SUSTAINABLE, FAIR AND ECOLOGICALLY SOUND DRINKING WATER SUPPLY IN **PROSPEROUS WATER-SCARCE REGIONS**

INNOVATIVE SOLUTIONS AND PLANNING TOOLS FOR ACHIEVING THE SUSTAINABLE DEVELOPMENT GOALS, USING **THE WATER CATCHMENT IN THE LIMA / PERU REGION** AS AN EXAMPLE

Universität Stuttgart

KIT Karlsruher Institut für Technologie

TZW Technologiezentrum Wasser

decon international

disy

Ingenieurbüro Pabsch & Partner Ingenieurgesellschaft mbH

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Executive Summary of Project Results

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1 Introduction

Today, the rapid growth of urban centers, population and economies is exacerbating water shortage in many regions of the world. This poses major challenges for water governance and the achievement of **Sustainable Development Goals (SDGs)** number 6, related to access to drinking water and sanitation. While competing water demand among different users is exerting pressure to limited water resources, state authorities and key stakeholders are demanding sustainable solutions to tackle these challenges. Since, in the sustainable management of water resources, water use and resource management are closely interwoven, the interdisciplinary approach of the **TRUST Project** "Sustainable, Fair and Ecologically Sound Drinking Water Supply in Prosperous Water-scarce Regions" integrates the expertise of researchers and professionals from the natural and social sciences as well as engineering.

2 Project objectives

TRUST developed innovative solutions for water resources management, taking as an example the **Lurin River Catchment in Peru**, as well as the formulation of planning tools for drinking water supply and sustainable wastewater management (see figure 1). Additionally, awareness raising and capacity building activities were developed to ensure the dissemination of results and knowledge, as well as the future adoption and implementation of the methodologies developed within the project.

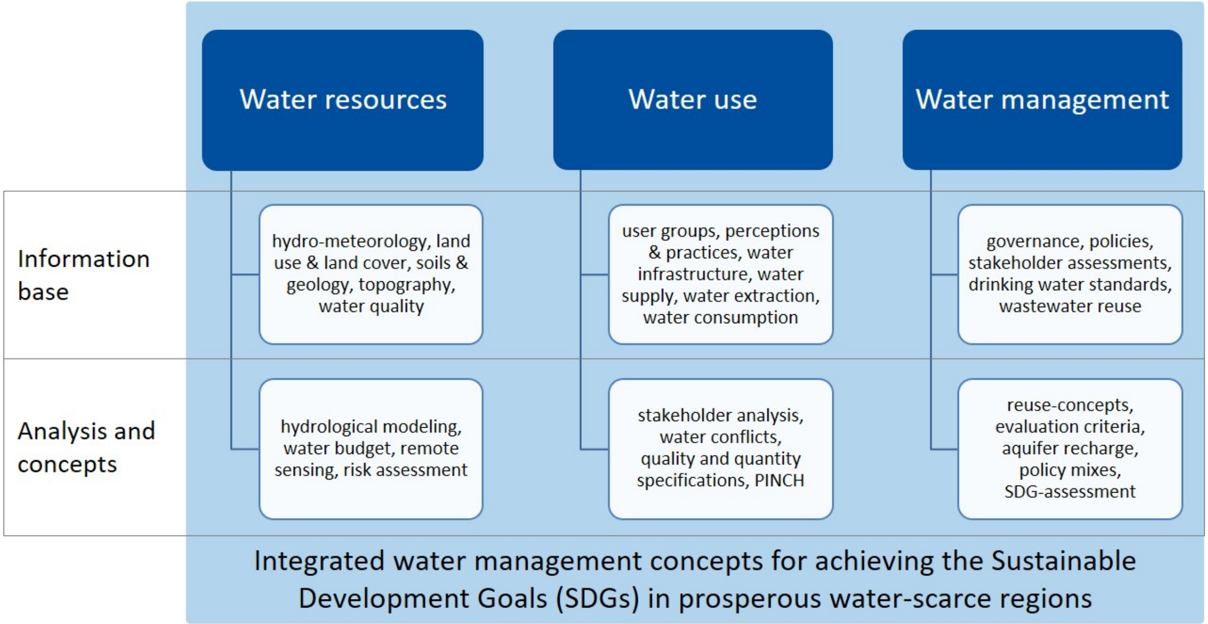

Figure 1: **Overview** of the TRUST approach along the three main domains "water resources", "water use" and "water management".

3 Main results of the project

3.1 Water resources

For the preliminary analysis of the Río Lurín catchment area, where local information about rainfall and discharge is sparse, hyperspectral imagery and data products, which relate point measurements and spatially distributed information were analysed using machine learning (ML) 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.

3.1.1 General catchment

3.1.1.1 Findings

a) The volume of water from the Lurín River that infiltrates the lower part of the catchment area into the aquifer is approximately 15 MMC/a.
b) The excess water from the Lurín River that is lost to the Pacific Ocean is approximately 55 MMC/a (between 48 and 64 MMC/a).
c) High risks for water resources in the catchment area due to the use of wastewater with low levels of treatment for irrigation of agricultural areas.
d) Low awareness among the population about the risks associated with water resources in the catchment area.

3.1.1.2 Recommendations

a) Implement measures in the upper part of the catchment area to retain and stabilize the water flow of the Lurín River so that it is not lost to the Pacific Ocean.
b) Increase awareness for the protection of water resources.
c) Propose a continuous water quality control program to avoid and mitigate fortuitous events related to the quality and availability of water in the catchment area.
d) Have good quality and reliable data - indispensable for informed decision making.

3.1.2 Upper catchment

3.1.2.1 Findings

a) Identified surface water quality problems regarding contamination with fecal bacteria during the dry season, while turbidity and microbiological contamination (including parasites) fluctuate during the rainy season.
b) Difficulties in the protection of reservoirs that are used both as a source of water for the population and for livestock.

3.1.2.2 Recommendations

a) Perform conventional analyses to evaluate the physical-chemical and microbiological quality of the local water.
b) Monitor continuously and transparently the quality of the water.
c) Communicate publicly the results of water quality analysis and its significance in relation to public health.
d) Develop systems for the treatment of drinking water and wastewater adapted to each municipality separately.

3.1.3 Lower catchment

3.1.3.1 Findings

a) Sustainable management of the aquifer must be ensured (quantitatively and qualitatively). The aquifer is heavily exploited, including for Lima's drinking water supply, and therefore must be protected to preserve the quality and quantity of the water.
b) The Lurín River (at the height of Cieneguilla) has a high percentage of wastewater (partly untreated). Consequently, microbiological contamination, but also, for example, nitrate and total organic carbon (TOC) are quite high.
c) Samples reflect good quality of groundwater, and good soil filtration capacity in the aquifer.
d) In some areas, a high concentration of nitrate (due to the infiltration of insufficiently treated wastewater) and calcium and sulphate ions (for geogenic reasons) was found.
e) Private wells are not sufficiently insured against possible flooding or other events that could lead to groundwater contamination.
f) Limited availability of data (both physical-chemical and microbiological).
g) Currently it is not possible to obtain reliable water quality data by remote sensing. The installation of sensors for telemetric data is unfavorable due to the possible loss of expensive equipment due to flooding or vandalism.

3.1.3.2 Recommendations

a) Conventional analyses are still necessary (both physical-chemical and microbiological in the laboratory) to assess water quality and associated risks.
b) For laboratory analyses, qualified sampling and analysis procedures are essential.
c) Analysis equipment that allows local actors to perform basic water analysis, can provide an additional mechanism for acquiring water quality data and should be more widely disseminated.
d) There is a need for technical and methodological capacity building.

3.2 Water use

A newly developed methodology, based on qualitative systems analysis, analyses the 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 ground water by different users as households, agriculture and industry (water quantity conflicts). Furthermore, there is insufficient treatment and/or insecure disposal of domestic and industrial wastewater 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, which are effective to jointly reach the objectives of the different users, while avoiding contradictions between policies and using synergies – and contributing to attain SDG 6.

3.2.1 General catchment

3.2.1.1 Findings

a) The diversity of actors in the Lurín River catchment area is complex and dynamic. Cooperation between current and new stakeholders, stakeholders from different sectors, as well as between upper and lower catchment area stakeholders, is a challenge.
b) The (latent) conflicts over water are boosted by a growing demand for industry and population growth.
c) There are important interactions between policies, measures and instruments implemented by different groups of users to achieve their respective objectives, what can generate conflicts.

3.2.1.2 Recommendations

a) The communication, the exchange and the cooperation of all the actors, especially between the actors of the upper and lower catchment area, could be reinforced by means of platforms of multi-stakeholder consultation.
b) There is a need to regularly bring together various water user groups throughout the catchment to develop and agree on joint understandings of issues and to develop and implement integrated water use strategies.

3.2.2 Upper catchment

3.2.2.1 Findings

a) The supply of drinking water based on self-management and carried out through community organizations faces the challenge of ensuring a sustainable supply with limited human and financial resources.
b) The functioning of communal water service providers such as JASS depends on personal capacities, technical support, as well as political priorities and social and cultural awareness.
c) There is a (potential) conflict of water use due to the joint use of the reservoirs for both population and agriculture (in addition to quality problems due to pollution).
d) The population's perception (in rural areas) of the risks associated with water differs in some cases from risk assessments based on scientific analysis. In these cases, the implementation of risk mitigation measures faces limited support by the population.

3.2.2.2 Recommendations

a) It is essential to find ways to improve water and sanitation services and to maintain these improved services through a combination of financial, technical, political and social support.

b) Develop appropriate financing instruments and operator models to achieve SDGs in the rural area, where tariff-based financing of water services is limited due to the higher poverty rate.
c) The communication, dialogue and participation can contribute to a better understanding of risks associated with water in the rural population and support the implementation of risk mitigation measures.

3.2.3 Lower catchment

3.2.3.1 Findings

a) The different types of water uses (domestic, agricultural, industrial) are managed and regulated by different actors with overlaps and uncertainties regarding the competencies and hierarchies of the regulatory bodies.
b) There are very diverse industries, of which only a small part is represented in the formal stakeholder dialogue platforms (ChiRiLu Water Resources Council, Multisectorial Technical Group of the Lurín River Catchment area)
c) NGOs and grassroots organizations are fairly well organized in the lower watershed and can be considered a resource in terms of civil society participation.
d) Households, agriculture and industry compete for the use of groundwater (*conflict of quantity*). In addition, water quality is threatened by insufficient and/or untreated wastewater (*quality conflict*).

3.2.3.2 Recommendations

a) A coherent, synergistic and sustainable water resources management plan includes in the lower catchment area safe wastewater treatment (and reuse, mainly for irrigation of agriculture and green areas, but also for industry).
b) Define the competences, responsibilities, obligations and tasks of the different regulatory bodies.
c) Implement decision-making instruments to avoid new conflicts. An improvement of wastewater treatment could lead to new conflicts, if users compete for the new resource for irrigation or for the recharge of the aquifer (through filtering galleries or managed artificial recharge) for the supply of drinking water.

3.3 Water management

TRUST developed for both small villages in the rural areas and urban metropolitan areas integrated water management concepts 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 potentially is a conflict-prone issue, this approach was intended to ensure participation of stakeholders and support of the local service provider. Additionally, a training and demonstration facility was set up to train the local operator on how to manage technical systems and to inform the community members about the importance of safe water and wastewater treatment. For the drinking water quality management, a newly developed decision support system 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.

3.3.1 General catchment

3.3.1.1 Findings

a) As for wastewater, there are still many settlements that do not have a sanitary system connected to a wastewater treatment plant.
b) The existing wastewater treatment plants do not necessarily operate properly.
c) The reuse of wastewater (mainly for irrigation) is already implemented (informally), but it is not safe from a hygienic point of view.
d) The planning and operation of drinking water and wastewater treatment plants pose a problem in rural areas.
e) In some cases, the necessary knowledge about the proper functioning of a wastewater treatment plant is insufficient.

3.3.1.2 Recommendations

a) For the operation and maintenance of wastewater treatment plants, issues such as energy supply, quantity-based dosing, periodically high turbidity/TSS and the presence of chlorine-resistant pathogens must be taken into account.
b) In general, safe access to drinking water should take priority over wastewater treatment in rural areas.
c) In the treatment of wastewater in rural areas, the influence of commercial activities (e.g., slaughterhouses) on the composition of wastewater should also be considered.
d) Local willingness and the possibility of adaptation to the local context is key to the application of water management concepts.
e) It is necessary to include stakeholders in the development of concepts, implementation and use of solutions (technical and organizational).
f) Wastewater is already being reused indirectly, so that the effluent from the treatment plant that was previously discharged into the Lurín River is being fully reused for irrigation purposes. Direct reuse is already taking place, although it is doubtful that the quality of the water fulfills the requirements for irrigation water.
g) Before implementing the reuse of wastewater, it is necessary to prove that the wastewater is treated safely.
h) Wastewater treatment plants must be based on a technology that allows constant treatment performance with low operating costs (e.g. using trickling filter technology).
i) Pilots and demonstration plants can play an important role in visualizing and comprehending the successful use and application of wastewater treatment technologies and contribute to their acceptance; ensure reliable commitment among the actors involved, as well as ensure conditions for successful cooperation and implementation of the concepts developed.

3.3.2 Upper catchment

3.3.2.1 Findings

a) Successful implementation of water chlorination in communities in rural areas is generally obstructed by lack of chemicals, maintenance, management concept (who pays, organizes and applies the chlorine), etc.

3.3.2.2 Recommendations

a) Adapted and simple technologies are required to treat drinking water, especially for communities in the upper catchment area (e.g. thick media or multi-stage filtration). Advanced treatment (e.g. membranes) will probably be too expensive and will also cause maintenance problems (management of public services, but also vandalism, etc.).

3.3.3 Lower catchment

a) Part of the population of the lower catchment area does not have access to drinking water and sanitation. The number of connections to the public drinking water and sewage network should be increased.
b) There is a great potential for the reuse of water, not as drinking water, but as service water for industrial processes or irrigation water in agriculture.
c) Treated river water and properly treated wastewater could be used for infiltration. With respect to the growing demand for water and the already excessive use of groundwater resources, such measures are particularly important.
d) There is much potential for reuse of wastewater from SEDAPAL and industrial plants, not as drinking water, but as water for industrial processes or irrigation water in agriculture.
e) Wastewater treatment plants should be based on a technology that allows constant treatment performance with low operating costs (e.g. using trickling filter technology).
f) Data for planning of wastewater treatment plants should be more detailed, e.g., emerging wastewater should be better controlled for nutrients such as nitrogen and phosphorus to be removed to exclude nutrient deficiencies in the biological stage. In addition, much more detailed monitoring of wastewater treatment plants at shorter intervals (daily) is required to allow stable operation as well as better process control.

3.4 Outlook and Future Applications

The use of remote sensing data and derived products using machine learning (ML) 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 (considering upper and lower part as well as all water using sectors). Concluding, 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 attain 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, it is recommended 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 allow gaining a socio-technical perspective regarding innovative drinking and wastewater management concepts.

FURTHER INFORMATION

Project TRUST Website: http://trust-grow.de/

Contacts of partner institutions of the project:

Institution	Contact	E-Mail address	Address
University of Stuttgart ZIRIUS Center for Interdisciplinary Risk and Innovation Studies	Christian D. León	christian.leon@zirius.uni-stuttgart.de	Seidenstr. 36 70174 Stuttgart
University of Stuttgart ISWA Institute for Sanitary Engineering, Water Quality and Solid Waste Management	Ralf Minke	ralf.minke@iswa.uni-stuttgart.de	Bandtäle 2 70569 Stuttgart
Karlsruhe Institute of Technology IWG Institute of Hydrology	Jan Wienhöfer	jan.wienhoefer@kit.edu	Otto-Amman-Platz 1 76131 Karlsruhe
Karlsruhe Institute of Technology IPF Institute of Photogrammetry and Remote Sensing	Sina Keller	sina.keller@kit.edu	Englerstr. 7 76131 Karlsruhe
TZW Water Technology Center	Sebastian Sturm	sebastian.sturm@tzw.de	Karlsruher Str. 84 76139 Karlsruhe
decon international GmbH	Heinrich Meindl	h.meindl@decon.de	Am Weidenring 58 61352 Bad Homburg
Disy Informationssysteme GmbH	Lucia Hahne	lucía.hahne@disy.net	Ludwig-Erhard-Allee 6 76131 Karlsruhe
Ingenieurbüro Pabsch & Partner GmbH	Holger Pabsch	h.pabsch@ipp-consult.de	Barienroder Str. 23 31139 Hildesheim
OTT Hydromet GmbH	Mario Keil	m.keil@ott.com	Ludwigstr. 16 87437 Kempten

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