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GRoW

WATER AS A GLOBAL RESOURCE

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Global analyses and local solutions for sustainable water resources management

Conference Proceedings

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Victoria Falls on the Zambezi River, at the border between Zambia and Zimbabwe; Foto: Vadim Petrakov / Shutterstock

Introduction to the funding measure GRoW: Water as a Global Resource

"The water and sanitation crisis is an urgent, interconnected challenge that requires a collective, coordinated response. "This statement opening the UN-Water 2030 Strategy[1], highlights the need to accelerate progress towards reaching the targets of Sustainable Development Goal (SDG) 6, which are alarmingly off-track at the start of the UN Decade of Action. Worldwide, billions of people still lack access to clean drinking water and sanitation. Both, population growth and climate change, exacerbate the water crisis. Over-allocation of water resources causes conflicting interests between various uses, such as in the agricultural and energy sectors or for maintaining healthy water-related ecosystems. In times of worldwide trade, local and regional water resources and systems are linked through global markets and supply chains. Therefore, sustainability of local water resources must be considered a global responsibility.

To help achieving the targets of UN SDG 6, the German Federal Ministry of Education and Research (BMBF) has initiated 'Water as a Global Resource' (GRoW), one of the largest contemporary research initiatives addressing water from a global perspective.

GRoW comprises twelve joint research projects and one transfer project, bringing together more than 90 funded institutions from research, business and practice. To support successful project implementation and transfer of research results into policy and practice, they worked together with numerous research and stakeholder organisations from case study basins around the world (see worldmap on p. 10-11)

After three years of applied research under the theme "Global analyses and local solutions for sustainable water resources management", GRoW puts forth a set of innovative methods and tools to support decision making and increase governance capacities in the water sector, while reflecting the close links between local and global action. The projects present local and regional solutions as well as improved global information and forecasts of water resources and demand, taking an integrated view at the multiple water-related challenges and how they are interlinked with, among other, energy, food security and climate change.

Each of the twelve projects focusses on one of three overarching topics:

1. Global water resources

The development of innovative assessments and management tools for water resources and their related ecosystems is central to the first topic. GRoW researchers derived action-relevant information from large volumes of raw data (e.g. from satellite-based remote sensing) and explored how technology and innovative, solution-oriented models can be applied to improve information flows. These compact solutions can significantly reduce the time between collecting data, analysing the need for action, and subsequent management decisions taken by companies and authorities.

2. Global water demand

The second topic focuses on analysing water demand and creating new incentive systems for using resources more efficiently. Future water demand must be assessed in light of the nexus between water, food and energy, to ensure that growing needs, e.g. for food production and renewable raw materials for energy generation are taken into account. Water footprints and reliable, understandable forecasts of trends in water demand are therefore important tools for decision-makers in businesses and authorities.

3. Good governance in the water sector

Good water governance, which is at the heart of the funding measure, requires information about water resources, water demand and make appropriate use of innovative technologies. GRoW researchers have, for example, contributed relevant information for measuring and documenting progress on the SDGs, identified suitable indicators for the multidimensional concept of sustainability and verified their applicability. Moreover, GRoW researchers developed methods and incentive mechanisms that enhance societal and individual motivations for sustainable water management.

1 https://www.unwater.org/publications/un-water-2030-strategy/

The GRoWnet networking and transfer project

The GRoW research activities are accompanied by GRoWnet, the networking and transfer project led by adelphi. GRoWnet aims to identify and effectively use synergies between the twelve joint research projects by strengthening cooperation and exchange between them. In addition, GRoWnet actively supports the projects in transferring and communicating their research findings and solutions to different target groups, such as the public, water experts, resource managers and policymakers. In doing so, GRoWnet aims to increase the overall impact of the funding measure.

The GRoW steering committee

The GRoW steering committee supports the work of the research projects. It consists of six external experts from development cooperation, policymaking and business, the coordinators of the twelve joint projects, representatives of the BMBF, the Project Management Agency Karlsruhe (PTKA) and the GRoWnet networking and transfer project. The objective of the steering committee is to increase impact, and practical applicability of the research activities. The committee supported GRoW projects in outreach activities and drafting policy recommendations, particularly in terms of achieving the SDGs. The overall structure of the funding measure GRoW is shown in Figure 1.

Overarching results and recommendations of the funding measure GRoW

GRoW made use of its critical mass of approximately 300 researchers jointly engaged on the topic of global water resources to draft overarching conclusions and recommendations:

- **"Safeguarding water resources in a globalized world: A science-based call for action"** addressing business and policy leaders (2020 - will be released at the final conference)
- **GRoW-Handlungsempfehlungen** an Entscheidungsträger der deutschen Politik und Wirtschaft (2020- will be released at the final conference - in German language)
- **Summary of highlights, results and recommendations of each GRoW project** (a living document)
- **SDG6 HLPF-Position paper:** Strengthening the evidence base for the SDG process (distributed ahead of the HLPF-meeting New York 2018)

All GRoW recommendations are accessible at: http://www.bmbf-grow.de/recommendations

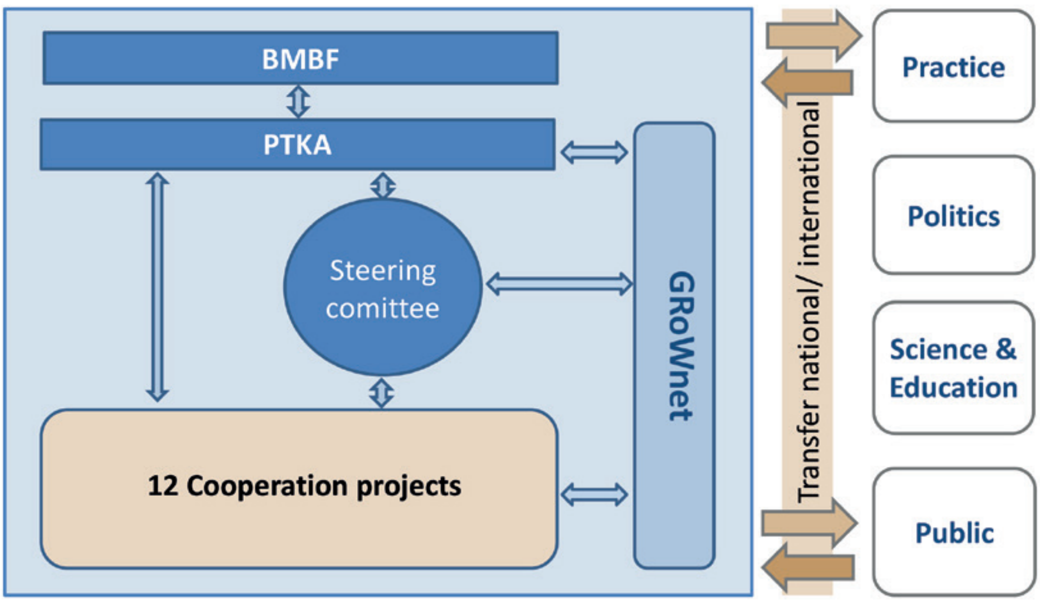


Figure 1: Structure of the funding measure GRoW (Source: PTKA)

Making GRoW more than the sum of its parts: The GRoW cross-cutting topics

While the twelve GRoW research projects cover very diverse topics, a number of thematic and methodological commonalities exist. In order to harness synergies and ensure that knowledge is shared across the individual projects, GRoW partners jointly worked on a series of cross-cutting topics over the past 3 years.

Under the direction of the steering committee, three main cross-cutting topics were selected:

1. **Incentive mechanisms in the context of governance**
2. **SDGs (Sustainable Development Goals): Hitting the targets**
3. **Water footprint**

GRoW partners eager to engage with fellow researchers and practitioners organised around these three cross-cutting topics. For each topic, a coordinator as well as an advisor from the external steering committee were selected to direct the work. Supported by GRoWnet, they organised workshops and online meetings. The outcomes of their joint work were presented in two dedicated sessions at the Stockholm World Water Week in 2019 and various briefing papers summarising shared insights and recommendations. For more details on the cross-cutting topics, please see the GRoW website: https://bmbf-grow.de/en/grow/grow-cross-cutting-topics

Incentive mechanisms in the context of governance

Coordinators:
Prof. Dr. mult. Rudolph (IEEM gGmbH – University Witten/Herdecke),
Alexander Grieb (formerly KfW),
Barbara Gerhager (GIZ)

A number of the GRoW joint research projects are working on incentive mechanisms (e.g. economic, legal and reputational) to encourage better water resources management. However, much like the effectiveness of new technologies and processes, the impact of these tools depends heavily on the political and social frameworks in the target regions. At the first meeting of the cross-cutting topic, participants therefore decided to work on the link between the macro and micro level of water governance, which implies scaling down the focus to, for instance, the level of water utilities in order to achieve SDG 6. In addition, three sub-working groups were defined:

- **Irrigated agriculture:** This group focussed on legal frameworks and the potential of social innovations and digitalisation in the agricultural sector.
- **Measuring governance:** This group facilitated inter-project exchange on operationalising governance and defining governance indicators for measurement purposes.
- **Turning governance research into practice:** This group assessed the link between the macro and micro level and collects aspects of good governance from the projects, since general principles of governance do not always fit the water sector.

All three subtopics have been explored, each with different GRoW projects involved. Activities and outcomes were presented to the sub-groups and external guests interested to participate. A number of special aspects, methods and data could be utilized within the GRoW community, such as those regarding agricultural irrigation in the context of water reuse and measuring governance to balance between competing economic, social and ecological aspects.

How to turn water governance research into practice was understood as a new and challenging issue. In order to accomplish ongoing research relevant for water governance, it was decided to analyse and assess reasons and drivers of failures of water services on the local level, and to digest the outcomes in a brief paper. A first draft of this paper, the Thesis Paper on "Seven Sins Against Local Water Management" was presented to the GRoW steering committee on 7 November 2019. Following a lively discussion, the recommendation from the committee was to continue this work and further verify and reconcile important details, keeping the format of a brief, compiled paper.

At the GRoW final conference, Prof. Rudolph will present a working paper entitled "**Good Water Governance: Seven sins against local water management**". The laymans version of this paper is available for download at the GRoW website: www.bmbf-grow.de/recommendations and at the GRoWnet booth on the virtual marketplace.

SDGs: Hitting the targets

Coordinators:
Prof. Dr. Claudia Pahl-Wostl (Osnabrück University),
Dr. Ursula Eid

Working towards achieving the SDGs in general, and SDG 6 in particular, is a key objective of all GRoW research projects. They develop and test innovative approaches that can help achieving the goals and devise new concepts and key figures for their progress evaluation. The cross-cutting topic addresses issues related to the achievement of SDG 6, including leveraging synergies and minimising trade-offs with other SDGs. In doing so, the GRoW researchers created a useful network for strengthening and effectively demonstrating the ways in which the individual projects and the overall GRoW funding measure contribute to the achievement of the SDGs.

The working group published a joint GRoW position paper highlighting what the GRoW projects see as key challenges and possible contributions in the process of achieving SDG 6. This paper was channelled into the political process of SDG 6 monitoring and has received positive feedback from a number of institutions in the context of the UN High-Level Political Forum on Sustainable Development in June 2018.

Two sub-groups were created to work on specific aspects of this cross-cutting topics: The first one, led by Dr Frank-Andreas Weber (FiW e.V), addressed "**Conflicting targets and synergies between different SDG goals**", with the aim of developing a new assessment procedure for evaluating projects and/or different policy plans and their effects on SDG interactions. The second one, led by Dr Anna Smetanova (TU Berlin), dealt with "**Indicators, data and models**", aiming at collecting examples from GRoW on how global SDG 6 monitoring can be complemented to provide insights for more sustainable water resources management.

Currently, both groups within the cross-cutting topic are working on summarizing the specific outputs to disseminate the final findings.

The group "conflicting targets and synergies" has developed a cooperative assessment procedure to seize synergies and avoid trade-offs between SDG 6 and other SDGs for improved decision making in planning processes. Four projects within the GRoW funding measure were selected to test the practicability of the proposed assessment procedure. The assessment procedure is designed based on the idea of integrating different types of knowledge in order to increase the scientific validity, policy relevance and social robustness of decision-making. It aims at minimizing conflicts and seizing synergies through context-specific assessment by incorporating different stakeholder groups with potentially differing perceptions of the conflicts at stake. At SIWI World Water Week 2019, the cross-cutting topic presented key insights and recommendations for assessing and addressing SDG trade-offs and synergies to an international audience of different stakeholders from the water sector. Based on this collaborative work, the group is currently finalizing a manuscript for publication in the peer-reviewed journal Sustainability.

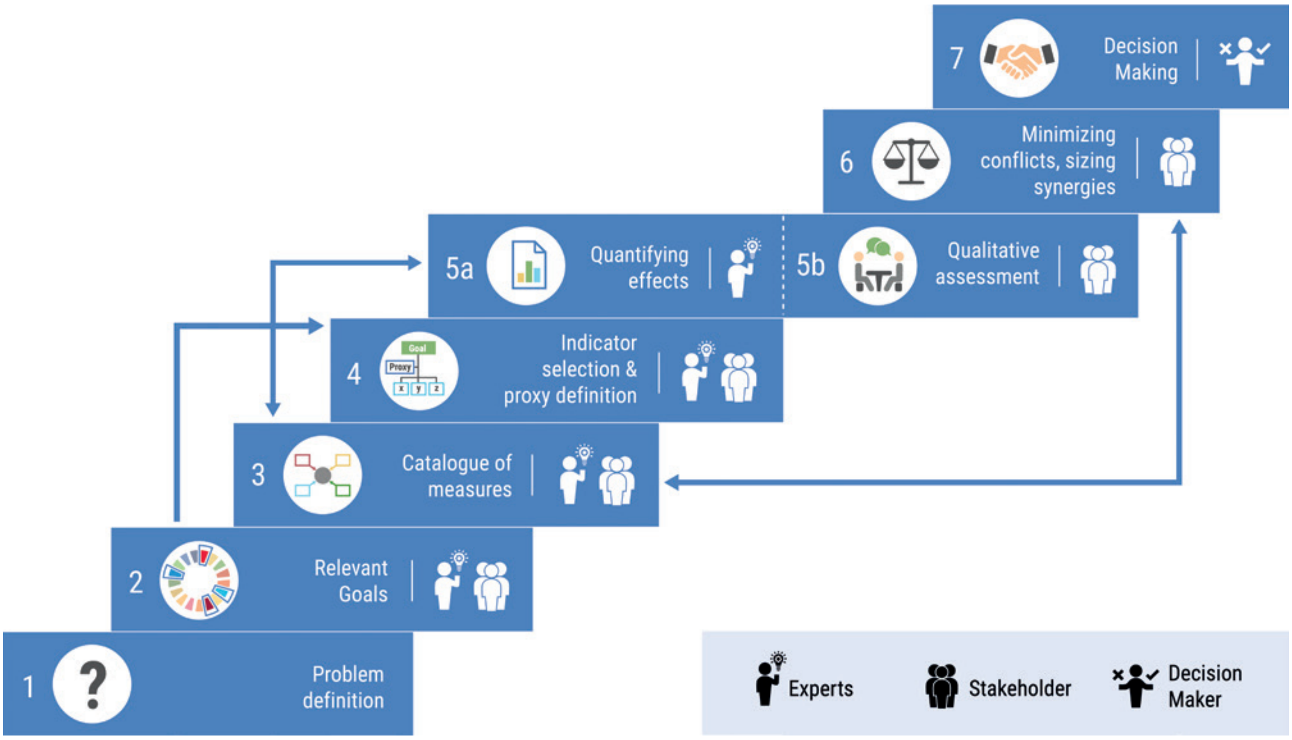


Figure 1: Proposed Assessment Procedure (© FiW e.V., Aachen).

Figure 2: Example for selected interlinkages between SDG 6 and other SDGs (© FiW e.V., Aachen).

A presentation on "New approaches towards assessing trade-offs and synergies between SDG 6 and other SDGs" and a draft policy brief on "Innovative indicators and monitoring concepts to support achieving SDG 6 in an integrated manner" are available for download on the GRoW website: https://bmbf-grow.de/en/grow-cross-cutting-topics/sdg-hitting-the-targets and at the GRoWnet booth on the virtual marketplace.

Water footprint

Coordinators:
Dr. Markus Berger (TU Berlin),
Dr. Falk Schmidt (IASS Potsdam)

Several of the GRoW research projects investigate how consumption and production is linked to and affects water resources in other parts of the world. They develop methods for measuring water footprints in order to identify areas where water is being used inefficiently, and implement practical measures to reduce the respective water footprint.

Within the cross-cutting topic, GRoW projects discussed three major issues: First, the potential of the water footprint as a tool to support mitigation efforts; Second, the relation between water footprints and the assessment of economic and social impacts; And third, how aspects of water quality (including groundwater) can be more effectively included in water footprint assessments.

At SIWI World Water Week 2019, GRoW organised the event "Supporting SDG 6 by advancing the water footprint tool" to present results of the work within this cross-cutting topics. GRoW researchers highlighted that the water footprint approaches developed in their projects are directly relevant to decision-making processes of the private and public sectors, either to reduce the water footprint at organisational level in supply chains, or to take more sustainable management and policy decisions on a regional level.

Based on the findings of the seven GRoW research projects working on the water footprint concept and the discussions within a cross-cutting working group, we recommend to:

1. Take a holistic perspective on the water footprint: In order to make meaningful use of the water footprint concept as a steering instrument to guide decision making at various levels, the impacts of water use need to be assessed in addition to liters of water consumed and polluted by applying recently developed methods.

2. Make use of the water footprint to identify where investment in more sustainable water use is most efficient. For private companies as well as for governments, it might be environmentally more beneficial and often economically more efficient to invest in water use efficiency measures at suppliers or in exporting countries which face high water stress rather than focusing on production-site or domestic measures only.

3. Analyse virtual water flows and resulting impacts in order to identify hotspots, for instance associated with European imports, and develop specific policy measures mitigating local water stress in the exporting countries. These could include providing incentives for more efficient water usage or steering specific technical development assistance. Policy measures based on virtual water trade analysis should consider local circumstances to prevent negative social and economic trade-offs, such as, reduced income or unemployment.

To collect and disseminate their recommendations on how to enhance and effectively apply the water footprint concept, participants in this cross-cutting topic published the GRoW policy brief "Advancing the Water Footprint into an instrument to support achieving the SDGs". The policy brief is available for download at the GRoW website: www.bmbf-grow.de/recommendations and at the GRoWnet booth on the virtual marketplace.

Moreover, the cross-cutting group developed a "water footprint toolbox" (https://wf-tools.see.tu-berlin.de/wf-tools/waterfootprint-toolbox/). Depending on the question stakeholders might have with regard to water footprinting – the app suggests a corresponding database, impact assessment method, standard or online tool.

GRoW Case study regions

GLOBAL WATER RESOURCES

ViWA
Danube River Basin (Romania, Hungary, Serbia, Bulgaria, Slovakia, Slovenia, Austria, Germany)
Zambesi River Basin (Zambia, Zimbabwe, Mozambique, Namibia)

GlobeDrought
Republic of South Africa, Zimbabwe, USA

SaWaM
Iran, Brazil, Sudan, Ethiopia, Ecuador, Peru, West Africa

MuDak-WRM
Germany, Brazil

MedWater
France, Italy, Israel, Palestinian territories

GLOBAL WATER DEMAND

WELLE
Belgium, Germany, South Africa, USA

InoCottonGRoW
Pakistan, Turkey

WANDEL
Germany, Morocco, Brazil

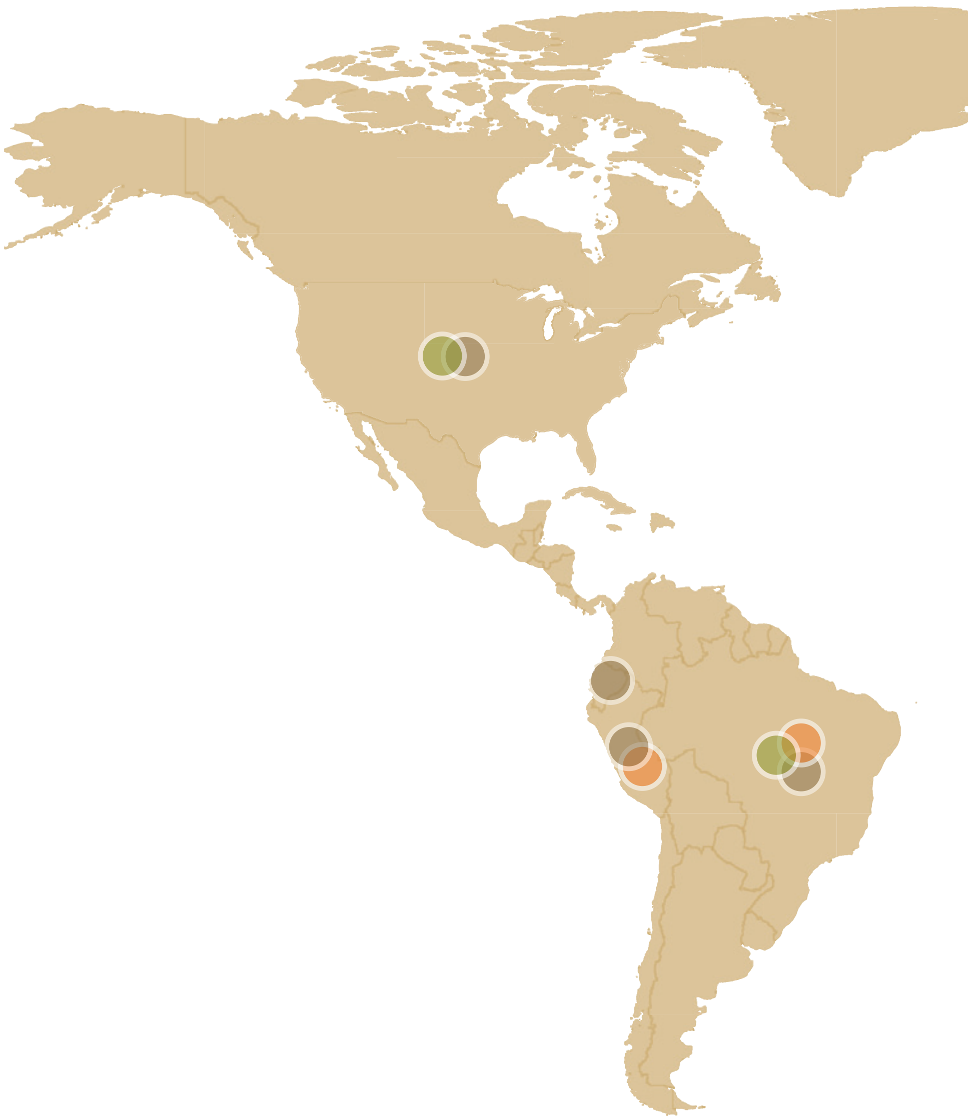
GOOD GOVERNANCE IN THE WATER SECTOR

STEER
Emscher (Germany)
Weser-Ems (Germany)
Guadalquivir (Spain)
Kharaa-Yeroo (Mongolia)
uMngeni (South Africa)
Zayandeh-Rud (Iran)

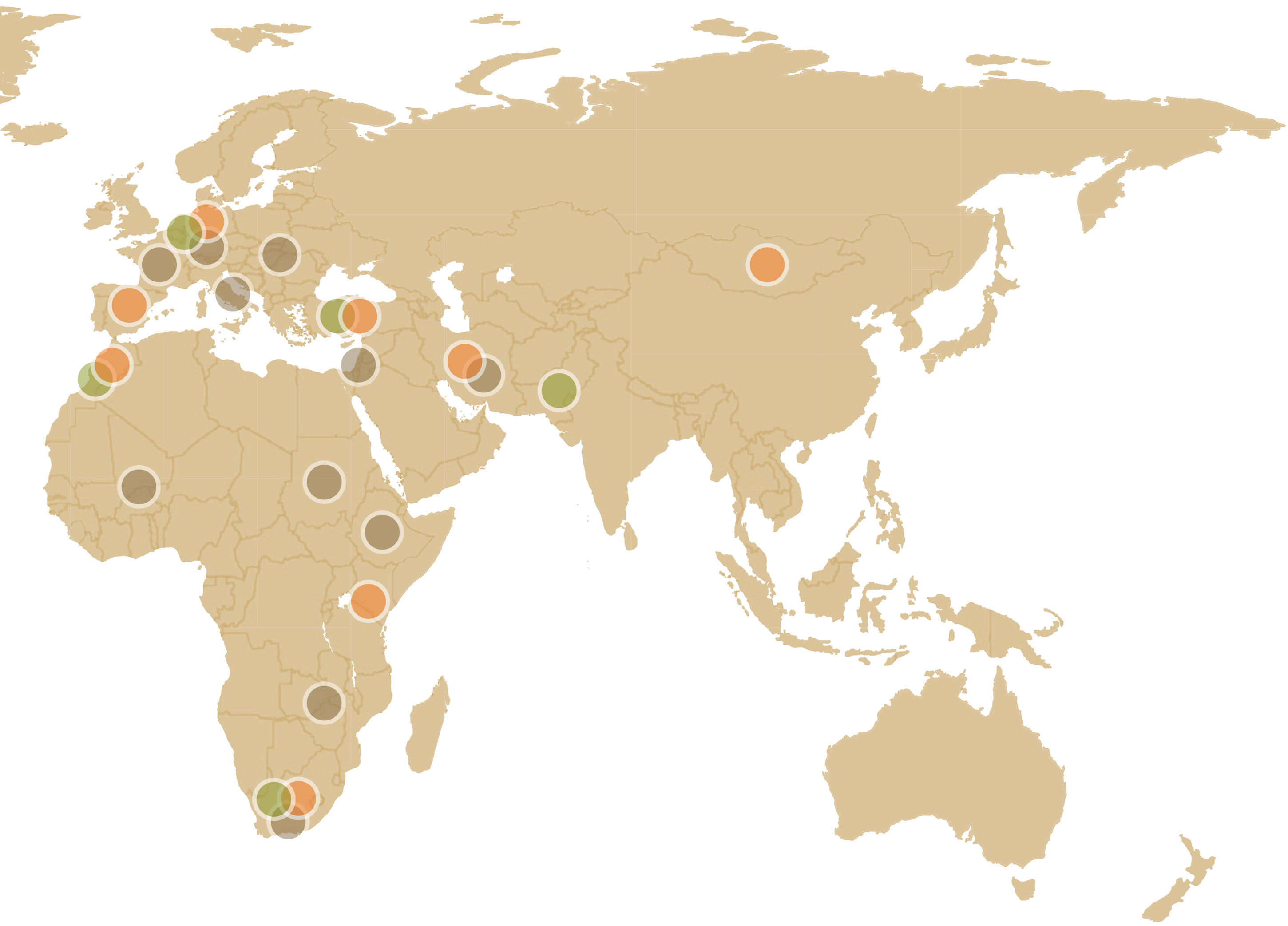
Trust
Peru

iWaGSS
Lower Olifants Catchment (South Africa)
Mara River Basin (Kenya)

go-CAM
North-Eastern Brazil, North-Western Germany, Turkey, South Africa



In addition to local case studies, global computer models were employed by the following projects: ViWA, SaWaM, GlobeDrought, WANDEL



(Stand: Oktober 2020)

ViWA – Virtual Water Values

Coordination

Prof. Dr. Wolfram Mauser, LMU Munich

German partners

- Kiel Institute for the World Economy (IFW)
- Leibniz University Hannover
- Helmholtz-Centre for Environmental Research UFZ Leipzig
- Leibniz Supercomputing Centre of the Bavarian Academy of Sciences and Humanities (LRZ), Garching
- GERICS Climate Service Center Germany, Hamburg
- VISTA GmbH, Munich
- Georg Hipp OHG (associated partner)
- BayWa AG (associated partner)
- GIZ (associated partner)

International Partners

- International Commission for the Protection of the Danube river (ICPDR)
- The Romanian Academy
- World Wide Fund For Nature (WWF)
- European Space Agency (ESA)

FURTHER INFORMATION

Project website: https://viwa.geographie-muenchen.de/

PROJECT GOALS

98% of global water use is allocated to producing food and biomaterials through green (rainfall) and blue (irrigation) water. **Agricultural water use efficiency (AWUE)** and sustainability have to increase globally to meet water- and food-related Sustainable Development Goals (SDGs). Global data on the efficiency and sustainability of the virtual water contained in agricultural goods traded on global markets is not available. ViWA aims at 1) developing ways to monitor AWUE with high resolution and accuracy; 2) identifying, through simulation, global hot-spots of inefficient and unsustainable agricultural water use and 3) analysing scenario alternatives for more sustainable agricultural water use, as well as their economic and environmental trade-offs. ViWA acts globally and regionally in the two pilot watersheds Danube and Zambesi. The results of ViWA aim at supporting global and regional organizations and companies in improving the sustainability of their water related decisions.

KEY RESULTS

- An innovative **AWUE monitoring system** based on incorporating Sentinel satellite observations into the high-resolution, coupled crop- and water simulations model PROMET was developed. The system monitors AWUE, water shortage, irrigation and yield expectations for 16 crops with a resolution of 1km/1d on a global scale. PROMET was run on the LRZ high-performance-computer SuperMUC with global meteo-drivers (e.g. ERA5 and CORDEX) and data from >15000 Sentinel-2 images to simulate the agricultural water cycle and actual crop growth globally and in the pilot regions.
- Annually varying global **hot- and cold spots of AWUE and yield** were identified. The monitoring system shows hot-spots of low AWUE e.g. in the East and South of sub-Saharan Africa (see Figure 1).

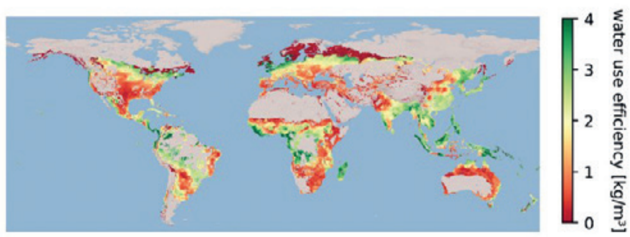


Figure 1: Global Water Use Efficiency of Maize (2015-2017) (Source: ViWA).

- AWUE and fertilizer use (rainfed, irrigated) was incorporated into the Computable General Equilibrium model ART for global trade. **Trade-offs of scenarios** of water decision alternatives were analysed. The scenarios depict the consequences of regulations, such as developing irrigation or intensifying agriculture. Generally, intensifying agriculture leads to a reduction of virtual water trade volume.
- Regionally, PROMET (resolution: 1km, 1h) was used as a tool to simulate coupled water-food-energy (WFE) nexus **water conflicts** in transboundary watersheds, such as water use for energy production vs. irrigation. The introduction of large-scale irrigation in the Danube basin (800 000 km^2) was used as an example for such an evolving nexus conflict. The effect of expanding irrigation on maize fields on river flows shows that maize yields can be doubled and AWEU increases at the expense of a serious reduction in average summer discharge in the Lower Danube and its tributaries. Economically, irrigated maize yield gains compensate losses in hydropower by a factor of more than 20.
- Tools to analyse the **ecological impacts of water use alternatives** regarding WFE nexus water conflicts were developed and used in the Danube basin. Locations of wetlands and groundwater flows were combined with the consequences of maize irrigation scenarios (see Figure 2).
- The global effects of regional **climate variability** induced water stress on regional agricultural yields, such as the one caused by El Niño in 2015, were simulated using high-resolution meteo drivers. CORDEX meteo drivers show, that large-scale meteorological anomalies like El Niño have pronounced impacts on regional agricultural water security and yields.

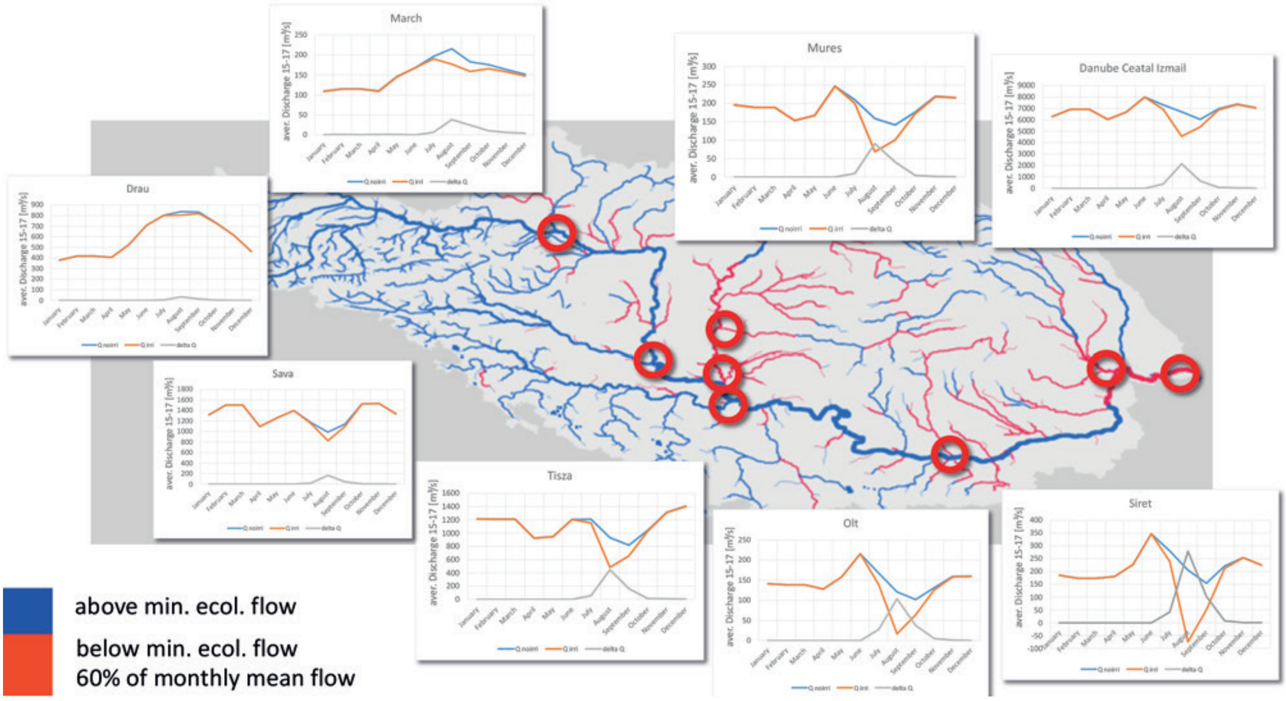


Figure 2: Assessment of July minimum flow changes through full maize irrigation from surface waters and selected monthly discharges with and w/o maize irrigation (blue line = no irrigation, red line = full irrigation of maize, blackline = withdrawal) (Source: ViWA).

OUTLOOK AND FUTURE APPLICATIONS

ViWA demonstrated how new **big-environmental-data** from EU's Sentinel-2 environmental satellites and global meteo-simulations (e.g. GERICS, ERA5) inform coupled hydrological/agro-physiological/groundwater process models. The result is a powerful global-to-local toolbox to monitor and analyse regional water conflicts in the context of the WFE nexus. Hot-spots and global teleconnections (e.g. El Niño) become visible. This improves downstream economic models and ecological assessment tools. They support stakeholders in assessing the local-to-global impacts and trade-offs of water-decisions and in resolving WFE nexus conflicts.

ViWA's results represent one first step towards fully integrating global big-environmental-data and simulations into transboundary management of natural resources on all scales, from local to global, with the purpose to ensure sustainable water, food and energy supply.

GlobeDrought – A global-scale tool for characterizing droughts and quantifying their impact on water resources

Coordination

Prof. Dr. Stefan Siebert, University of Göttingen

German partners

- University of Bonn
- Goethe University Frankfurt
- United Nations University
- Remote Sensing Solutions GmbH
- Deutsche Welthungerhilfe e.V.

International Partners

- Joint Research Centre of the European Commission (JRC), Ispra, Italy
- World Wildlife Fund (WWF)
- University of Free State, Republic of South Africa
- South African Weather Service
- National Disaster Management Centre, Republic of South Africa
- University of Zimbabwe

FURTHER INFORMATION

Project website: https://grow-globedrought.net/

PROJECT GOALS

The main goal of the project is to provide a risk analysis of adverse drought impacts for agricultural systems and public water supply. It produces a spatially explicit description of drought risks at global and national scales. The results are presented in a web-based drought information system, which consists of the components (i) long-term drought risk, (ii) drought status, and (iii) an experimental early warning system. The global component of the system allows to consistently comparing drought risk for different countries and the drought status for different periods. Assessments that are much more detailed are provided for the case study region Southern Africa (incl. South Africa and Zimbabwe) to support national drought risk management. In contrast to other operational early warning systems, data from process-based models is combined with data from remote sensing to make use of the advantages of both data sources in the analysis of drought hazard and drought status.

KEY RESULTS

Advanced methods for integrated drought risk analysis developed

A comprehensive review of the literature on drought risk assessments revealed conceptual and methodological deficiencies, and highlighted the need for impact-specific assessments when analysing drought risks. Based on stakeholder consultations during the first project workshop, it was decided to focus on drought risks for irrigated and rainfed agricultural systems, and for water supply. GlobeDrought developed novel approaches for assessing the drivers and spatial patterns of drought risk for agricultural systems and public water in an integrated manner at the global scale and applied it to South Africa and Zimbabwe at the sub-national scale.

Improved resolution and extent in drought hazard analysis by combining process-based models and remote sensing

Several indicators derived from remote optical sensors were successfully applied to study drought hazard at high spatial resolution. These indicators showed high correlation to indicators derived from process based hydrological- or crop water models. Assimilation of GRACE gravity data in the global hydrological model WaterGAP resulted in an improved representation of long-term trends in water storage changes, e.g. by non-sustainable groundwater use. Combination of remote sensing and process-based models allowed mapping drought hazard for long periods, at high spatial and temporal resolution and to project future changes in drought hazard.

Vulnerability to drought systematically analysed using a participatory approach

Based on expert and stakeholder consultation, appropriate drought vulnerability indicators and their weighting were identified for irrigated and rainfed agricultural systems in Zimbabwe, South Africa and at global scale. They were then combined with hazard and exposure to study drought risk. For the first time, spatiotemporal changes in vulnerability of agricultural systems to drought since 1990 are studied and compared to variability in drought hazard.

Various channels used for knowledge dissemination and transfer

15 articles in international scientific journals have been published describing the methods developed in the project and over 10 additional studies are in progress. The results of the global and regional assessments are presented in a web-based drought information system[1]. Joint publications with key stakeholders facilitated the use of our data and products, for example in the Global Drought Monitor or by politicians and citizens. Twelve digital lectures and webinars have attracted the attention of several hundred participants and are available on the eLearning Platform of the project website.

1 Available at http://map3d.remote-sensing-solutions.de/globedrought/GlobeDroughtPortal

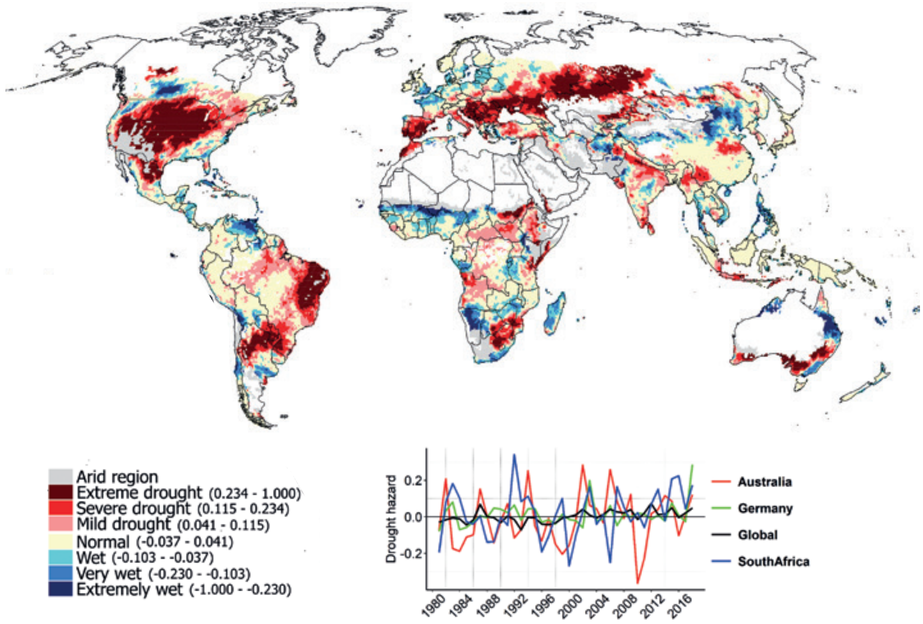


Figure 1: *Drought hazard for rainfed agricultural systems in year 2012 (top) and in period 1981-2018 for South Africa, Germany, Australia and at global scale (bottom). (Source: Eyshi Rezaei et al., unpublished)*

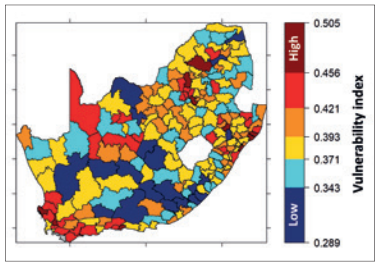


Figure 2: *Vulnerability to drought of rainfed agricultural systems in South Africa at the municipality level (Source: Meza et al., unpublished).*

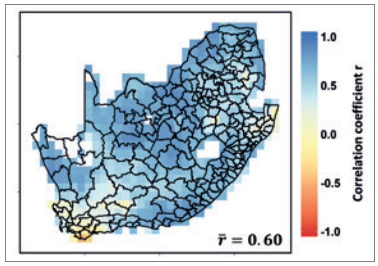


Figure 3: *Correlation between modelled and remotely sensed ratio between actual and potential evapotranspiration for rainfed crops in South Africa in period 2001-2018 (Source: Eyshi Rezaei et al., unpublished).*

OUTLOOK AND FUTURE APPLICATIONS

We learned that appropriate indicators used for drought risk analyses differ depending on the specific drought impact that is studied. Consequently, data and methods used for irrigated agriculture vary considerably from those used for rainfed systems. Methods and tools for monitoring and forecasting of drought hazard at global and regional scale have been developed, but the applicability for specific purposes depends a lot on the availability and quality of remote sensing and climate input data. More research is required to test the proficiency of seasonal weather forecasts for drought projections. While drought hazard cannot be completely controlled, more efforts are needed to reduce the vulnerability of exposed systems to drought. By providing insights not only into spatial hotspots (i.e. regions of particularly high drought risk), but also on the underlying drivers of risk, GlobeDrought offers important entry points for strengthening resilience. More research is needed to investigate which interventions reduce vulnerabilities most effectively, and whether these strategies can be generalized across space and time.

SaWaM – Seasonal Water Resources Management: Regionalized Global Data and Transfer to Practice

Coordination

Prof. Dr. Harald Kunstmann, Karlsruhe Institute of Technology, Institute for Meteorology and Climate Research (KIT/IMK-IFU)

German partners

- University of Potsdam
- University of Stuttgart
- Philipps University of Marburg
- Helmholtz-Centre for Environmental Research Leipzig (UFZ)
- Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences
- TU Berlin
- Tractebel Engineering GmbH
- Gesellschaft für Angewandte Fernerkundung GAF AG

International Partners

- The Khuzestan Water & Power Authority KWPA, Iran
- Fundação Cearense de Meteorologia e Recursos Hídricos (Foundation Cearense for Meteorology and Water Resources, FUNCEME), Brazil
- Agencia Nacional de Aguas (National Water Agency, ANA), Brazil
- Ministry of Water Resources & Electricity, Dams Implementation Unit (DIU), Sudan
- Sudanese Meteorological Authority (SMA), Sudan
- Prefectura Loja, Ecuador
- Universidad Técnica Particular de Loja (UTPL), Ecuador
- Gobierno Regional Piura, Peru
- West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL)

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FURTHER INFORMATION

Project website: http://grow-sawam.org

PROJECT GOALS

Increasing frequencies of droughts and heat extremes, as well as increasing precipitation variabilities in semi-arid regions fuel conflicts over water use and call for mitigation of impacts of climate change (Figure 1). Proactive and sustainable water management is required, which can benefit from hydro-meteorological seasonal forecasts and high-resolution, near-real-time measurements. For comprehensive water management, all sources and sinks of freshwater resources need to be known, including not only the full hydrology, but also ecosystems regarding the food-energy-water nexus. With semi-arid regions being hot spots of erosion, further sediment input, transport and deposition are key for sustainable reservoir operations. The SaWaM project addresses the question whether regional water management and in particular dam operation in semi-arid regions can be improved by the use of global, publicly available information with a focus on near-real-time and seasonal timescales. With the provision of a tailor-made information system of supportive regionalized information for each of our semi-arid study basins in Iran (Karun), Brazil (Sao Francisco), Ethiopia-Sudan (Tekeze-Atbara and Blue Nile), and Ecuador-Peru (Catamayo-Chira), we target the local water managers and emphasize the use of near-real-time information and seasonal forecasts in hydrological decision-making.

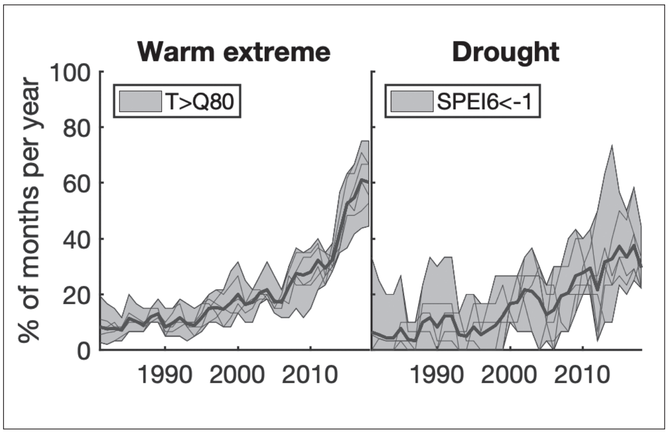

Figure 1: Increasing frequencies of very warm and drought months per year in the regions of São Francisco (Northeast Brazil), Niger, Volta (West Africa), Tekeze-Atbara, Blue Nile (Northeast Africa) and Karun (Iran) from 1981-2018 evaluated by ERA5 reanalysis data.

KEY RESULTS

Publicly available satellite- and global model information for transboundary water management

The main variables necessary for regional water management can be derived from global, publicly available, in-situ, model-based and remote-sensing information. However, the development of these approaches still requires **local knowledge and quality-controlled local data. Global information** can serve **as a valuable complement** where there are gaps in local information.

Development of a regional operational hydro-meteorological seasonal forecasting system

A fully-integrated model chain produces **seasonal forecasts** on regional hydro-meteorology at **0.1° horizontal resolution** and with **forecast horizons up to seven months ahead** (Figure 2). Comprehensive forecasts were achieved via bias correction and regionalization of publicly available global seasonal forecasts. The representation of uncertainties due to ensemble simulations and the needs of specific users were elaborated through **active stakeholder integration**, including intensive interaction in **on-site workshops** and revision of the provided online-tool.

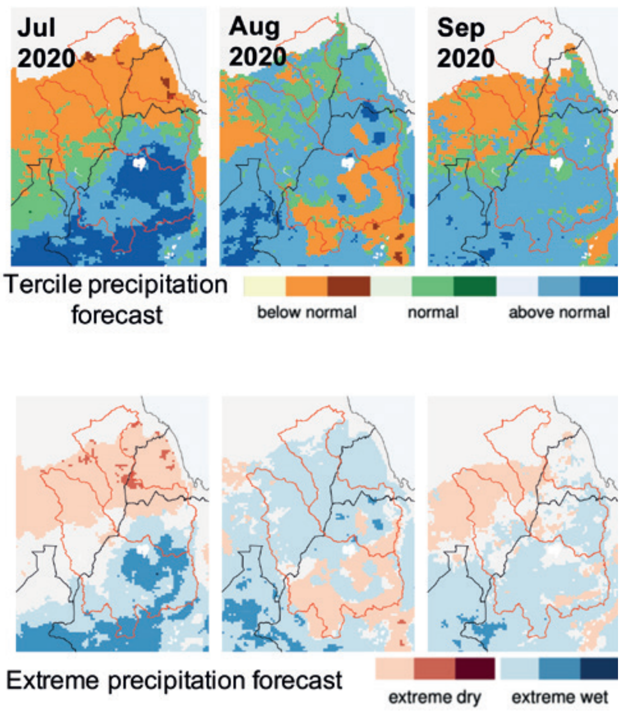

Figure 2: Forecast of the most likely tercile (top) and extreme (bottom) precipitation category issued on 01.07.2020 for July, August, and September 2020 over the transboundary Tekeze-Atbara and Blue Nile basins. Our forecasts predicted high probabilities of above normal and even extreme wet conditions across large parts of Ethiopia. During this three-month period, heavy rainfall particularly in Ethiopia led to record water levels of the Blue Nile, which then caused severe flooding across 16 Sudanese states and affected more than 3,000,000 people.

Seasonal forecasts provide economic benefit for regional water management

Switching towards **seasonal-forecast-based early actions proved to save expenses** and support climate proofing. If perfect seasonal forecasts and optimal action are defined as 100% economic savings, the SaWaM seasonal-forecast-based actions for droughts could achieve **70% of maximum possible economic savings**. For all semi-arid study regions, including West Africa, high potential **economic values** do not only occur for short forecast horizons, but **up to seven months ahead**. The assessment of economic value allows stakeholders to understand the forecast skill from an economic perspective, offering a broader range of possible applications of seasonal forecasts.

Multi-aspect drought assessment by monitoring, remote sensing and forecasting

The comprehensive, multi-disciplinary approach of SaWaM allows for a multi-aspect drought assessment, bringing together **monitoring, remote sensing and forecasting**. Droughts are studied not only from a hydro-meteorological point of view, but also with respect to their **implication on ecosystems**. Water shortages did not necessarily entail negative ecosystem anomalies when freshwater resources remaining available were used for irrigation.

Erosion hot spot analysis tool helps to prevent reservoir sedimentation

A newly developed hot spot analysis tool identified erosion hot spot areas that particularly contribute to the sedimentation of water reservoirs, thereby impairing water management. The tool could provide **decision support on preventative land management** for areas where improved land management has the largest impacts on reservoir sedimentation.

OUTLOOK AND FUTURE APPLICATIONS

Comprehensive forecasting months ahead proved to be possible when applying modern post-processing of publicly available global seasonal forecasts. Seasonal-forecast-based early action provides clear economic benefits, stressing the advantage and necessity of considering seasonal forecasts in hydrological decision-making. On-site workshops in our study regions were crucial for our success, particularly for accessing local data and creating profound impact. Building trust over years of close cooperation is required to overcome initial skepticism and is key to effectively transfer developed methods and information into practice. User-friendly visualization of probabilistic forecasts in cooperation with companies and stakeholders requires long iterations, which are still on-going. Future application of our derived products is ensured by the operationalization of the hydro-meteorological model chain of seasonal forecasts and selected near-real-time information, as well as their provision in the SaWaM online-tool. The implementation and further development of methods is now planned for Europe and Germany.

MuDak-WRM – Multidisciplinary Data Acquisition as Key for a Globally Applicable Water Resource Management

Coordination

PD Stephan Fuchs, Karlsruhe Institute of Technology (KIT), Institute of Water and River Basin Management, Department of Aquatic Environmental Engineering (IWG-SWW)

German partners

- KIT IWG-WK, Institute of Water and River Basin Management, Department of Water Resources Management
- KIT IPF, Institute of Photogrammetry and Remote Sensing
- University Koblenz Landau, Institute of Environmental Physics
- HYDRON GmbH, Karlsruhe
- 52°North - Initiative for Geospatial Open Source Software GmbH, Münster
- EFTAS GmbH, Münster
- Wupperverband, Wuppertal
- TriOS Mess- und Datentechnik GmbH, Rastede

International Partners

- Paraná State Sanitation Company (Companhia de Saneamento do Paraná, SANEPAR), Curitiba
- Federal University of Paraná (Universidade Federal do Paraná, UFPR), Curitiba
- University Positivo, Curitiba
- Paraná Water Resources Institute (Águas do Paraná), Curitiba
- Paraná Institute of Rural Development and Assistance (Instituto Paranaense de assistência técnica e extensão rural, (EMATER), Curitiba
- Simepar (Paraná Meteorological Institute), Curitiba
- Lactec Research Institutes, Curitiba
- Instituto Ambiental do Paraná (IAP)
- Agência Nacional de Águas (ANA)
- The Nature Conservancy Brasil (TNC)

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FURTHER INFORMATION

Project website: http://www.mudak-wrm.kit.edu/

PROJECT GOALS

Under rising pressure on land use in catchments and water quality deterioration in rivers, eutrophication and loss of good water quality threaten many reservoirs around the world. In order to implement successful measures to protect water quality, the precise assessment of the actual situation as well as predictions of medium to long-term changes are an important basis for decisions. Besides the general availability of numerous models for terrestrial and aquatic ecosystems, most models are complex and data demanding and the adaptation to specific questions is often limited.

The core aim of MuDak-WRM is to investigate to which extent the ecological situation within a reservoir (trophic status) and in the catchment of the reservoir can be represented and modelled based on a simplified set of parameters. In order to reduce the effort and costs of monitoring, the MuDak-WRM team set out to increase the understanding of catchment-lake related and internal lake processes, which are relevant for water quality. The key aspect is to identify all relevant parameters influencing the long-term behavior of the reservoir. Based on the obtained understanding, we developed a minimum monitoring concept for the specific compartments of the reservoir (catchment, river, water column, sediment). The complexity and data demand of applied models (nutrient and sediment input, water balance, water quality, hydrodynamics) was reduced to allow for an easier and global application.

The MuDak-WRM project addresses reservoir operators, authorities (environmental ministries and agencies), reservoir planning/design companies, companies working with environmental monitoring and modelling, and other researchers.

Figure 1: Sediment front in the inflow region of Passaúna reservoir (© T. Bleninger).

KEY RESULTS

- On the catchment site, the MuDak-WRM project developed **automatized remote sensing approaches** to retrieve land-cover and urban soil sealing on a yearly basis, the Leaf Area Index and surface albedo with monthly resolution. Within the reservoir, Chlorophyll-a and total suspended matter were obtained every five days and water temperature every 16 days.
- A **simplified water balance** model with increased input data from remote sensing and reduced spatial resolution was successfully applied to increase global applicability.
- A **low-complexity sediment and phosphorous emission model** was set up for one German and one Brazilian reservoir. The model was validated using the reservoirs as long-term accumulation points.
- A **multiple-method approach** leads to a high-resolution sediment investigation of the accumulated sediment and phosphorous mass, creating the basis for a lifetime assessment, phosphorous release model and hydrodynamic sediment distribution modelling (Figure 2).

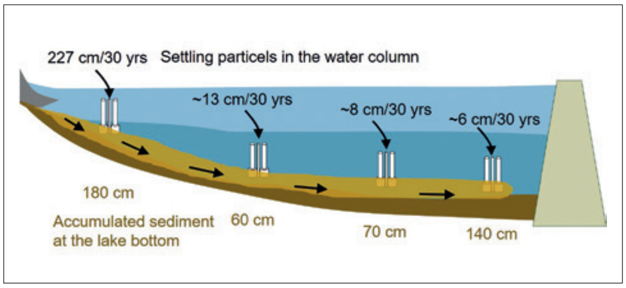


Figure 2: Siltation inside the reservoir shows importance of density currents by the difference of settling and accumulated sediment. (Source: S. Hilgert, MuDak-WRM).

- Integration, visualization and storage of variable data types as real-time water quality data and raster-based catchment data in a **Sensor Web application** (Figure 3).

The findings from the MuDak-WRM project with its high-resolution investigation of Passaúna reservoir lead to the conclusion that **simplified management patterns cannot be transferred** to other reservoirs. The necessity to create a one-time **robust data base** including precise bathymetry, water balance, actual nutrient stock (water and sediment) and a basic understanding of specific lake processes (e.g. P-fixation by iron and carbonate or influence of pre-dam structures on stratification and transport dynamics) needs to be emphasized. In order to keep the operator in control of the long-term development of the water body, a **minimum water monitoring** at the inflows and at one location inside the reservoir needs to be implemented. For larger reservoirs, this monitoring can be supplemented by continuous supervision of lake development (turbidity, Chl-a, Temp.) using satellite imagery.

In our case, modelled nutrient and sediment input **underestimated the flux by 50 %**, while even long-term in-river sampling was prone to massive underestimation, in this case by 7 to 14 times. Episodic flood events seem to have a severe effect on the development of a reservoir; however, they are hard to catch with regular monitoring.

Consequently, an assessment of in-reservoir sediment mass seems to be the most robust approach for long-term accumulation of sediment and phosphorous. It is the best option to adapt and validate low-complexity models for the operator.

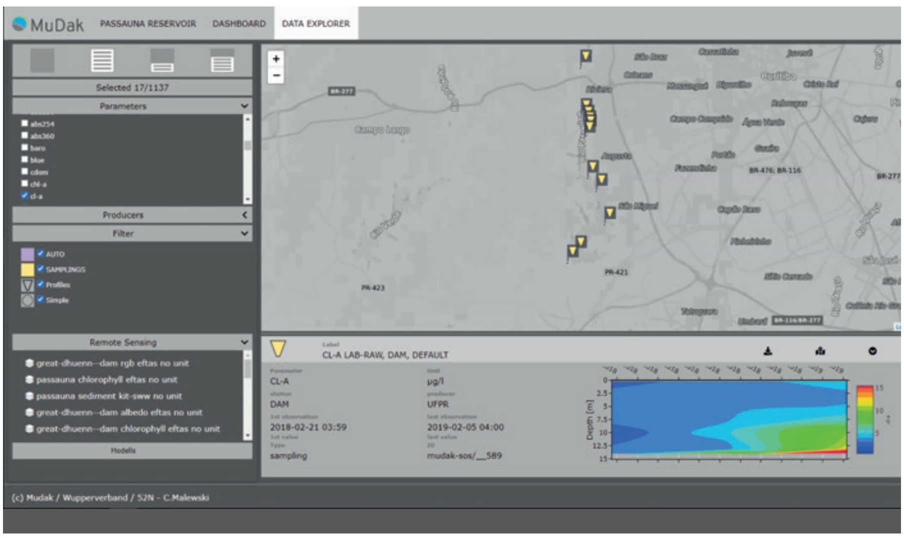


Figure 3: Visualization of sampling locations and water quality parameters in the web client (Source: MuDak-WRM).

OUTLOOK AND FUTURE APPLICATIONS

- For most reservoirs, the first full assessment of the actual state is the essential basis for all future management practices.
- Internal storage of nutrients may threaten good water quality under changing conditions; therefore, it plays a major role for lake management.
- Pre-dams seem to be a promising protection measure for lakes with deteriorating quality or increasing pressure from the catchment.
- Consistent storage of monitoring data and availability via online applications are essential for the assessment of the actual and future water status.

MedWater – Sustainable management of politically and economically relevant water resources in highly dynamic carbonate aquifers of the Mediterranean

Coordination

Prof. Dr. Irina Engelhardt, TU Berlin

German partners

- TU Berlin
- University of Göttingen
- University of Bayreuth
- University of Würzburg
- VisDat GmbH
- BAH Berlin

International Partners

- Bureau de Recherches Géologiques et Minières (FR)
- Montpellier Méditerranée Métropole (FR)
- Università degli Studi di Napoli Frederico II (IT)
- Centro Euro-Mediterraneo sui Cambiamenti Climatici (IT)
- Israel Hydrological Service (IL)
- Mekorot Water Company Ltd. (IL)
- Ben-Gurion University of the Negev (IL)
- Hebrew University of Jerusalem (IL)
- Ariel University / Eastern R&D Center (IL)
- Palestinian Water Authority (PS)

FURTHER INFORMATION

Project website: http://www.grow-medwater.de

PROJECT GOALS

Circa 10% of the world's population relies on groundwater resources from karst aquifers. Due to their complex geological structure, prediction of groundwater flow is extremely difficult, which complicates their management. The Intergovernmental Panel on Climate Change estimates that precipitation in the Mediterranean region, where karst aquifers are particularly common, will decrease by up to 27% until 2100. In addition, the Mediterranean will experience a population growth of 100 million until 2030. To adapt to these challenges, MedWater develops new tools and strategies for better management of groundwater resources from karst aquifers. The project focusses on the Western Mountain Aquifer (WMA) in Israel and the Palestinian Territories. As a key result, a web-based decision support system is developed in close cooperation with decision-makers. Results are transferred to aquifers with similar climates and flow characteristics in Italy and France.

KEY RESULTS

MedWater investigated various methods of calculating the spatial and temporal distribution of groundwater recharge. With the Soil & Water Assessment Tool (SWAT), we determined a **long-term**

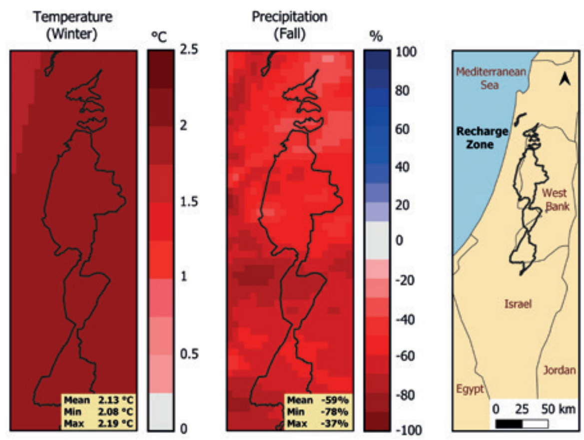


Figure 1: A high-resolution climate model until 2070 predicts warmer winters, increasing fall and winter evaporation. Combined with less precipitation, this phenomenon will significantly decrease groundwater recharge of the WMA (Source: MedWater).

average recharge for the WMA of 145 mm/a (1990-2018) (Figure 2a). The recharge zone plays an important role for ecosystem services and provides 20% of river flow regulation, 70% of flood regulation, 80% of soil erosion regulation, and 75% of water quality regulation. Shifts in climate will affect both groundwater resources and ecosystem services. High-resolution climate projections show a seasonal increase of temperature by 2.13°C until 2070, while precipitation will decrease by up to 59% in the fall (Figure 1). Due to shifts in climate, mean annual groundwater **recharge will decrease by 18%** (1980-2000 vs. 2050-2070).

Identification of the karst conduit network was enabled using the Stochastic Karst Simulator (Borghi et al., 2012) (Figure 2b), which computes karst structures based on paleoclimatic reconstructions of the Mediterranean Sea level and climate over the last 6 million years. Simulations show that **the geometry of a karst network is highly controlled by the position of past karst springs**. This "soft" information on karst development allows for the generation of a sound hydraulic parameter field.

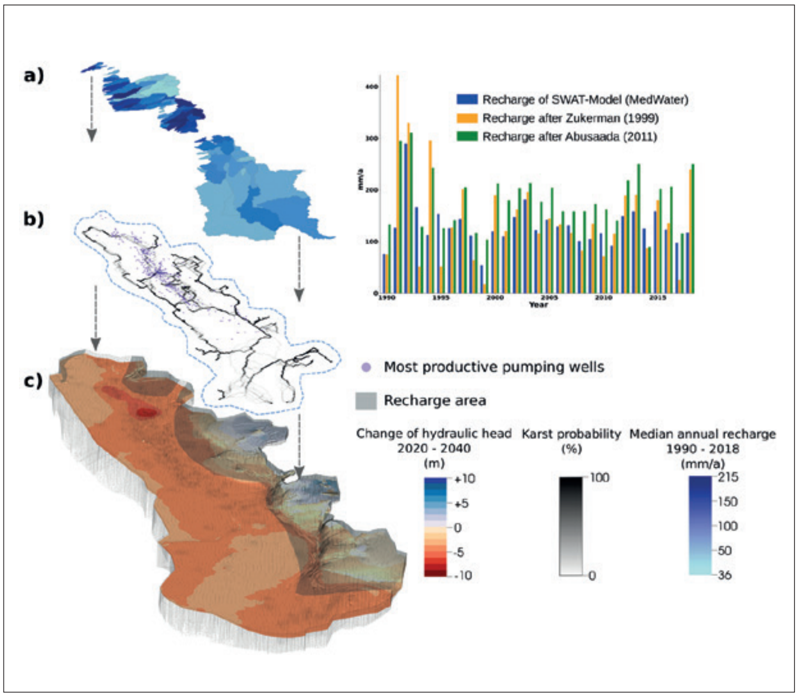


Figure 2a, b, c: Spatial and temporal recharge distribution, probability of the location of highly permeable conduits and simulated drawdown (2020 – 2040) of the groundwater table (Source: MedWater).

With a multi-continuum model (HydroGeoSphere), we simulated the vadose zone dynamics together with the groundwater flow system (Figure 2c). Scenario analyses explored the impact of pumping rate adaption and indicate a **rapid 2 m groundwater level decline over the next 5 years followed by a further drop of 3 m by 2040** in a resource-intensive scenario.

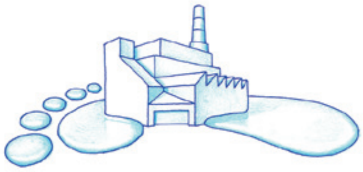
Agricultural food production is by far the highest water user in Israel. **1,806 MCM of virtual blue water (BW) was used for Israel's food production in 2005**. Of those, 11% comprised BW for exports. For local BW consumption, wheat, apples, olives, and peaches are the highest water users, while potatoes, dates, grapes, and olives are most water-intensive with respect to exports.

The **Decision Support System** (DSS) includes results of the groundwater model, recharge estimates, climate projections, and scenario analyses. Employing analytical functions, the DSS simulates the aquifer response to changes of parameter sets or pumping rates. A **multi-objective optimization (MOO) framework** allows water users to test groundwater management strategies: Groundwater extraction and water injection wells are optimized with respect to demands (e.g. agricultural, municipal) and water sources (e.g. desalination, treated wastewater).

On the global scale, we created **generalized models** for different types of Mediterranean karst aquifers. A **Groundwater Stress Index** combines information about groundwater recharge, storage, and abstraction rates, as well as groundwater-dependent ecosystems, among other things. Simulating climate-driven changes in groundwater stress results in a **global vulnerability map of 356 karst aquifers**. We even found that 52 carbonate aquifers will have moved to more extreme arid climates (e.g., steppes or deserts) by 2100.

OUTLOOK AND FUTURE APPLICATIONS

MedWater models allow for quantification of available water resources at short, i.e. daily time scale, and for predictions used in long-term management concepts. By coupling numerical modelling with user-friendly tools, we provide a solid knowledge base for decision-making. An adapted management of karst aquifers makes use of their different storage system types, i.e. store flood water following intensive recharge events, which can be abstracted later during droughts. This requires differential pumping and injection schemes and a proper real-time operation of the storage system. Especially vadose zones of karst systems are an important storage compartment if they extend over hundreds of meters. Temporal and spatial variation of recharge was not fully quantified in MedWater and should be addressed more in detail in the future. Finally, management of karst aquifers in the circum-Mediterranean area is impeded by the presence of saltwater bodies. Future research efforts should be placed on the management of karst water resources surrounded by saline water, employing hydraulic control techniques or engineering barriers.



WELLE – The Water Footprint of Organizations: Local Measures in Global Supply Chains

Coordination

Prof. Dr. Matthias Finkbeiner, Chair of Sustainable Engineering, TU Berlin

German partners

- German Copper Alliance (Deutsches Kupferinstitut Berufsverband e.V.)
- Evonik Nutrition & Care GmbH
- Neoperl GmbH
- Thinkstep AG (now Sphera Solutions, Inc.)
- Volkswagen AG

FURTHER INFORMATION

Project website: https://welle.see.tu-berlin.de/

PROJECT GOALS

Most companies measure and manage water consumption at their premises only. However, most of a company's water consumption typically occurs along global supply chain stages, such as sourcing of raw materials or generation of electricity, but also during the use phase of products. The goal of WELLE was to develop a framework for companies (and organizations in general) to identify and analyze these hidden water consumption hotspots and to provide tools to help mitigating them.

KEY RESULTS

The Organizational Water Footprint (OWF) Practitioners' Guidance[1] provides a framework that is both comprehensive and easily applicable for assessing the entire water footprint of a company. It illustrates the OWF method developed in the project, which follows life cycle thinking and builds up on established environmental assessment frameworks, namely the Water Footprint (ISO 14046) and Organizational Life Cycle Assessment (ISO 14072). The practitioners' guidance aims to increase the accessibility of the OWF method for non-experts and thus to facilitate its application. While companies are aware of their direct water consumption at their premises, they usually lack information on their indirect water consumption associated to production of raw materials or generation of energy. Therefore, **a regionalised inventory database providing water consumption data and information on resulting local water-scarcity impacts** has been developed for a wide range of raw and intermediate materials, energy supply, transportation and the use and operation of buildings and offices.

Finally, the OWF method and database were integrated into a free OWF online tool[2]. The WELLE OWF Tool is a free online application which assists companies in calculating their Organizational Water Footprint. Users can enter the direct water use at premises as well as indirect upstream activities (e.g. amounts of purchased materials and energy), indirect downstream activities (e.g. volumes of water consumed in products' use phases), and supporting activities (e.g. business trips). By linking this information to the activity-specific water consumption data provided by the WELLE database, the organization's water consumption along

1 https://welle.see.tu-berlin.de/owfguide.pdf
2 https://wf-tools.see.tu-berlin.de/wf-tools/owf/

its value chain is determined. Further, the WELLE tool applies country-specific characterization factors to the country-specific water consumption data available in the WELLE database. This way, it allows for analyzing resulting local impacts.

Concurrent to the development of the OWF method, inventory database and online tool, four OWF case studies were conducted. The German Copper Alliance assessed the OWF of the European copper production, Evonik Nutrition & Care GmbH assessed the OWF of the chemical and biotechnological production of amino acids, Neoperl GmbH assessed the OWF of their entire company and Volkswagen AG assessed the OWF of its production site in Uitenhage, South Africa. The OWF case studies revealed that an organization's direct water consumption at its premises or production site(s) usually contributes to less than 5% of its total OWF. Often, this figure is even lower when considering the potential water-scarcity impact of the accounted water consumption. Next to providing valuable practical insights into the dynamics of the involved organization's water footprint, the case studies also steered the development of the OWF method, database and online tool and ensured their applicability in a broad context.

The case studies revealed that strategies to optimize the OWF need to consider an organization's entire value chain as more than 95% of its water footprint are usually hidden in supply chains. Next to on-site focused environmental management systems (EMAS, ISO 2015), a cooperation with suppliers and stakeholders at the river basin level (water stewardship), a consideration of a product's water footprint in the development phase (ecodesign), as well as sustainable procurement strategies (purchase of water efficient materials, certification of suppliers, etc.) are of high relevance. While the leverage of reducing an organization's water footprint is usually larger in supply chains, the organization's control on water consumption patterns is decreasing along supply chain levels. Ideally, an organization's water scarcity mitigation strategy comprises the concurrent implementation of several measures tackling all water use hotspots, regardless of the life cycle stage at which they occur. When trying to reduce an OWF, care should be taken to avoid shifting water-related environmental impacts to other environmental burdens (e.g. from the water to the carbon footprint).

OUTLOOK AND FUTURE APPLICATIONS

As many companies urge to better understand and manage their global water footprint, the WELLE project developed an organizational water footprint method. A practitioners' guidance supports companies in understanding and applying the method. A regionalised inventory database for assessing the potential water consumption impacts of raw and intermediary materials, as well as energy and services, facilitates application of the OWF method. Both the OWF method and the regionalised water inventory data were integrated into a free online OWF tool, which has proved its applicability in diverse case studies with several companies. Finally, WELLE provided recommendations to improve a company's water footprint and to mitigate water related hotspots along global supply chains, comprising water stewardship measures, a sustainable procurement strategy, and ecodesign activities.

In the future, the regionalised water inventory database should continuously be improved and extended. In addition to the currently available water consumption data, water pollution aspects should be included to allow for analysing a comprehensive water footprint profile. Moreover, implementing policies to increase transparency of supply chains would enable companies to conduct a more accurate OWF assessment. Likewise, this would incentivise suppliers of water-intensive raw materials and intermediary goods to implement best-practice water management measures. Finally, companies, policy makers and the public need to understand that it is usually environmentally more advantageous and economically more efficient to save water at hotspots in supply chains, rather than at water abundant premises.

Figure 1: Regional water consumption (blue bars) and resulting local impacts (red bars) caused by a company at its production site (Germany) and along its global material supply chains determined by the free OWF online tool (© WELLE OWF tool, TU Berlin).

InoCottonGROW – Innovative impulses reducing the water footprint of the global cotton-textile industry towards the UN Sustainable Development Goals

Coordination

Dr. sc. Frank-Andreas Weber, Research Institute for Water and Waste Management at RWTH Aachen (FiW) e.V.

German partners

- TU Berlin
- Hochschule Niederrhein, University of Applied Sciences, Krefeld
- IWW Rheinisch-Westfälisches Institut für Wasserforschung gGmbH, Mülheim an der Ruhr
- Julius-Maximilians-Universität Würzburg
- Rheinische Friedrich-Wilhelms-Universität Bonn
- RWTH Aachen University
- Hochschule Ruhr West, Mülheim an der Ruhr
- Thies GmbH & Co. KG, Coesfeld
- A3 Water Solutions GmbH, Saerbeck
- LAR Process Analysers AG, Berlin
- SEBA Hydrometrie GmbH & Co. KG, Kaufbeuren
- Lippeverband, Essen
- CHT Germany GmbH, Tübingen (associated partner)
- Universität Stuttgart (subcontractor)

International Partners

- University of Agriculture (UAF), Faisalabad
- National Textile University (NTU), Faisalabad
- National University of Sciences and Technology (NUST), Islamabad
- Punjab Irrigation and Power, Punjab Irrigation & Drainage Authority (PIDA), Lahore
- Pakistan Council Of Research in Water Resources (PCRWR), Islamabad
- WWF Pakistan, Lahore
- Kohinoor Mills Limited, Kasur
- Style Textile, Lahore
- Sapphire Fibres Limited, Lahore
- Pakistan Textile Exporters Association (PTEA)
- All Pakistan Textile Mills Association (APTMA)
- The Urban Unit, Urban Sector Planning & Management Services Unit (Pvt.) Ltd.
- Environment Protection Department, Government of the Punjab
- Cleaner Production Institute (CPI), Lahore
- GIZ Pakistan
- İstanbul Üniversitesi Merkez Kampüsü, Turkey
- Water Use Association Söke, Turkey

PROJECT GOALS

InoCottonGROW aims at contributing to **sustainable water use along the cotton-textile value chain** from cotton fields to textile industry and wastewater treatment. In case studies in Pakistan and Turkey, both major suppliers of German textile demand, our goal was to advance the water footprint (WF) concept to become a meaningful regional steering instrument in managing scarce water resources. By producing a 14-minute documentary video, an internet-based WF tool, organizing roadmap workshops, and assessing the integration of the WF concept into textile labels, the aim was to improve national water-policy decision-making and raise the awareness of internationally operating brands, retailers, and German consumers for sustainable textile consumption.

Case studies were conducted in the Lower Chenab Canal irrigation system (LCC, 15,700 km^2, irrigation water entitlement approx. 8 billion m^3/year, 12 million inhabitants) in the Indus Basin in Punjab, Pakistan, and at the Water Use Association Söke in the Büyük Menderes Basin, Turkey.

Figure 1: Cotton irrigation is water-intensive. © FiW e.V., Aachen.

FURTHER INFORMATION

Project website: www.inocottongrow.net

KEY RESULTS

We applied **complementary methods**, including (M1) satellite remote sensing, (M2) field experiments and crop-irrigation modelling, (M3) hydrologic and (M4) hydraulic modelling, (M5) survey on the institutional framework of water use in cotton farming, as well as (M6) textile company audits, and (M7) laboratory and full-scale dyeing trails in textile finishing.

Five demonstrations investigated strategies for WF reduction: (D1) flexible irrigation strategies to increase water productivity, (D2) water-saving textile machinery, (D3) resource-efficient dyestuffs, (D4) textile wastewater treatment by anaerobic treatment of highly polluted wastewater of desizing, (D5) pollutant analysis and regulatory enforcement of wastewater effluent standards.

Cotton Irrigation: Allocation of irrigation water among farmers in Pakistan is organized by certain formal and informal rules known as the Warabandi system, in which water is allocated proportionally to each farm size in strict rotation. Our models confirmed that LCC is undersupplied: water demand exceeds supply. Field demonstrations concluded that, besides irrigation technology, scheduling and farmer training are key to minimize unproductive losses. However, canal lining is not the ultimate solution, since groundwater serves as intra- and inter-annual storage for irrigation wells. More flexibility is needed within Warabandi to cope with climate change; starting bottom-up at farm-level. Comparing cotton yields achieved in Turkey with those in LCC, we observed two to five times higher yields at the same actual evapotranspiration. Low cotton yield in LCC is only partly due to water stress. Scattered, lower-income farmers find it hard to afford quality inputs like good-quality seeds. Despite water stress, we find heat stress is likely to dominate due to climate change.

Textile industry: We demonstrated that a water-use reduction of up to almost 20% is feasible in reactive black shade dyeing by installing water efficient textile machinery. Introducing advanced dyestuff can further reduce water use up to 40% under certain conditions, but Pakistani companies are rarely in a position to pay higher prices, despite water and energy savings. We find process-integrated measures often go along with energy savings, but little WF reduction.

Figure 2: Water use in textile finishing (© FiW e.V., Aachen).

Wastewater treatment: Functioning effluent treatment plants are key for reducing the grey WF, but only a few textile mills in Pakistan can afford operating aerobic activated sludge treatment due to energy cost, poor maintenance, and lack of regulative enforcement. We demonstrated that low-hanging fruits do exist by operating a pilot-scale anaerobic moving bed bioreactor for energy-efficient pre-treatment of textile desizing wastewater for biogas production. Despite the positive amortization of investments, we were not yet able to initiate full-scale application of this technology in Pakistan.

Water Footprint: Region-specific water scarcity footprints (WSF) were calculated for 17 irrigation subdivisions in LCC. The average WSF amounts to 2,333 m³ deprived per ton cotton. These results are on average about 40 % higher than the WSF calculated by means of country-level scarcity factors. A free accessible web-based water footprint tool (http://wf-tools.see.tu-berlin.de/wf-tools/inoCotton/#/) is online for users to calculate their specific WF reduction potential, such as implementing improved irrigation technology or wastewater treatment.

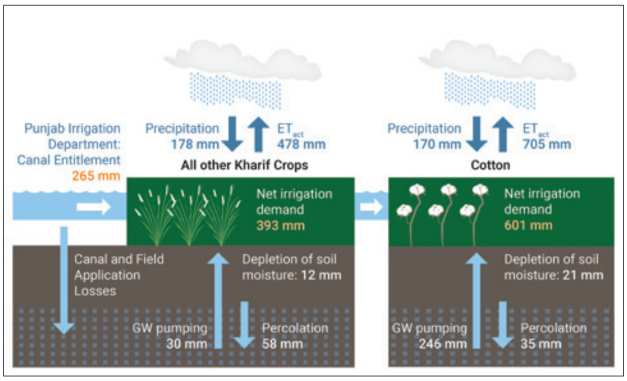


Figure 3: Water availability, demand, and consumption in Kharif season May to September based on plant demand model (Mean 2004-2013) (© FiW e.V., Aachen).

OUTLOOK AND FUTURE APPLICATIONS

InoCottonGROW identified several feasible measures to increase the efficiency and productivity of water consumption and to reduce water pollution along the cotton-textile value chain. By combining measures in **consistent policy scenarios**, we conclude that their implementation is not only crucial for achieving UN-SDG 6, but also provides **synergies for achieving other UN-SDG targets**.

The Water Footprint approach provides opportunities for **science-based water policy**, promoting coherent policy across different sectors (agriculture, textile, water, trade). Good water governance is key and groundwater governance must not be neglected. Our research indicates that the time to act is now: **Far more ambitious approaches are needed** to set the global framework for sustainable cotton-textile consumption.

WANDEL – Water Resources as important factor in the energy transition at local and global scale

Coordination

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Prof. Dr. Rüdiger Schaldach, Center for Environmental Systems Research, University of Kassel

German partners

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- Institute for Hydraulic Engineering and Water Resources Management, University of Kassel (WAWI)
- Osnabrück University (USF)
- Institute for Environment and Human Security, United Nations University, Bonn (UNU-EHS)
- Leibniz-Institut für Gewässerökologie und Binnenfischerei im Forschungsverbund Berlin e.V. (IGB)
- Wuppertal Institute for Climate, Environment and Energy gGmbH (WI)
- WAGU – Gesellschaft für Wasserwirtschaft, Gewässerökologie und Umweltplanung mbH
- KIMA Gesellschaft für elektronische Steuerungstechnik und Konstruktion mbH
- mundialis GmbH & Co. KG

International and associated partners

- German Federal Institute of Hydrology (BfG)
- Wasser- und Schifffahrtsamt Hann. Münden
- Regierungspräsidium Kassel
- Bayerische Elektrizitätswerke GmbH
- Bayerisches Staatsministerium für Umwelt und Verbraucherschutz
- Land Oberösterreich (Austria)
- Uniper Kraftwerke GmbH
- Brazil: Brazilian Agricultural Research Corporation (Embrapa), Instituto Agronômico de Campinas (IAC)
- Morocco: Drâa Association of Renewable Energies (Ouarzazate), University Ibn Hohr (Agadir), Ministère de l'Energie, des Mines, de l'Eau et de l'Environnement, Agence Nationale pour le Développement des Zones Oasiennes et de l'Arganier, Haut-Commissariat aux Eaux et Forêts et de la Lutte Contre la Désertification

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FURTHER INFORMATION

Project website: https://wandel.cesr.de/de/

PROJECT GOALS

Is water a limiting factor for energy transition? It is well known that different energy systems possess different water demands. These, in turn, directly influence water availability at power plant locations, or, indirectly, elsewhere in the world. Direct water consumption, such as for cooling of thermal power plants, or the manipulation of river flows for hydropower generation, influence local water and environmental systems at the location of the power plant. However, impacts on water resources in remote regions, due to e.g. coal or copper mining, are much less known. This global 'teleconnection' between energy production and potential water issues causes a conflict between the sustainable development goals "clean water and sanitation" (SDG 6) and "affordable and clean energy" (SDG 7). The WANDEL project investigated water consumption along the entire energy supply chains in an integrated and interdisciplinary way, in order to evaluate local and global trade-offs and synergies between these two SDGs in a changing environment. Our approach combined local and global analyses for the acquisition of data, formulation of a spatially explicit water footprint, development of energy and water demand scenarios and the assessment of impacts on global water resources. Moreover, the project developed technical and governance tools to guide decision makers and stakeholders and to make them aware of potential negative impacts of different energy systems on water resources.

KEY RESULTS

Analyses of the WANDEL project show that strategies for transition to clean energy should not only be evaluated according to their potential reduction of greenhouse gas emissions, but should also consider the consumption of water and hence direct and remote impacts on water resources. At global scale, energy scenarios with ambitious targets for a low-carbon energy system result in a lower intensity of water usage. However, compared to current conditions, the total amount of water withdrawn and consumed globally will only decrease if the transformation of the energy system is accompanied by an efficiency increase of power plant and cooling technology. Otherwise, water demand increases compared to scenarios with less ambitious decarbonization targets. Conducting a **water footprint** analysis along the entire energy supply chain, i.e. including local and distant water needs, allows for the comparison of water used per generated unit of energy across various energy systems. More specifically, four different power plants located in three countries, with different energy systems were evaluated. A coal power plant with water cooling on the river Weser and a run-of-river power plant on the Danube (both in Germany), and two international case studies: a concentrated solar power plant in Morocco (see Figure 1) and the use of sugarcane bagasse for electricity production in Brazil. The water footprint analyses showed that energy systems relying on renewable resources have less impact on water resources, but only if the system reuses waste material. Risk and sustainability analyses of all case studies showed a rising vulnerability of the energy supply with increasing frequencies of water scarcity and drought. Especially in arid regions, water is already a scarce resource and a limiting factor for economic growth and agricultural productivity. There, human and ecosystem health, sustainable energy generation, as well as water supply, are endangered in a changing environment. Biodiversity represents another factor that should be considered in the evaluation of strategies for transition to low-carbon energies. WANDEL showed that the global increase in the number of hydropower plants particularly influences river systems with high biodiversity values, i.e. systems rich in fresh-water-megafauna species (see Figure 2) are highly impacted by the fragmentation of river systems.

Figure 1: Mirror of the Noor power plant in Ouarzazate, Morocco (© H. Oppel).

To address the problems identified, the WANDEL project developed several tools for technical and governance guidance. A new approach, the **Environmental Sustainability Assessment (ESA)**, allows to evaluate the sustainability of anthropogenic processes and upstream supply chains against the background of potential global environmental impacts. ESA provides an interface between the established Environmental Impact Assessment and science-based sustainability indicators. Furthermore, a set of indicators for energy and water security were developed, which allow to assess the sustainability of actions, based on the vulnerability of water resources and energy systems. This approach also considers the institutional capacity in the target regions. A new **water management tool and a simulator** for the training of personnel have been developed. These tools ensure an optimal control of water management systems (barrages and reservoirs) and increase the efficiency and security of waterways. Finally, the WANDEL project pursued an open data approach. All data generated within the project is provided on the WANDEL-Share platform. The open data policy of the project provides a solid foundation for resilient decision-making in the context of the transition to low-carbon energy systems.

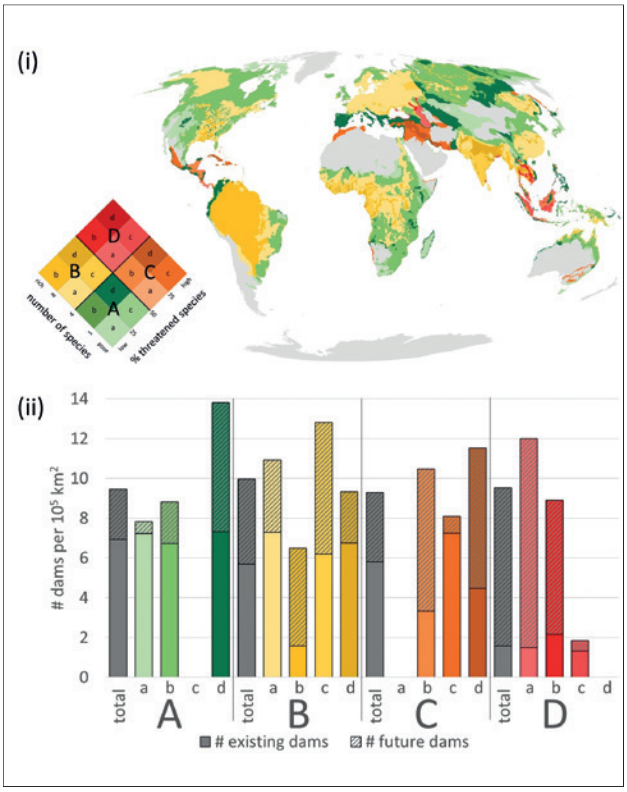

Figure 2: (i) Choropleth map of sub-catchments according to species richness and threat status on a global scale (species presence reference scenario). (ii) "Density" of dams per 105 km² in different sub-catchments according to richness-threat categories. (A): low richness (≤4 species), low share in threatened species (≤50%); (B): high richness (>4 species), low share in threatened species; (C): low richness, high share in threatened species (>50%); (D): high richness, high share in threatened species. Existing dams: bold colour; Future hydropower dams: striped colour. (Source: Zarfl et al. 2019).

OUTLOOK AND FUTURE APPLICATIONS

Spatially explicit analyses at local to regional levels (or catchment areas) are necessary in order to adequately assess the impact of energy systems on water resources in terms of water scarcity and water quality deterioration. This includes spatially explicit analyses of mining, for example iron-ore mining for steel production, used for the construction of power plants. Such activities are likely to put considerable pressure on regional water resources in terms of quantity and quality. Moreover, environmental impacts beyond the contribution to regional water scarcity and water quality deterioration should be identified in a systematic and comprehensive way along the entire supply chain of energy systems. They need to be assessed in the context of regional water-energy security. This will not only help to reduce direct impacts on water resources, but also to avoid problem-shifting through the use of technologies that cause other potentially negative environmental impacts at the expense of other world regions. Technical and governance tools developed in the WANDEL project support the fulfilment of these requirements and will promote the realization of SDG 6 and SDG 7 goals.

STEER – Increasing Good Governance for Achieving the Objectives of Integrated Water Resources Management

Coordination

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German partners

- Osnabrück University
- Ecologic Institute
- German Development Institute (DIE)
- University of Kassel
- Oldenburgisch-Ostfriesischer Wasserverband (OOWV)
- Emschergenossenschaft

International Partners

- Isfahan University of Technology (Iran)
- Confederacion Hidrográfica del Guadalquavir (Spain)
- River Basin Authority Khaara-Yeruu (Mongolia)
- University of KwaZulu Natal (South Africa)

FURTHER INFORMATION

Project website: www.steer.uni-osnabrueck.de

PROJECT GOALS

In many regions of the world, water resources are under increasing pressure because different human water uses are not sufficiently coordinated. The resulting decline in water quality or quantity harms the environment and leads to conflicts among competing water users from different sectors, e.g. drinking water supply, agriculture or nature conservation.

The STEER project dealt with the question how coordination and cooperation can be improved to solve problems related to the use of water resources by different actors. A main goal was to develop a diagnostic approach, which facilitates a better understanding of how various factors related to the water governance and management system, as well as environmental and societal context conditions, affect coordination in water management. Another main goal was to formulate context-sensitive recommendations for better water governance in order to solve water problems and to use water resources in a more coordinated and sustainable way. STEER organized transdisciplinary processes in five of its six in-depth case studies to identify regional coordination challenges, adapt the diagnostic approach, assess the suitability of various instruments for coordination, and develop policy recommendations. Furthermore, the project applied the diagnostic approach to an extended set of cases covering the six in-depth and 21 further cases in various world regions to explore conditions associated with successful coordination.

Target groups are practitioners who wish to improve coordination and cooperation among stakeholders in order to solve regional water problems, as well as scholars of water governance and Integrated Water Resources Management (IWRM).

KEY RESULTS

A diagnostic approach allows analysing complex water problems and developing solutions

Many water problems are persistent and hard to solve because of their complexity. This can, for example, include numerous actor groups with different interests, incompatible sectoral policies, fragmented water management responsibilities, power asymmetries among stakeholders, and low implementation capacity of water management bodies. The diagnostic approach of STEER facilitates detailed analyses taking into account the peculiarities of regional governance and management arrangements and of environmental and societal conditions. This allows identifying the deeper causes of resource problems and developing targeted solutions. STEER developed recommendations for six in-depth case studies: Emscher (Germany), Guadalquivir (Spain), Kharaa-Yeroo (Mongolia), uMngeni (South Africa), Weser-Ems (Germany), and Zayandeh-Rud (Iran).

Polycentric systems are particularly effective

Polycentric water governance and management systems are characterized by decentralized power and decision-making, combined with mechanisms for coordinating various (semi-)autonomous units of governance. Analyses of the extended set of cases with Qualitative Comparative Analysis (QCA) revealed that polycentric systems show significantly better performance in harmonizing different sectoral policies and strategies to solve water problems.

The STEER water governance tool supports regional solutions

STEER developed a water governance tool to support practitioners in water management. It builds on the diagnostic approach and is accessible online[1]. Users can describe their regional water governance and management systems by answering several questions. Based on user input, the tool makes a diagnosis of what aspects should be improved. The water governance tool also suggests coordination instruments that fit the diagnosis and can help addressing current weaknesses.

1 www.watergovernancetool.eu

Figure 1: Waterworks in the county of Oldenburg, Germany. The regional water supplier and farmers cooperate on a voluntary basis to reduce nitrate in groundwater (© OOWV).

OUTLOOK AND FUTURE APPLICATIONS

Analyses of the six in-depth case studies built on comprehensive data gained through stakeholder interviews and document analyses, complemented with quantitative data from international datasets. The assessments have provided clear evidence that persistent water problems require approaches that are able to deal with complexity. The underlying causes of coordination deficits can reside deeply in established structures of the governance and management system. A thorough analysis is necessary to reveal relevant factors that influence complex water problems. The diagnostic approach of STEER has proven its usefulness for making a rigorous diagnosis and consequently suggesting a tailored therapy that addresses the identified coordination deficits. However, in practice it may not always be possible to tackle all causes. For example, solving a regional water problem may require the harmonization of incompatible sectoral policies at national level, which is beyond the scope of the regional stakeholders and requires longer-term change. Nevertheless, as complex water problems do not have a single cause, it should be possible to address at least some coordination deficits if the stakeholders are willing to do so and to achieve a certain mitigation of the problem. The diagnostic approach supports the prioritization of measures based on their effectiveness to tackle the most prominent coordination deficits and on the likelihood that they can be implemented in a specific setting. The involvement of various stakeholders in a transdisciplinary process was beneficial in STEER in-depth case studies. It was the basis for tailoring research to the specific regional situation, and the consideration of diverse perspectives allowed approaching a water problem in many facets. Furthermore, the participatory process supported exchange and trust-building between different stakeholders, which is an important requirement for social learning and joint problem solving.

The STEER water governance tool facilitates a simple diagnosis in other regions and proposes instruments for improving coordination. In this way, the tool can support regional processes. However, users of the tool should critically reflect both the diagnosis and the instruments proposed for therapy. Ideally, the diagnosis should be embedded in a stakeholder process that includes broader discussions. Only in this way can the complexity of water problems be addressed adequately.

TRUST – Sustainable, fair and ecologically sound drinking water supply for prosperous water-scarce regions: Innovative planning tools for achieving the SDGs using the water catchment in the Lima/Peru region as an example

Coordination

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German partners

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- Karlsruhe Institute for Technology, Institute for Water and River Basin Management (KIT-IWG)
- Karlsruhe Institute for Technology, Institute of Photogrammetry and Remote Sensing (KIT-IPF)
- German Water Centre (TZW: DVGW-Technologiezentrum Wasser)
- decon international GmbH
- Disy Informationssysteme GmbH
- Ingenieurbüro Pabsch & Partner Ingenieurgesellschaft mbH
- OTT HydroMet GmbH

International Partners

- District Municipality of San Andres de Tupicocha (Peru)
- National Agrarian University La Molina (UNALM, Peru)
- National Engineering University (UNI, Peru)
- National Water Authority (ANA, Peru)
- Water Utility of Lima (SEDAPAL, Peru)

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FURTHER INFORMATION

Project website: www.trust-grow.de

PROJECT GOALS

In many prosperous regions of the world, fast growing urban centres, population and economies are exacerbating water shortage. This poses major challenges to water governance and reaching SDG 6. While competing water demand among different users is exerting pressure on limited water resources, state authorities and main stakeholders ask for sustainable solutions to tackle these challenges. Since water resources, water use and water management are closely interwoven, the TRUST interdisciplinary approach integrated expertise from researchers and practitioners from natural, engineering, and social sciences. Taking the Río Lurín catchment area in Peru as an example, TRUST developed innovative solutions for water resources monitoring, as well as planning tools for safe drinking water supply and sustainable wastewater management (see Figure 1). The project implemented capacity building measures in order to ensure dissemination and sustainability.

KEY RESULTS

Water resources modelling

In the Río Lurín catchment, local information about rainfall and discharge is sparse. For its preliminary analysis, hyperspectral imagery and data products, which relate point measurements and spatially distributed information, were analysed using machine learning techniques. Rainfall estimation in the upper part of the catchment, where most rainfall is occurring, was further refined by including new monitoring stations and developing a local interpolation scheme. Even with the improved rainfall input, hydrological modelling was only successful in matching observed discharge for individual years, and not over longer time spans, which possibly hints at still inadequate (discharge) data. Stream gauges installed by TRUST, however, allowed estimates of the infiltration of river water into the aquifer that is mainly used for water supply in the densely populated lower part of the catchment, and the water surplus draining to the Pacific Ocean.

Water use conflicts

A newly developed methodology, based on qualitative systems analysis, describes interactions between alternative policy measures and strategies to reach the different objectives of water users. It results in a policy-interaction model providing strategic decision-support for water regulators and stakeholders to develop conflict-free and sustainable water use concepts. For the Río Lurín catchment, it showed that there is competitive use of surface and/or groundwater by different users including households, agriculture and industry (water quantity conflicts). Furthermore, there is insufficient treatment and/or insecure disposal of domestic and industrial wastewaters threatening the quality of surface and groundwater sources (water quality conflicts). The analysis revealed that there are several alternative policy mixes for the Río Lurín catchment that are effective to jointly reach the objectives of the different users, while avoiding contradictions between policies and using synergies – and contributing to reaching SDG 6.

Water management concepts

TRUST developed integrated water management concepts for both small villages in rural areas and urban metropolitan areas considering the local (geographical, hydrological, political, economic, cultural and social) boundary conditions, as well as the preferences and concerns of relevant actors. As access to water is a potentially conflictual issue, this approach was intended to ensure participation of stakeholders and support of the local service provider (see Figure 2). Additionally, a training and demonstration facility was set up to train local operators on how to manage technical systems and to inform community members about the importance of safe water and wastewater treatment. A newly developed decision support system for drinking water quality management has been tested in two areas of the case study. This tool is based on the Water Safety Plan (WSP) concept, focusing on risk analysis in the catchment area.

Figure 2: Workshop with local authorities and water users in San Andrés de Tupicocha, Peru (© C. D. León).

OUTLOOK AND FUTURE APPLICATIONS

The use of remote sensing data and derived products using machine learning approaches to support the development of hydrological models remains challenging. The results can support the analysis in areas where data availability is limited, but cannot replace the setting up of (new) monitoring stations. Detailed field campaigns remain necessary for quantifying and modelling hydrological systems in a sufficient manner. Policy-interaction modelling to develop conflict-free and sustainable water policy mixes can support water regulators and stakeholders to develop new strategies for preventing conflicts with respect to water use. Local actors, who participated in a transfer workshop in the Río Lurín catchment, valued the integrative perspective of the policy mixes, which consider upper and lower part, as well as all water using sectors.

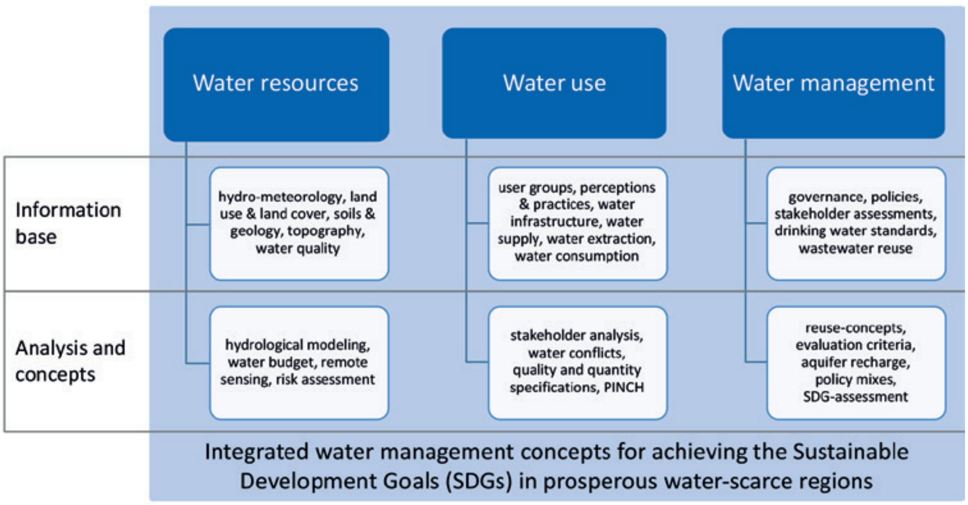

Figure 1: Overview of the TRUST approach along the three domains "water resources", "water use" and "water management" (Source: TRUST).

Policy-interaction modelling and its results are a useful starting point for integrated water planning processes, contributing to reduce goal conflicts, to meet the demand of all water users and to reach SDG 6. Training and capacity building of local water service providers, as well as awareness-raising of the local water users, were identified as key factors for successful implementation and long-term operation of drinking water and wastewater treatment plants. For this purpose, TRUST recommends to set up a pilot plant as a training module before implementing a large-scale plant. Through implementation of participatory formats during the planning process, it is possible to learn about local perceptions, priorities and practices, and to gain a socio-technical perspective regarding innovative drinking and wastewater management concepts.

iWaGSS – Integrated Water Governance Support System

Coordination

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- Institute of Water and River Basin Management (IWG), Karlsruhe Institute of Technology
- Center for Development Research (ZEF), University of Bonn
- LAR Process Analysers AG, Berlin
- Disy Informationssysteme GmbH, Karlsruhe
- Global Water Franchise Agency GmbH, Berlin
- Die Gewässer-Experten!, Lohmar

International Partners

South Africa

- Water Research Commission
- Kruger National Park, South African National Parks
- Ndlovu Node Phalaborwa, South African Environmental Observation Network
- Department for Water and Sanitation
- Council for Scientific and Industrial Research
- Centre for Environmental Economics and Policy in Africa, University of Pretoria
- Rivers of Life Aquatic Health Services, University of Mpumalanga
- Institute for Water Research, Rhodes University
- International Water Stewardship Programme, GIZ Pretoria
- Association for Water and Rural Development
- Lepelle Northern Water
- Palabora Mining Company
- Ba-Phalaborwa Municipality

Mozambique

- International Center for Water Economics and Governance in Africa, Eduardo Mondlane University, Maputo

Kenya

- Kericho Water Resources Authority
- Nayangores, Amala & Talek Water Resources User Associations

FURTHER INFORMATION

Project website: www.iwagss.com

PROJECT GOALS

South Africa has ambitious water-related development goals, which are in line with the Sustainable Development Goals or even surpass them. The country has established a highly ambitious and worldwide-acknowledged body of water legislation, but is struggling with implementation of national legal regulations to meet the challenges at the local level.

This implementation gap between macro level (legislation/institutional framework) and micro level (local water management institutions and decision makers) results inter alia in water crises, deterioration of resources, collapsing infrastructure and substandard water services (Figure 1).

Figure 1: Underperforming wastewater treatment plants in the Phalaborwa municipality (left: Lulekane WWTP © D. Musiol; right: Namakgale WWTP © J. Wenschuh).

Increasing water demand and impacts of climate change exacerbate these problems. The objective of the research project iWaGSS is the development and practical pilot implementation of an **innovative water governance system based on information and communication technology tools** (ICT). The chosen pilot area and research issues are representative for other basins in Southern Africa and other parts of the world. Results can be transferred to other water management areas.

KEY RESULTS

Lack of effective governance systems

Research in the Olifants catchment has shown that there is – broadly spoken – no lack of legal institutions or water resources, but a lack of effective governance systems and efficient management practices. Water scarcity is often rather an indication of insufficient water management and governance failure, rather than a root cause of water-related problems.

The **iWaGSS real-time water management system** (Figure 2) links different tools and methods (e.g. risk assessment, surface water modelling, real-time water quality monitoring) in a single data management and decision support system providing reliable and transparent information for both water managers and stakeholders.

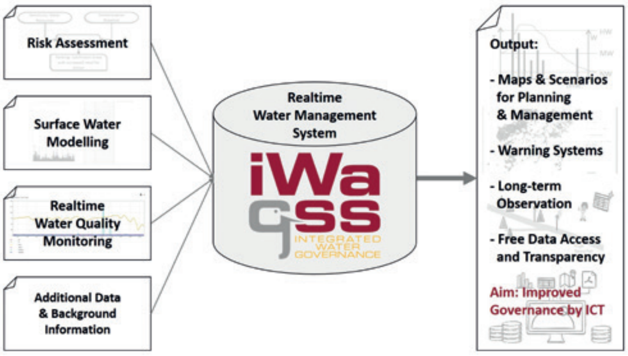

Figure 2: Components of the iWaGSS real-time water management system (Source: IEEM).

Involvement of stakeholders and informal actors

Absence or failure of formal institutions and organisations leads to **informal institutions**, e.g. user forums and (informal) feedback loops of self-organisation and self-regulation, taking over administrative and management functions to fill some of the gaps. Main actors are for example civil society organisations, conservation and research organisations, representatives of industry, agriculture and tourism, and NGOs. Although these informal institutions act without (or beyond) their legal mandate, have no or limited enforcement capacities and often lack resources and information, they are an integral part of the so-called 'management in the muddled middle' between the rules-in-form of governance and the rules-in-use on micro level.

Easily accessible and reliable data and information are key for efficient resources management.

The project's main output, besides management support and planning scenarios, is access to free and reliable data for all stakeholders and increased transparency that will help a) to improve the (informal) management of the water resources and b) to hold responsible public servants and managers to account. Especially where governance institutions are not established, respectively not working properly, **participation and transparency are key factors to improve resources management and water governance**.

Economic aspects of water management

To overcome the challenges of aging and collapsing infrastructure and substandard services, **incentive mechanisms in the context of governance** and economic aspects have to be taken into account. iWaGSS addresses the "Seven Sins against Local Water Management" to improve water and environmental services. Furthermore, the lack of public sector funds, especially in developing countries, is a huge challenge to achieve the SDGs. One main goal is to improve water utility management and to increase service coverage. **Sustainable financing mechanisms** include result-based elements that incentivise the delivery of defined outputs, integration of commercial funding sources (blended or hybrid finance) and professionalisation of services to improve local water management.

iWaGSS Highlights:

- Development of a GIS-based real-time water management system (Figure 3)
- Use of drones for river monitoring and surface water modelling
- Hydro-morphological modelling to improve reservoir operation for sustainable water supply
- Planning scenarios based on hydrodynamic models and contamination risk assessment
- O&M concepts for water infrastructure and services
- Integration of ecosystem services, economic aspects and transboundary interactions

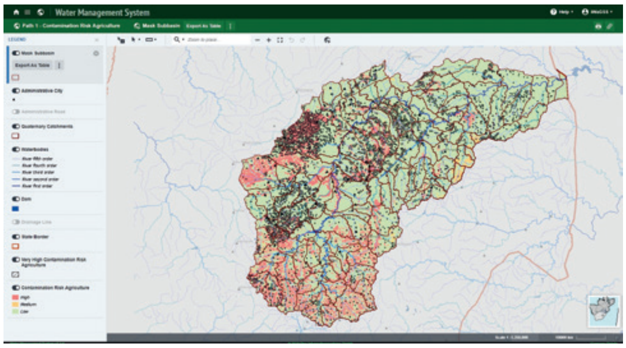

Figure 3: iWaGSS Water Management System (Source: Disy Informationssysteme).

OUTLOOK AND FUTURE APPLICATIONS

iWaGSS addresses both insufficient governance practices and mismanagement on local level that result in water crises, waste of resources and destruction of human livelihoods and natural ecosystems. The iWaGSS real-time water management system has been developed as a practical tool for decision-makers, water managers and stakeholders. Apart from necessary material and human resources, transparent provision of reliable data has been identified as a key requirement for sustainable water resources management. Supporting and empowering local stakeholders, non-state and informal actors is a promising way to improve the situation and achieve the SDGs. The absence or failure of government authorities and public administration still remains a serious challenge for the water sector.

Based on the South African case study and the transfer study in Kenya, the iWaGSS results are transferable to other regions with similar challenges. The pilot system developed for the Lower Olifants catchment will be used by SANParks, SAEON and local stakeholders in the Olifants catchment.

go-CAM – Implementing strategic development goals in coastal aquifer management

Coordination

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German partners

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- Oldenburgisch-Ostfriesischer Wasserverband (OOWV), Brake
- Leibniz Institute for Applied Geophysiscs (LIAG), Hannover
- Niedersächsischer Landesbetrieb für Wasserwirtschaft, Küsten- und Naturschutz (NLWKN), Aurich
- INSIGHT Geologische Softwaresysteme GmbH, Köln
- GISCON Geoinformatik GmbH, Dortmund

International Partners

- Buffalo City Metropolitan Municipality, Eastern Cape, South Africa
- Rhodes University, Grahamstown, South Africa
- Akdeniz University, Faculty of Engineering, Antalya, Turkey
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FURTHER INFORMATION

Project website: https://www.tu-braunschweig.de/lwi/hywag/forschung-projekte/gocam

PROJECT GOALS

The achievement of water supply security is one outstanding aim of the Sustainable Development Goals (SDGs) of the UN 2030 Agenda for Sustainable Development. Climate change, saltwater intrusion and human impacts, such as intensive agriculture, deeply affect freshwater supply, especially in coastal regions. It is threatened in many countries worldwide. Firstly, achieving the ambitious aim of SDG 6 requires a full understanding of the complex water resource system under consideration of resource sustainability and quality protection (scientific expertise). Secondly, a profound knowledge of important driving forces e.g. demographic change, climate change, governance structures or economic state of a region is essential to target current and future challenges. Finally, sustainable water resource management depends on the transparency and objectivity of decision-making processes and therefore on the dialogue among stakeholders in the water sector of coastal regions (societal needs). This link between science, practice and policy is still missing. Overcoming this gap is needed in order to address the continuing water quantity and quality problems in coastal zones. Therefore, the go-CAM project includes and addresses water agencies, water supply companies and local universities in four international case study regions. The main goal of the project is the development of an easy to handle, open and conferrable online dialogue platform (Coastal Aquifer Management, CAM) that enables a user-oriented evaluation of complex numerical modelling and research results against the background of regional characteristics (hydrosystem, water management, water governance), as well as different stakeholder demands.

KEY RESULTS

The synergetic interplay of modern subsurface reconstruction techniques, numerical hydro(geo)logical modeling tools, as well as complex monitoring systems, is key to understanding water resource systems and to identifying evaluation indicators in complex coastal and ecosystem settings.

Model improvements and innovative monitoring approaches

The models were adapted to the region-specific challenges and subjected to various methodological refinements. New methods of geological and parameter modelling were developed for the reconstruction of the subsurface, providing the necessary basis for the development of specialized hydrogeological models for the simulation of groundwater dynamics and saltwater intrusion. The results of geophysical investigations form the second important basis for density dependent groundwater modelling. The areal evaluation of HEM data (Helicopter Electro Magnetic) of the resistances serves to define the initial condition of salt/freshwater distribution. For the monitoring of the salt-freshwater boundary a novel monitoring system in the form of the SAMOS electrode array was installed. It records the dynamics of the salt-freshwater interface and can be used for the calibration of the groundwater model. The consideration of the complex drainage system in the coastal regions further required an adjustment of the river boundary condition in the groundwater model software package d^3f++. These adaptations and method developments have led to good model results and thus created the basis for the calculation of management and climate scenarios. Ensembles of climate change scenarios (Cordex-Data) in combination with management scenarios (water extraction from reservoirs) have been calculated using the modelling system PANTA RHEI to create a reliable bandwidth of possible future conditions. Additionally, four different methods for BIAS correction (linear scaling, power transformation, distribution mapping, LOCI) were tested. The results of the hydrological modelling serve on the one hand as input for the groundwater models and on the other hand, like the groundwater model results themselves, as indicators (see Table 1) for the evaluation on the basis of a Coastal Aquifer Management (CAM).

Table 1: Evaluation parameters and related indicators, "new groundwater resource status indicators" for SDG Targets 6.3, &.4 and 6.6, for the coastal aquifer management (CAM-Tool).

Evaluation parameter	Indicator
Chloride concentration [mg/l]	Chloride concentration in aquifers of the geest and marsh landscape, degree of salination: d^3f++ calculation
Groundwater recharge [mm/yr]	Trend of groundwater recharge differentiated in geest and marsh landscape: PANTA RHEI calculation
Groundwater head [m a.s.l.]	Trend of the groundwater table and head in the geest and marsh landscape: d^3f++ calculation
Freshwater volume [Mio m3]	Available fresh water volume, differentiated according to groundwater and dam systems: d^3f++ and PANTA RHEI calculation
Drought Index [-]	Changing numbers of dry days based on a drought index
Water budget [mm/yr]	Positive or negative amount balance in the model area and groundwater abstraction area: PANTA RHEI and d^3f++ calculation
Discharge [m^3/s]	Increasing or decreasing discharge at the sluices and pumping stations at the coast: PANTA RHEI calculation
Nitrate concentration [mg/l]	Trend of Nitrate concentration of groundwater

Indicators for the assessment of water management conditions

The CAM assessment is based on indicators that are subject to combined evaluation. These indicators are derived from the results of the above mentioned models. These results can be uploaded into the CAM using a direct interface, the CAMup software. The indicators used in CAM are water management variables and appraisal factors for the hydrosystems and their physical and socio-ecological settings. In the course of a participation process, eight indicators were identified and implemented in CAM. The weighting of the indicators, as well as the objective functions for the evaluation can be selected, adapted and discussed by different users, for instance from water supply companies and the agricultural sector.

Dialog platform Coastal Aquifer Management (CAM)

The CAM tool consists of four levels: The first level (CAMup) is used to load indicators in raster format and all relevant data into the platform. The second level is used for an interactive selection of water management options by choosing scenarios, target functions and weighting factors. The main challenge here was to integrate the interactive tools, which use multi criteria decision analysis techniques (MCDA), such as composite programming to evaluate data. One target function can be assigned to each selected indicator. The target functions in the platform are customizable and can be displayed, changed, and saved interactively in a diagram or by entering parameters. Besides, these target functions could be also regionally distributed. The third level provides an output (calculation result) after using the input indicators from level 1 and the selected options from level 2. The calculation results can be previewed and saved for later analysis. In the fourth level, the stored calculation results from level 3 can be displayed side by side by two users and thus be subjected to an interactive comparison and analysis. This supports the dialogue between different interest groups.

OUTLOOK AND FUTURE APPLICATIONS

The CAM-tool provides a bundled and easy to grasp representation of the current state of water management in different regions and allows the visualization and evaluation of future changes. These changes can be made visible with the help of CAM and will provide stakeholders with a basis for evaluation and discussion. It is possible to develop integrated adaptation strategies and to reassess the new model calculations in the CAM. Due to its open data structure, it can be supplemented by further indicators (also based on other SDG 6 targets) and maps and is transferable to other regions.

The CAM platform is online and open for access for different users, like water agencies, water supply companies and universities worldwide. This makes the CAM a valuable tool for transferring the scientific understanding of water resources into modern practice-orientated water management and governance structures.

German core partners engaged in GRoW