importance of water resources. Sustainable Development Goal 6 (SDG 6) specifically aims to "ensure availability and sustainable management of water and sanitation for all." More concretely, SDG6 seeks to ensure that, by 2030, everyone has access to clean drinking water and adequate sanitation systems. At the same time, water-related ecosystems are to be protected or restored as natural basis of life.

By launching the dedicated funding measure "Water as a Global Resource (GRoW)", the German Federal Ministry of Education and Research (BMBF) contributes to the resolution of conflicts arising in relation to the "blue gold" and thus promotes the achievement of SDG 6. GRoW is part of the BMBF initiative "Research for sustainable development (FONA3)". The funding measure involves more than 90 institutions that are active in research, business and water management practice and includes a total of 12 joint research projects, all of which cover three main subject areas: global water resources, global water demand and good governance in the water sector.

A defining feature of GRoW is that it links local and global action. In today´s world of global trade, it is not enough to focus solely on the needs of people in one specific region; through worldwide transfer in virtual water local and regional resources and hydrologic systems are globally interconnected now. With this in mind, the GRoW projects seek to develop both, local and regional solutions, and to improve the global data situation as well as global forecasting on water resources and water demand. The project partners use global climate models to provide seasonal local predictions for water availability in reservoirs and compile location-specific, high-resolution maps on global water efficiency, amongst others. Measures such as textile labelling-schemes are intended to minimize the water footprint in the Asian cotton textile industry, for example.

The GRoWnet networking and transfer project runs parallel to the GRoW research activities. The main aims of GRoWnet are to tap into the synergies between the joint projects, foster implementation of the solutions developed, and boost the overall impact of the GRoW initiative. A dedicated steering committee made up of the 12 GRoW project coordinators and experts from business, water management practice and international cooperation functions as an interface between research and practice and facilitates knowledge exchange at the same time.

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GRoW Joint Research Projects

SUBJECT AREA: GLOBAL WATER RESOURCES

ViWA
Virtual Water Values: Multiscale Monitoring of Global Water Resources and Options for their Efficient and Sustainable Use
Project Coordination:
Prof. Dr. Wolfram Mauser, LMU, München

SaWaM
Seasonal Water Resources Management for Semi-Arid Areas: Regionalized Global Data and Transfer to Practice
Project Coordination:
Prof. Dr. Harald Kunstmann, KIT, Garmisch-Partenkirchen

GlobeDrought
Developing a Global-Scale Tool for Characterizing Droughts and Quantifying their Impact on Water Resources, Crop Productivity, Trade in Food Products, and the Need for International Food Aid
Project Coordination:
Prof. Dr. Stefan Siebert, Universität Göttingen

MuDak-WRM
Multidisciplinary Data Acquisition as the Key for a Globally Applicable Water Resource Management
Project Coordination:
Dr. Ing. Stephan Fuchs, KIT, Karlsruhe

MedWater
Sustainable Management of Politically and Economically Highly Relevant Water Resources in Hydraulically, Climatically and Ecologically Highly Dynamic Carbonate Groundwater Aquifers of the Mediterranean
Project Coordination:
Prof. Dr. Irina Engelhardt, TU Berlin

SUBJECT AREA: GLOBAL WATER DEMAND

InoCottonGRoW
Innovative Impulses Reducing the Water Footprint of the Global Cotton Textile Industry towards the UN Sustainable Development Goals
Project Coordination:
Dr. Frank-Andreas Weber, RWTH Aachen

WELLE
Water Footprints in Companies: Organizational Water Footprint – Local Measures in Global Value Chains
Project Coordination:
Prof. Dr. Matthias Finkbeiner, TU Berlin

WANDEL
Water Resources as Important Factors in the Energy Transition – Conditions Needed at the Local and Global Level
Project Coordination:
Dr. Martina Flörke, Universität Kassel

SUBJECT AREA: GOOD WATER GOVERNANCE

TRUST
Sustainable, Fair and Environmentally Sound Drinking Water Supply for Prosperous Regions with Water Shortage: Developing Solutions and Planning Tools for Achieving the Sustainable Development Goals using the River Catchments of the Region Lima/Peru as an Example
Project Coordination:
Christian León, Universität Stuttgart

STEER
Increasing Good Governance for Achieving the Objectives of Integrated Water Resources Management
Project Coordination:
Prof. Dr. Claudia Pahl-Wostl, Universität Osnabrück

iWaGSS
Integrated Water Governance Support System
Project Coordination:
Prof. Dr. Karl-Ulrich Rudolph, IEEM gGmbH, Witten

go-CAM
Implementing Strategic Development Goals in Coastal Aquifer Management
Project Coordination:
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https://bmbf-grow.de/en

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GRoW
WATER AS A GLOBAL RESOURCE

ViWA – Efficient and Sustainable Water Management in Agriculture

Water as a Global Resource (GRoW)

Agriculture is by far the largest consumer of the Earth's available freshwater. In many places, water extraction and use for agricultural purposes is neither efficient nor sustainable. When agricultural goods are traded worldwide, the water needed to produce them is embedded in the product itself with no regard for the water-related costs involved, whether direct or follow-up costs. The main aim of the joint research project ViWA is to examine, from the local to global level, water consumption in food production and develop incentives for sustainable water use.

Global Trade in Virtual Water

A large proportion of agricultural products produced worldwide are traded across international borders. The global competitiveness of these products depends very much on the local production costs. Up till now, however, local water availability has not entered into the equation, nor has the efficiency or sustainability of agricultural water use. This has now changed, with factors such as these becoming increasingly important, not least in light of the vast amounts of virtual water flowing between countries, virtual water being the volume of water needed to produce the commodity in question.

ViWA seeks to develop instruments that deliver more precise data on how efficient or, indeed, how wasteful water use in agriculture is. Further, for the first time, the project partners are conducting an economic analysis on global trade flows that factors in the actual water consumption from the producer to the consumer. These results are then used to develop incentives for more sustainable use of water in agriculture.

Determining Global Water Consumption in Agriculture

To measure water consumption and sustainability in food production at local and regional level, the joint project employs a combination of observational methods, combining data collected from environmental satellites with global weather and climate data. Using the resultant high resolution, up-to-date, location-specific data, the researchers are able to simulate crop water use efficiency, crop yield and virtual water flows for the primary products in agricultural trade, for the time being in pilot regions. This data forms the basis of a global economic analysis of virtual water flows which encompasses available data on volume, efficiency, scarcity and sustainability of the water resources used in agriculture.

These findings represent the baseline for the simulation of global agricultural trade and the development of model scenarios that demonstrate the impact of sustainable water use on regions with scant water supply and on those with plentiful water resources. Furthermore, the vulnerability of agriculture and ecosystems to climate variability can be analyzed.

Supercomputer at Leibniz Supercomputing Center (LRZ) in Garching, Germany. The SuperMUC is used to calculate global crop yield, water needs and other key parameters in high spatial resolution (1x1 km).

How Sustainable is Water Use?

Data on water consumption or water efficiency in agriculture, however, does not provide enough of a basis for conclusions to be drawn on the sustainability of agricultural water use. For this reason, the researchers' approach is to attempt to establish a correlation between natural water resources and the total consumption of all users in a specific geographical region. The amount of usable water for agriculture or industry, for example, is restricted by the water requirements of sensitive water-dependent ecosystems such as wetlands.

Virtual Water Values

Intensive wet rice farming in paddy fields south of Moshi at the foot of Kilimanjaro in Tanzania

To ensure that water requirements are taken into full consideration, existing methods of analysis are adapted and combined to create new, innovative methods. One focus of the project partners' work is the identification of global hotspots, where water is not being used sustainably, as well as water surplus regions (referred to here as "cold spots").

There are many different reasons why available water resources are being overused, one possible reason being the existing mechanisms of spatial water management. By engaging in intensive dialogue with relevant industrial and public water users, the project thus seeks to identify both institutional obstacles and potential, and use this information to formulate recommendations for sustainable water management.

By gathering high resolution observational data, the researchers have the means to ensure that both global and local aspects are factored into the development and analysis of practical solutions for a more sustainable and more efficient use of water resources. This includes ensuring more sustainable virtual water trade.

Funding Measure
Water as a Global Resource (GRoW)

Project Title
Virtual Water Values: Multiscale Monitoring of Global Water Resources and Options for their Efficient and Sustainable Use (ViWA)

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SaWaM – Global Information for Regional Water Management in Arid Regions

Water as a Global Resource (GRoW)

Dry areas make up some 40 percent of the Earth's land surface. How much water will be available in these regions in the future? How can water reservoirs and agricultural irrigation in these regions be managed? Sustainable and scientifically sound water resource management can achieve a lot, especially in semi-arid areas. This makes it all the more important to know about the actual availability of water resources in these regions. In the joint research project SaWaM, the project partners are examining whether and how readily available global information and seasonal predictions can be used to improve regional water management in arid areas.

Improving the Information Basis

In semi-arid regions, for months at a time there is less precipitation than evapotranspiration, and the dry periods are long and pronounced. For the countries affected, having as precise a picture of the current and future available water resources is of the essence. In the majority of developing and newly industrialized countries, however, observational data on the water cycle is becoming increasingly scarce owing to the reduction in the number of environmental monitoring stations in the region.

In the SaWaM project, the partners are devising methods with which the information required can be derived from readily available global data obtained by means of remote sensing. To do so, various modelling techniques are applied, including seasonal weather prediction modelling, water balance modelling and sediment deposition modelling for reservoirs. The results derived from the mathematical models are combined with near realtime global satellite data.

The project partners visiting the hydrometeorological monitoring stations in the Upper Atbara Dam Complex (al-Quadarif, Sudan)

The problem, however, is that for the time being readily available global information does not meet the requirements for regional water management. The resolution of available global information is not sufficient to answer regional questions, and does not depict regional processes precisely. To be able to use the global data in regional forecasting, the researchers begin by adapting the data to a total of five semi-arid target regions. These are located in Sudan, Iran, Brazil, Ecuador and West Africa, meaning that the analysis covers a wide range of starting points with varying conditions specific to each region.

Focus on Seasonal Forecasting

In regions where water is scarce, water availability for the season ahead, i. e. for the following six to twelve months, is crucial. Adapting water resources management early enough can help mitigate the crop losses resulting from water shortages, for example. For this reason, for practical reservoir management purposes as well as for irrigation farming in semi-arid regions, reliable seasonal forecasts are vital sources of information on the long-term average water supply. In fact, weather services have been providing seasonal forecasts for some time now, factoring in this important forecasting period. How efficiently these work, however, depends greatly on the specific conditions in the target regions. The researchers in the SaWaM project are thus investigating whether seasonal weather forecasts are suitable instruments to aid decision-making in regional water management processes and if so, how well suited they are.

In the SaWaM project, with the help of various data processing methods and in cooperation with local partners, global seasonal forecasts are adapted to the specific conditions in the different areas of interest. The researchers then take this regional hydrometeorological information – e. g. precipitation, evapotranspiration, wind and temperature – and use it as a starting point to develop new modelling systems. While hydrological models are used to draw conclusions on runoff, ground moisture and sediment delivery, ecosystem models are used by the project partners to make predictions on factors such as the water requirements for vegetation or the expected crop harvest for the following season. Just how effective these methods are is being explored by the project partners in the catchment basin areas of the Kārūn River (Iran), Rio São Francisco (Brazil), the Atbarah River and the Blue Nile (Sudan). The catchment areas of the Catamayo-Chira River (Ecuador) as well as the Volta and Niger River (West Africa) serve to demonstrate the transferability of the project results.

New Online Information System to Serve as Prototype

The seasonal information is to be made available on an online platform. A prototype for this online information system, which can be used in decision-making processes, is being developed in close cooperation with local partners and potential end users in the target regions. In this way, direct transfer of global information to practical regional water management is guaranteed.

Regular workshops are held in the target regions to foster mutual cooperation on the online information system. These workshops also promote exchange of methodology and information among participants and provide a platform for planning joint research activities. To ensure the methods devised continue to be used beyond the project duration, project participants are also offering training to local partners.

Water management in semi-arid regions 2,000 years ago: the Kārūn River in Shushtar (Khuzestan Province, Iran)

Funding Measure
Water as a Global Resource (GRoW)

Project Title
Seasonal Water Resources Management for Semi-Arid Areas: Transferring Regionalized Global Information into Practice (SaWaM)

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GRoW
WATER AS A GLOBAL RESOURCE

GlobeDrought – Information System for Better Drought Management

Water as a Global Resource (GRoW)

Drought is a global problem. But how do such dry periods come about in the first place and how do they impact water resources, crop productivity, food trade and the need for international aid? The researchers involved in the joint project GlobeDrought are examining drought occurrence and the risks of drought worldwide. The aim is to translate the study findings into an information system that will enable near real-time drought severity monitoring and facilitate drought forecasting.

Factoring in Global Impacts

In times of drought less water is available than required. The agricultural industry is especially hard-hit by water scarcity. Loss of crops leads to food and fodder shortages and, in extreme cases, can even end in famine. Usually, this worse-case scenario does not happen because societies have learned to adjust to drought hazards, e. g. by building reservoirs, tapping into groundwater resources, irrigating crops, or by importing food. However, drought-induced production bottlenecks in major food exporting countries such as the US, Brazil, Argentina or Australia, can push up food prices on the global markets. This affects poor population groups, in particular, who struggle immensely to address their own bottlenecks with the help of imports.

In order to take such long-distance impacts in a world of globalized trade into account, the project examines drought occurrence and the risks of drought around the world.

Reservoir in South Africa in March 2018, almost completely dried out due to persistent drought

In addition to analyses at global level, the project also conducts detailed analyses of regions that are especially impacted by droughts, southern Africa in particular. The main aim of the project is to use the findings to develop a web-based information system for comprehensive drought risk assessment. .

Risk Analysis Using Web-Based Information System

Most conventional drought early warning systems do little more than report on the actual situation. Such systems are especially lacking in contextual information: how do droughts come about in the first place and how do they develop? What are the socio-economic effects of the different types of drought, which can be categorized using meteorological, hydrological or agricultural criteria such as precipitation shortfall, temperature, evapotranspiration, soil moisture and runoff? Do they result in income loss and food scarcity, for instance? This lack of information is what the GlobeDrought project seeks to address with the help of an integrated drought information system.

To this end, the researchers' work involves the analysis of extensive socio-economic information and data obtaining using remote sensing techniques. This data is then combined with calculations acquired from hydrological and plant growth models. The analysis is performed both on a global scale and for regions that are at particular risk of drought and suffer significantly from the consequences, i. e. southern Africa, the West Indies, eastern Brazil and the west of the US.

GlobeDrought merges these regional and global components in the GlobeDrought information system. Regional project partners and future users of the information system are involved both in defining the concept and developing the system. The aforementioned risk assessment is supplemented by a drought early warning system – developed as a prototype. It will enable the given degree of drought severity to be monitored in near real-time and drought development for the subsequent 12 months to be forecast..

More Effective Prevention with Early Warning System

The projects' drought information system is designed to complement systems that are already in place. It can be used to compare drought risk by region, enabling effective risk mitigation measures to be developed. In particular, it is hoped that the early warning system created by the project partners will provide political decision makers and international stakeholders in the field of humanitarian aid with information that will enable early recognition of critical drought conditions and the potential need for emergency aid.

Vegetation has been strongly affected by persistent drought in South Africa, as seen in this photograph taken in March 2018

Funding Measure
Water as a Global Resource (GRoW)

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Developing a Global-Scale Tool for Characterizing Droughts (Meteorological, Hydrological, Agricultural) and Quantifying their Impact on Water Resources, Crop Productivity, Trade in Food Products, and the Need for International Food Aid (GlobeDrought)

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GRoW

WATER AS A GLOBAL RESOURCE

MuDak-WRM: Forward-thinking Management of Reservoirs Worldwide

Water as a Global Resource (GRoW)

Reservoirs are used all over the world to supply water and generate electricity, with around one third of the water required for agricultural irrigation currently coming from these sources. Over 100,000 water reservoirs exist, with hundreds more in the planning or under construction. The problem, however, is that reservoirs also constitute a significant encroachment on the river ecosystem, impeding waterway continuity and dramatically impacting the speed of water currents. One of the consequences of this is that reservoirs become collecting points for sediments, fertilizers, and pollutants that adversely affect water quality. The aim of the joint research project MuDak-WRM is to develop a simple model that provides a long-term overview of reservoir water quality and that can be readily transferred to other countries around the world.

Simple Models for Ease of Application

Reservoir water quality depends largely on its drainage basin and how that area is managed. To develop a model that effectively depicts the processes taking place in reservoirs, the river drainage area has to be factored in. If large quantities of nutrients flow into the reservoir from intensive agriculture or forestry or a densely-populated area, this can lead to overfertilization of the reservoir or what experts refer to as "eutrophication". This then supports the growth of "cyanobacteria" (more commonly known as blue algae), which, in turn, produce toxins that can make the water in the reservoir unsuitable for use as drinking water.

With this in mind, MuDak-WRM project partners are keen to develop a straightforward model that facilitates the prediction of medium- to long-term changes in reservoir water quality. One of the research project's key objectives is to reduce the complexity of the scientific methods underpinning the model and the data it requires. This will make it easier to apply the model in regions with limited data availability, for example in developing countries.

Proper Measurements Mean Better Monitoring

In order to acquire a deeper understanding of the dynamic interplay between the drainage area and the water reservoir and to determine the optimum measurement points for reservoir monitoring, project researchers employ a range of methodologies, including innovative remote sensing techniques. Alongside multispectral satellite images provided by the European Space Agency (ESA), hyperspectral cameras attached to drones are used to acquire detailed spectra of the light reflected by the reservoir. In addition, the project partners investigate whether and to what extent remote sensing techniques can be used to aid the labour- and cost-intensive sampling process on the ground. Using this approach, project partners aim to develop a concept for optimized monitoring. The plan is for this "minimum monitoring" to encompass a set of basic parameters that effectively describe reservoir condition and are especially suited to forecasting at the same time.

The new measurement techniques, remote sensing technology, and modelling approaches will initially be tested at the Große Dhünntalsperre reservoir in North Rhine-Westphalia (Germany), where an extensive measurement network is already in place and local staff are familiar with the key processes. The next step will be to transfer the methods and techniques to the Passaúna reservoir and its drainage area in the Brazilian state of Paraná. Using a real-time data

Measurement platform equipped with water quality sensors (foreground) and water extraction at the Passaúna reservoir (background) network (sensor web), the project researchers and reservoir operators can access the measurements taken at any time.

This data network is used to access, maintain as well as visualize the data acquired both remotely and in situ. This enables the reservoir operators to capture and evaluate complex environmental data more rapidly and more effectively. By comparing the findings from the two case studies, the project partners can ensure that the knowledge acquired and methods developed are easily transferrable to other reservoirs.

Scientific Basis for Reservoir Management

The model to be developed as part of this project is intended to enable river dam operators to make scientifically sound decisions regarding the sustainable management of reservoirs, water quality and the river drainage area. It is hoped that the model will help answer questions such as "what is the volume of nutrients per year a reservoir can tolerate before water quality starts to deteriorate". Political stakeholders and authorities could also use the model to support their decision-making with a view to determining sustainable forms of land-use and land management in the drainage area. Dedicated reforestation, for instance, is one measure that could be taken to combat increasing soil erosion. It prevents large quantities of nutrients leeching out of fallow soil during heavy rainfall and being carried into the river and finally being deposited in the reservoir. This scenario is just one of the many challenges in water reservoir management.

Two doctoral students from the Karlsruhe Institute of Technology (KIT) extract a drill core for sediment analysis

Funding Measure
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Multidisciplinary Data Acquisition as the Key for a Globally Applicable Water Resource Management (MuDak-WRM)

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GRoW

WATER AS A GLOBAL RESOURCE

MedWater – How to Manage Scarce Groundwater Resources in the Mediterranean Sustainably

Water as a Global Resource (GRoW)

Many parts of the Mediterranean have already been affected by water scarcity and the region is considered a hotspot of climate change. The region's population is also set to increase dramatically in the coming decades, with forecasts expecting the total number to reach as much as around 651 million people in 2030 – more than double the population recorded in the year 2000. Climate change, population growth and other extraneous factors such as increasing urbanization and changing land use patterns all present huge challenges for water resources and ecosystems in the Mediterranean. This has had a particularly strong impact on aquifers in hydrologically sensitive karst areas; large expanses of water soluble limestone are especially prevalent in the Mediterranean. MedWater is a joint research project which seeks to develop strategies and new management tools to ensure fair and sustainable availability of scarce water resources in Mediterranean karst areas.

Preserving Water Resources and Ecosystems

One of the 17 Sustainable Development Goals (SDGs) formulated by the United Nations in 2015 is to manage the available water resources sustainably. This goes beyond the water management concepts applied to date. Sustainable resource management as envisaged by the SDGs requires a holistic approach that takes not only people's water consumption into consideration but also the requirements of ecosystems as well as extensive and fair access to drinking water and water for socio-economic development.

The implication here is that, when utilizing water resources, the social and economic factors as well as the impact on the environment all play a role. Bearing the sustainability goals in mind, the primary objective of the MedWater joint project is therefore to develop tools that facilitate better management of the scarce water resources in the carbonate aquifers of the Mediterranean region. MedWater's regional focus is the Eastern Mediterranean (Israel and the Palestinian Autonomous Territories) as well as France and Italy.

Developing New Forecasting and Management Tools

Water from karst areas supplies approximately one quarter of the world's population. But karst groundwater is also particularly prone to contamination. Due to the many subterranean caverns, the groundwater generally reaches very high flow velocities. At the same time, due to their low storage capacity, carbonate aquifers also react immediately to precipitation. Effects of climate change therefore quickly become apparent in the behaviour of carbonate aquifers. Sustainable management of theses aquifers thus requires dedicated concepts.

The key components of the management tools developed in the MedWater project are forecasting models which map the behaviour of highly dynamic groundwater resources. These models enable us to predict the short- and long-term development of water resources and ecosystem services, factoring in extraneous factors such as land use, climate and technological developments. The researchers use model calculations to test different water use and water distribution scenarios. This enables them to determine the impacts of water use on water availability and water-related ecosystem services in a specific area, taking into consideration the water footprint of the import and export of foodstuffs, as well.

Groundwater recharge zone in a karst area

MedWater

On this basis, the project partners are seeking to develop tools to optimize an integrated approach to water management which is tailored to specific geographic, social, financial and environmental conditions. These improvements take a wide range of factors into account including ecosystem services, biodiversity, water quality, costs, energy consumption and the availability of water resources. The project findings are also to be transferred to the global level using remote sensing data. This is done with the help of an evaluation matrix where different types of drainage area, soils and precipitation distribution patterns are grouped into areas where carbonate aquifers are present.

Ecosystems develop along small streams at the Dead Sea

Implementing Improvements in Practice

The main product of this joint project is a globally applicable web-based decision support system that provides water management proposals. This creates the foundation for increased water use efficiency and the preservation of water resources, securing access for all population groups at the same time.

To ensure that the system is used by local stakeholders in future, the project partners have involved key regional partners such as water supply companies, farmers, agricultural authorities and businesses located in the study regions at an early stage of the development. Dedicated training sessions and workshops are held to ensure knowledge transfer.

Funding Measure
Water as a Global Resource (GRoW)

Project Title
Sustainable Management of Politically and Economically Highly Relevant Water Resources in Hydraulically, Climatically and Ecologically Highly Dynamic Carbonate Groundwater Aquifers of the Mediterranean (MedWater)

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GRoW
WATER AS A GLOBAL RESOURCE

InoCottonGROW – Reducing the Water Footprint of the Global Cotton Textile Industry

Water as a Global Resource (GRoW)

Germany is a country rich in water. Yet we also utilize substantial quantities of water from other countries whose water resources are far sparser. Our demand for water-intensive cotton textiles such as jeans, T-shirts or bedding is one of the main contributors to water scarcity and water pollution in the majority of cotton producing countries in Asia. What is more, population growth and climate change further exacerbate what are already huge water economy challenges in these countries. Using case studies and demonstration projects in Pakistan, the German-Pakistani joint research project InoCottonGROW aims to achieve sustainable water use along the cotton-textile supply chain – from the cotton field to the coat hanger. A key component of this is the concept of the water footprint.

Advancing the Concept of the Water Footprint

Pakistan is the world's fourth-largest producer of cotton and a major exporter of textiles to the German market. Vast quantities of water are used in the irrigation of cotton plants as well as in dyeing and other finishing processes in the textile industry. In addition, rivers, soil and groundwater are increasingly being contaminated due to salination, the excessive use of pesticides and fertilizers as well as the discharge of untreated wastewater from textile manufacturing.

In InoCottonGROW, 14 research and industry partners from Germany and 13 partners from Pakistan work hand in hand to identify technically, economically and institutionally feasible ways of increasing the efficiency and productivity of water use along the entire cotton textiles supply chain in Pakistan. The water footprint, i.e. total water consumption, will be used to help achieve this. The goal is to further develop the concept of the water footprint such that it can be used as a management tool to aid Pakistani decision-makers in managing scarce water resources as well as help German consumers make informed choices when purchasing textiles.

More Sustainable Water Use in Practice

The project partners begin with an analysis of current water use and pollution in cotton farming and the textile industry and evaluate the effects on human health, ecosystems and competing uses. In five demonstration projects in the Pakistani province of Punjab, the partners show in practice how the water footprint of the cotton textile industry can be reduced to a level that is more in line with UN Sustainable Development Goals (SDGs):

The project explores a wide range of options including effective irrigation strategies, the use of environmentally compatible dyes, water-saving textile machinery, different textile wastewater treatment technologies, pollutant analytics, and water quality monitoring to enable authorities to control wastewater discharge limits.

Textile wastewater flows through drains into the River Chenab and the River Ravi

Up till now, the method used to calculate water footprints has not been specific enough to evaluate the impacts of far-reaching technical and political decisions at regional level and to influence decision making. For this reason, a regional database and a method for evaluating effectiveness is to be added. This new approach is used to model the impact the cotton textile industry has on water scarcity, human health, ecosystems and freshwater resources in Punjab. It also establishes a link to selected UN SDG indicators, such as Goal 6 "Clean Water and Sanitation". Subsequent scenario analyses enable the researchers to examine the extent to which a low water footprint for the cotton textile industry can contribute to the implementation of UN SDGs. The project also looks at Turkey with respect to the transferability of the findings in Pakistan to other cotton producing countries around the world.

Warabandi canal irrigation system for cotton plants. Groundwater is pumped when there is insufficient water in the canals.

Implementing Measures and Raising Public Awareness

To facilitate widespread implementation of the measures investigated, workshops are held and local expertise developed in cooperation with Pakistani partners, including agricultural organizations, textile firms, universities, official bodies and ministries. To sensitize global brands and retailers as well as German consumers to the importance of sustainably produced textiles, the InoCottonGRoW project also involves the development of various public awareness measures. In the planning are short documentaries, an internet-capable water footprint tool and research into an effective water footprint label for textiles.

Textile finishing plant in Faisalabad (Punjab province)

Funding Measure
Water as a Global Resource (GRoW)

Project Title
Innovative Impulses Reducing the Water Footprint of the Global Cotton Textile Industry towards the UN Sustainable Development Goals (InoCottonGROW)

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GRoW

WATER AS A GLOBAL RESOURCE

WELLE – Corporate Water Footprint to Help Mitigate Water Scarcity at Local Level

Water as a Global Resource (GRoW)

Companies tend to measure and manage their water consumption at their production sites. Often more relevant, however, is the water consumption of suppliers or along energy and material supply chains. What is more, not all water consumption has the same impact everywhere: while regions that are rich in water will not suffer too greatly if some of it is removed, in areas where water is in scarce supply, removing it will further aggravate the situation. The goal of the joint research project WELLE is to determine the overall water footprint of a company and introduce practical measures to reduce water scarcity at local hot spots in global value chains.

Corporate Water Footprints – Local and Global

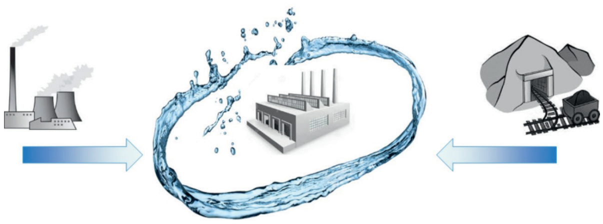
A single person in Germany consumes around 130 litres of water a day. This figure, however, only covers direct water needs for everyday activities such as showering, cooking or doing laundry. If the water consumed in the production of our food, clothing and other everyday items is factored in to the equation, per-capita water consumption would be as much as some 3000 litres a day.

With the majority of products being manufactured in cross-border value chains, much of our water consumption actually takes place outside of Germany. Often the water used in the production of such import goods comes from parts of the world where water is in short supply: cotton from Central Asia, for example, or grain from North Africa or ore from desert regions. At the same time, companies measure and manage their water consumption primarily at their production sites, despite the fact that the water consumption in the energy and material supply chains is far more significant. Thus, beyond the factory gates, the local impact of water scarcity cannot even be identified, let alone mitigated.

New Methodology and Practical Applications

As part of the WELLE project, in order to identify local environmental impacts within global value chains, the first step is to develop a method of calculating corporate water footprints. This approach factors in both direct water consumption at production sites and indirect consumption in energy and material supply chains, enabling a company's global water risk to be analyzed and measures for water footprint reduction to be initiated.

Besides developing a new methodology, the researchers are also focusing on improving existing water consumption data on technical processes. This task involves the creation of a water inventory database showing where the water used in global value chains has actually been taken from. Using four case studies, the industry project partners also test and optimize both methodology and data. Building on this, a calculation tool is developed with which other companies can easily calculate their global corporate water footprints. The WELLE project takes an innovative approach, where an existing, well established method of determining company-wide environmental impacts is combined with a dedicated method of determining local impacts on water scarcity.



Corporate water footprint factors in the entire production supply chain (purchased products and materials) as well as product use and disposal

Reducing Local Water Scarcity

In the second half of the project, the industry partners introduce what are known as water stewardship processes at the hot spots along their supply chains. The term 'water stewardship' refers to the notion that every user of water is responsible for the impact their consumption has on this shared resource and that everyone strives to achieve the common goal of sustainable resource management. In the WELLE project water stewardship processes are manifested in dedicated measures to reduce local water scarcity. These measures are implemented in cooperation with local stakeholders such as suppliers, local authorities, NGOs as well as other local companies. The concrete measures give the water footprint, which is a global indicator, a local dimension. Further, it is hoped that industry-specific recommendations will encourage other companies to acknowledge their global water risks and address them at the local level.

With the help of dedicated measures at local level, companies are hoping to reduce water scarcity at the environmental hot spots in their supply chains

Funding Measure
Water as a Global Resource (GRoW)

Project Title
Water Footprint for Companies - Local Measures in Global Value Chains (WELLE)

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GRoW
WATER AS A GLOBAL RESOURCE

WANDEL – How Do Available Water Resources Impact the Energy Transition?

Water as a Global Resource (GRoW)

The energy and water sectors are inextricably linked. Water is needed for cooling purposes in power generation and the water supply system requires energy for pumping, for instance. The United Nations' Sustainable Development Goals (SDGs) include goals for both water and energy: SDG 6 focuses on "Clean Water and Sanitation", while SDG 7 aims to achieve "Affordable and Clean Energy". Due to the interdependency of the sectors, the energy transition can trigger conflict between these two SDGs, if renewable energy systems consume more water than conventional systems, for example. But the reverse is also true, with there being a potential for synergies between these two goals. The joint research project WANDEL seeks to explore whether and how water availability advances the development and use of renewable energy systems regionally and globally as well as how these energy systems impact the water resources.

The Water Footprint of Energy Systems

Energy generation from renewable sources often requires less water than energy from fossil fuels. Nevertheless, certain renewable energy systems, such as solar thermal power plants in regions with scarce water resources, for example, can result in conflict with other water utilization requirements and hamper the continued development of renewable energy.

A key component of the analyses conducted within the WANDEL project is the water footprint concept. It includes every process along the energy supply chain that requires water, whether direct water consumption at the power station site or indirect consumption, for example if copper is imported for the construction of a plant and water is required to extract this raw material in the export country. Further, it is not only the individual instances of water consumption that are important but also their impact on the respective water resources: it is just as important to factor pollution into the evaluation as it is to take the removal of water into account. A key consideration here is also whether water resources in a respective region are abundant or rather scarce. This analysis is underpinned by an evaluation scheme which is based on case-specific environmental sustainability studies.

Gundelfingen power plant on the Danube. Here, river barrages are used to produce electricity.

For the first time, this enables project researchers not only to analyze the effects of energy generation at the local and regional level but also to assess far-distance impacts on other regions around the world, taking water availability into consideration. The current situation is critical: recent studies on global water availability indicate that water in certain regions could become increasingly scarce in the future. Climate change might exacerbate this situation.

Detailed Analyses for Four Case Studies

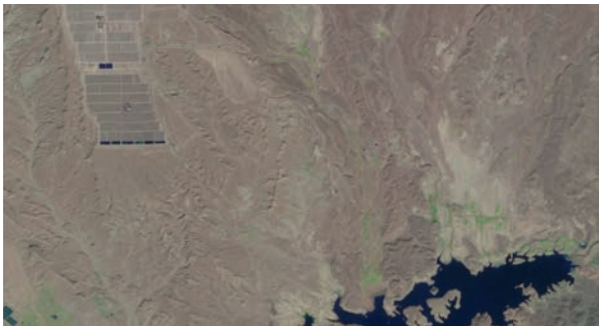
The project presents detailed analyses for four case studies, involving regional stakeholders in the process: In the Upper and Middle Weser catchment in Germany, power is generated using conventional coal-fired plants, while the Upper Danube case study focuses on hydroelectric power generation. In the Drâa Valley in Morocco, a solar thermal power station already exists and two more are under construction. In the case study for the Dos Patos River area in Brazil, biomass from sugar cane is converted into power.

In the Weser case study, the WANDEL project is looking at the impact the decision to replace thermal power plants with other energy sources has on Germany's energy transition. In the case of the hydroelectric power plants on the Danube, the aim is to optimize energy generation by factoring in other utilization interests such as environmental protection. In the Morocco case study, the focus is on reducing water consumption in light of rapidly advancing social and economic development. And, lastly, at the Dos Patos River in Brazil, the primary interest of the project partners is how to use the available water resources more efficiently.

Using a Global Approach to Identify Regional Hotspots

Not only are project partners seeking to identify particularly water-intensive process steps along energy supply chains. They also aim to identify areas around the world where there is potential for conflict between the goals of water resource protection and energy generation systems. In the WANDEL project, global spatial analyses are supported by remote sensing technologies and computerbased geo information systems and the findings are presented visually. The spectrum of energy systems covered by the case studies as well as the range of climatic and economic conditions in the regions investigated also enable the transfer of project findings to other catchment areas with similar conditions.

In cooperation with regional partners, the researchers are developing innovative and dedicated technical and governance solutions tailored to each region, designed to help reduce or even prevent conflict between the two sustainability goals for water and energy. Here, legal and regulatory requirements play a role, as do the water consumption of different technologies, and energy and land use scenarios.



Satellite image of the Noor solar thermal power plant in the Drâa Valley in Morocco. The solar panels can be seen in the top left of the picture.

Funding Measure
Water as a Global Resource (GRoW)

Project Title
Water Resources as Important Factors of the Energy Transition at the Local and Global Level (WANDEL)

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GRoW

WATER AS A GLOBAL RESOURCE

TRUST – Integrated Drinking Water Supply in Prospering Regions with Water Shortages

Water as a Global Resource (GRoW)

Climate change is exacerbating water shortages, especially in regions that are already struggling with water scarcity. The area surrounding the burgeoning Peruvian capital Lima, for instance, is particularly hard-hit. The city is located in the coastal desert at the foot of the dry west side of the central Peruvian Andes. The lion's share of the city's drinking water originates from the Rimac River, which frequently has a restricted flow owing to the dry climate. The city therefore increasingly relies on groundwater for its supply, meaning these resources are severely stretched to meet the high demand for drinking water as well as industrial and agricultural irrigation water. As part of the joint research project TRUST, experts from various disciplines are collaborating to develop holistic planning tools as well as innovative water supply and sewage disposal concepts based on the example of the Lima region.

Sound Data Basis for Cleverer Decision-Making

In Peru, as in many other regions of the world, there is a lack of comprehensive data on the quantity and quality of the available water resources. Suppliers and planning authorities can only achieve effective water resource management, however, if they have access to sufficient information on the condition of the country's water bodies. In collaboration with four partners from industry and water management, researchers from the fields of engineering as well as from the natural and social sciences based in Stuttgart and Karlsruhe are therefore seeking to develop innovative methods of collecting and recording necessary data for the Lima region. To this end, water experts have been conducting field campaigns and have developed a hydro-meteorological monitoring network with regional stakeholders. This network furnishes information on the distribution of precipitation, runoff behaviour, and flow velocity in the region. The data acquired on the ground is supplemented by data obtained using state-of-the-art remote sensing techniques. On the basis of this data – acquired both on site and using remote sensing – project researchers are able to model regional water supply far more accurately than was previously the case. In addition, one of the project partners is developing an application that will give the general public as well as suppliers, planners or farmers access to available data online.

Sustainable Water Resources Management

Building on these results, the project partners are seeking to develop optimized overall management concepts for water supply, sewage disposal and water reuse. Their objective is both to use the limited available water resources in the most efficient way possible and to involve local stakeholders in the development, evaluation and planning of dedicated concepts. The biggest challenge here is, using existing resources as sparingly as possible, achieving the primary goal to secure the supply of clean drinking water, while meeting the water needs of competing sectors such as agriculture and industry at the same time.

A newly developed software-based decision support system (DSS) will help local utility companies to identify areas with a high risk of water contamination and to define measures needed to ensure safe drinking water despite these conditions. TRUST thus combines state-of-the-art remote sensing methods, regional water balance modelling and strategic decision-making tools. In order to provide a comparison for the Lima region findings, and to ensure

A water reservoir in the upper drainage area of the Lurín River in the province of Lima provides irrigation water during the dry season that these results are transferrable, the drainage area of a reservoir in Saxony (Germany) is also included in the analysis. This means that the new concepts can also serve as a successful model for other regions with similar problems.

Negotiating Interests Using New Participation Processes

Decisions made by stakeholders in the water sector can lead to conflicts over water use, for example between commercial agriculture and the general population. In order to avoid this, within the framework of the TRUST project, potential conflicts are to be analyzed and different interests negotiated using special participatory procedures. Supported by a partnering consulting company, social science researchers are developing approaches that are adapted specifically to local conditions so as to ensure that those affected are involved in the process. Using this method gives different interest groups an opportunity to present their views on the water system. It aids to identify those combinations of water management measures, which enable the achievement of rival objectives in the most conflict-free way possible. To help establish the methods developed and embed the project results in the region, TRUST also provides support to local partners in the form of dedicated training programs and educational activities.

School students visit a drinking water tank in the district of San Andrés de Tupicocha, Huarochirí province, Peru

Funding Measure
Water as a Global Resource (GRoW)

Project Title
Sustainable, Fair and Environmentally Sound Drinking Water Supply for Prosperous Regions with Water Shortage: Developing Solutions and Planning Tools for Achieving the Sustainable Development Goals Using the River Catchments of the Region Lima/Peru as an Example (TRUST)

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GRoW
WATER AS A GLOBAL RESOURCE

STEER: Enhancing Coordination in Water Management

Water as a Global Resource (GRoW)

In many regions around the world, water resources are not being used sustainably. Pollution and overuse of surface water and groundwater bring major social, ecological and economic problems in their wake. Conflicts can arise in situations where one particular water use degrades the quality or depletes the amount of water available to such an extent that other uses are restricted or even not possible at all. Such conflicting demands for water often have negative effects on the environment. The joint research project STEER seeks to find innovative forms of coordination and cooperation to help resolve such conflicts in water use and water management. Central to the project is a diagnostic approach where the researchers identify typical problems and develop suitable strategies for finding solutions.

Inadequate Coordination of Water Use

Whether drinking water for private use, water for agricultural irrigation or water used in cooling systems in power generation plants: the different uses of water in different parts of the world are often not adequately coordinated, resulting in conflicts between users. And this situation is very likely to be exacerbated by global trends such as population growth, economic development and climate change. Conflicts relating to the use of water resources also affect Germany. Water supply companies, for example, have been grappling with the problem of nitrate contamination in groundwater resulting from excessive fertilization in agriculture, and have indicated that costs for drinking water supply may therefore increase in the future.

Strategies for Solving Typical Water-Related Problems

Over the past two decades, Integrated Water Resource Management (IWRM) has become popular across the globe as a means of making the use of water resources more sustainable. The idea behind this concept is to bring the requirements that different users and types of water use have into line with one another. In reality, however, Integrated Water Resource Management is proving harder to implement and many challenges still remain.

Often the causes of water-related problems are known. The real issue lies in finding solutions, because this requires the involvement of stakeholders from sectors other than the water industry – agriculture, the energy sector or urban planning, for instance. These stakeholders often have different interests and goals. To align these, effective coordination mechanisms are needed. This includes, for example, legal frameworks to harmonize the aims and mechanisms in place at the different dedicated authorities, as well as the appropriate involvement of relevant stakeholders in strategy development, or various forms of voluntary cooperation between different sectors. The ability to successfully align different areas is known as good cross-sectoral governance.

This is the starting point for the STEER project. It seeks to develop innovative ways to improve steering capacities in order to solve water resource problems, one of the key points of interest being the development of new forms of coordination and cooperation. Using in-depth case studies in South Africa, Mongolia, Spain and Germany, the researchers will investigate what impact certain governance-related factors such as statutory requirements or coordination between different authorities and other underlying conditions (e. g. pressure on water resources) have on the effectiveness of harmonization and cooperation measures and hence the overall success of Integrated Water Resource Management. STEER seeks to determine the conditions under which certain aspects of effective governance systems are transferrable. On the basis of these analyses, the

Catchment basin for unpurified wastewater from mining activities in the Kharaa River catchment in Mongolia project partners will develop strategies for solving existing conflicts over the use of water resources.

STEER is unique in its diagnostic approach to identify promising strategies, which can be used to resolve typical problems in the water sector, so that they are transferrable to a large number of similar situations. The project findings will be made available to users from research and water management practice in the form of an online platform. Besides diagnostic tools for analyzing complex water resource problems, the platform will also feature support to identify appropriate strategies and solutions.

Less Conflict and More Synergy

The STEER project is intended to contribute to solving water conflicts among different sectors and to create synergies that foster the implementation of sustainable water resource management. In selected regions, the project seeks to achieve model agreements between local stake-holders with the aim of improving coordination of water use. On the global level, STEER will help achieve the United Nations sustainable development goal to implement IWRM worldwide. The project envisages several user groups to benefit from the research findings including regional stakeholders from the water sector (e. g. water associations, river basin organizations), national ministries and administrations as well as international organizations advocating the sustainable management of water and land resources. The project findings may also be of interest to researchers and consultants active in the field of water management.

River Emscher in Bottrop: intensive land use on both sides of the river hampers renaturalization.

Funding Measure
Water as a Global Resource (GRoW)

Project Title
Increasing Good Governance for Achieving the Objectives of Integrated Water Resources Management (STEER)

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iWaGSS –Easing Water Stress with Real-Time Water Management

Globale Ressource Wasser (GRoW)

According to UN figures, over 2 billion people around the world are currently affected by water stress. In future, due to population growth and burgeoning economic development, water extraction is expected to increase, particularly in sub-Saharan Africa. For the world-renowned Kruger National Park in South Africa, securing adequate water supply for people, animals and plants is already proving to be a challenge. In order to alleviate the water scarcity in the area, partners in the joint project iWaGSS are seeking to develop a computer-aided real-time water management system.

Development of a Modular Water Management System

Within the Kruger National Park, a designated UNESCO Biosphere Reserve, a plethora of users, including the mining sector, industry, agriculture and (eco)tourism all compete for the scarce water resources. Further, the situation in the national park is steadily deteriorating due to the growth of the neighbouring town of Phalaborwa and the resultant increased demand for water. To ensure that existing water resources continue to be available for future use and improve the situation in the long term, the joint research project iWaGSS, comprising eight German and seven South African partners, plans to develop a computer-aided real-time water management system and pilot it in the region. The aim is for the system to support regional decision-makers and improve governance in the water sector.

The water management system comprises four modules combining risk assessment, new techniques for real-time water quality monitoring, hydrological modelling and socio-economic indicators.

A herd of elephants at the Olifants River in South Africa's Kruger National Park

More specifically, the project will first identify areas which are particularly susceptible to contamination. Based on a risk assessment potential mitigation measures will then be weighed up. The creation of a real-time monitoring network is intended to enable constant water quality monitoring both in the Kruger National Park and in the surrounding area as well as help ensure that countermeasures are taken promptly in the event of an emergency. Hydrologic models simulate the streamflow to predict the spatial and temporal distribution of pollutants in the water. With the analysis of socio-economic aspects, particularly in terms of water efficiency, ecosystem services and financial concepts, the project seeks to support the local and regional stakeholders responsible for water management and to improve water resource management sustainably.

On-Site Testing in the Kruger National Park

Many years of practical experience have shown that it is often not the national legislation and regulations but rather the actual implementation on the ground which is the decisive factor for effective and efficient water management. The iWaGSS model region in north-east South Africa, on the Mozambique border, was selected in close cooperation with the South African project partners because the region's development makes it very susceptible to water problems.

The area is located along the lower reach of the Olifants River and covers rural regions with subsistence farms, predominantly agricultural zones, economically significant mining and industrial areas headquartered in Phalaborwa, as well as ecologically important nature reserves, such as parts of the Kruger National Park.

The Olifants is the most important source of water in the central part of the national park. However, the river is in a poor state in terms of both the quality and the quantity of water. Water use in the upper reach of the Olifants (for mining, agriculture, industry, energy generation and municipal water supply) reduces the amount of water that reaches the lower stretches of the river. Further, these types of water use lead to deterioration in water quality and an increase in sedimentation. The pilot region is one of the most challenging water management regions in southern Africa and is therefore particularly well suited for testing the iWaGSS concept in practice.

Practical Experience Improves Concept Transferability

Using a modular real-time water management system, the project partners are seeking to improve information flow and facilitate forward-looking sustainable resource management. Their hope is to be able to shorten the reaction times of the authorities and water management institutions. Based on the four modules, the plan is also to develop a user-friendly decision-support system. The researchers are also working on the elaboration of environmentally sustainable recommendations for action and scenarios for tackling acute damage such as water pollution. The intention is for the practical experience gained through the project to serve as a basis for the future transfer of the concept to other regions with overstretched water resources, both in Africa and worldwide.

View over the mining area bordering the Kruger National Park

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GRoW
WATER AS A GLOBAL RESOURCE

go-CAM – Sustainable Management of Water Resources in Coastal Regions

Water as a Global Resource (GRoW)

In coastal regions around the world, sustainable water use poses major challenges, with climate change, rising sea levels, the risk of salinization, the discharge of nutrients from agriculture, and low elevation placing significant pressure on water resources in these areas. Demographic growth and ever-increasing water demand from industry are adding to this stress. Water conflicts are becoming increasingly common as a result of the overexploitation of water resources. The aim of the joint project go-CAM is to use modelling to forecast the development of water resources in coastal regions, taking into account the various contributory factors. Based on these models, project researchers will develop different options for the comprehensive and sustainable management of coastal water systems.

Understanding Processes with Scientific Models

Climate change will have a particularly palpable impact on the economic and living conditions of people in coastal areas. Is the supply of freshwater to coastal regions guaranteed in the long term? How significant is the risk of salinization caused by rising sea levels? How well informed are the key stakeholders in the water sector about the consequences of increasing water stress in coastal regions? To explore these questions, go-CAM project partners are developing an integrated, transferable management system for coastal zones. This planning tool will be part of an online dialogue platform called "Coastal Aquifer Management (CAM)". The system offers possible courses of action to address challenges in water management specific to coastal areas. These can be applied in practice and are highly transferrable to coastal areas worldwide. As a basis for the research, case studies in northern Germany, Brazil, Turkey and South Africa are being analyzed in detail.

Innovative eco-hydrological models form the basis for assessing both, water availability and water demand in coastal regions. The project researchers use these models to produce water balance estimates that indicate the amount of water theoretically available for sustainable use in a specific region without deterioration of the regional resources. These models are also used to estimate regional groundwater recharge and distribution. They factor in the complex structures of coastal water catchments, e. g. the geological characteristics of the underground, as well as the specific climatic conditions and nutrient inputs. By applying given climate, socioeconomic and demographic scenarios, the project researchers use the models to calculate estimates for the future availability and quality of regional water resources.

Groundwater monitoring site with data logger. The data is used to model future water balances in coastal regions.

Developing Regional Strategies

Not only do the models outlined provide insights into the water systems and underlying processes in coastal areas; they can also be used to test the impact of different decisions in the water sector on coastal water resources. This involves decisions being analyzed according to a range of criteria; here, the primary objective is sustainable use of resources.

Modelling results and decision analyses outputs are fed into a coastal zone management system that facilitates the development of optional regional management strategies. This planning tool will be readily available on the online CAM dialogue platform and is to be transferred to coastal regions worldwide.

Transfer to Partner Regions Around the World

In cooperation with representatives of different interest groups in the regional case studies, the project partners calculate the estimated future water demand in the respective regions, i.e. Friesland (north-west Germany), the metropolitan region of Recife (in north-east Brazil), Antalya (Turkey) and the Eastern Cape (South Africa). Within the scope of this cooperation with partner regions, the developed regional strategies are to be translated into concrete action; this way the CAM dialogue platform will be introduced internationally. By way of accompanying workshops with various user groups, the project strengthens the acceptance of the new methods and the overall project findings. A PhD programme with associate partners from around the world is also intended to ensure that the methods and tools developed will continue to be applied beyond the project's conclusion.

Wiedel pumping station and sluice gate in northern Germany: sustainable strategies in the context of coastal zone management need to consider different interests and water demands.

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