***Good governance in the water sector***

# go-CAM: Implementing strategic development goals in coastal aquifer management

## PARTNER INFORMATION

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- **International Partners in case studies:**
  - Buffalo City Metropolitan Municipality, Eastern Cape, South Africa
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- **Countries of case studies:**
  - North-Eastern Brazil
  - North-Western Germany
  - Turkey (Antalya)
  - South Africa (Eastern Cape)

## 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. The main goal of the project is the development of an online dialogue platform (Coastal Aquifer Management, CAM) that enables a user-oriented evaluation of complex numerical modelling and research results.

## KEY RESULTS

**The synergetic interplay of numerical hydro(geo)logical modelling tools, modern subsurface reconstruction techniques, as well as complex monitoring systems is key to understanding the water resource systems and to identify 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, which records the dynamics of the salt-freshwater interface and can be used for the calibration of the groundwater model (Figure 1). 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 (see Figure 1) 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 Tab.1) for the evaluation on the basis of a Coastal Aquifer Management (CAM).

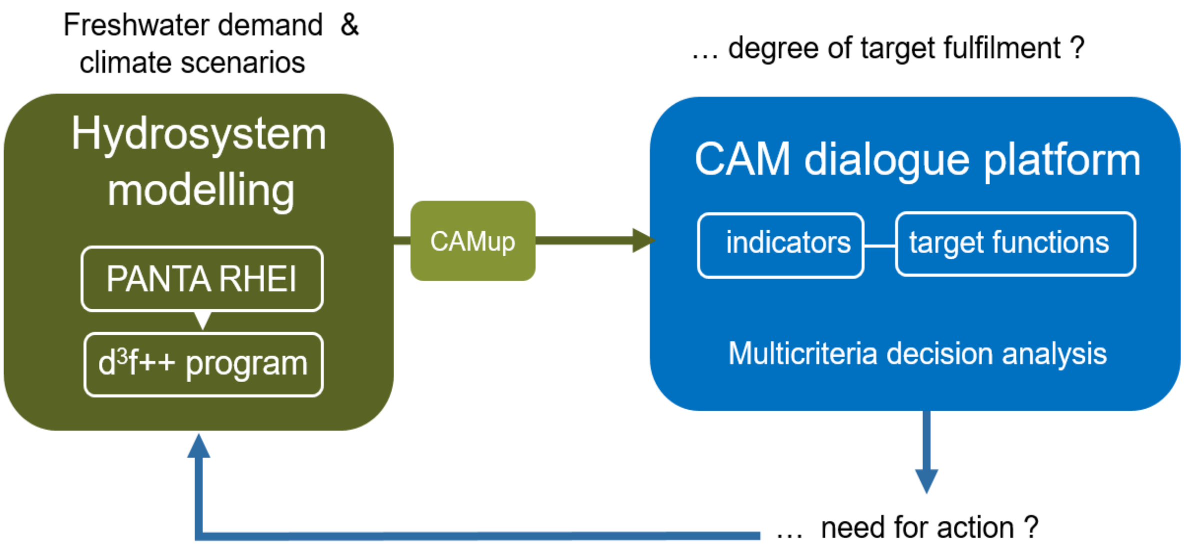


**Figure 1:** Our groundwater model **d$^3$f++** (distributed density driven flow) and **PANTA RHEI** (deterministic semi distributed hydrological model). In case the water indicators and the target functions continue to diverge, a need to improve can be generated by CAM measures.

**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 (Figure 1). 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.

**Table 1:** Evaluation parameters and related indicators of the CAM tool (so called new groundwater resource status indicators) as developed in the go-CAM project to address the SDG targets 6.2., 6.4. and 6.6.

| Evaluation parameter | Indicator |
|---|---|
| Chloride concentration [mg/l] | Chloride concentration in aquifers of the geest and marsh landscape, degree of salination: d$^3$f++ 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$^3$f++ calculation |

| | |
|---|---|
| Freshwater volume [Mio $m^3$] | Available fresh water volume, differentiated according to groundwater and dam systems: d³f++ and PANTA RHEI calculation |
| Drought Index [-] | Change a number 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 d³f++ 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 |

**Dialog platform Coastal Aquifer Management (CAM)**

The CAM tool consists of four levels (see Figure 2): 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.

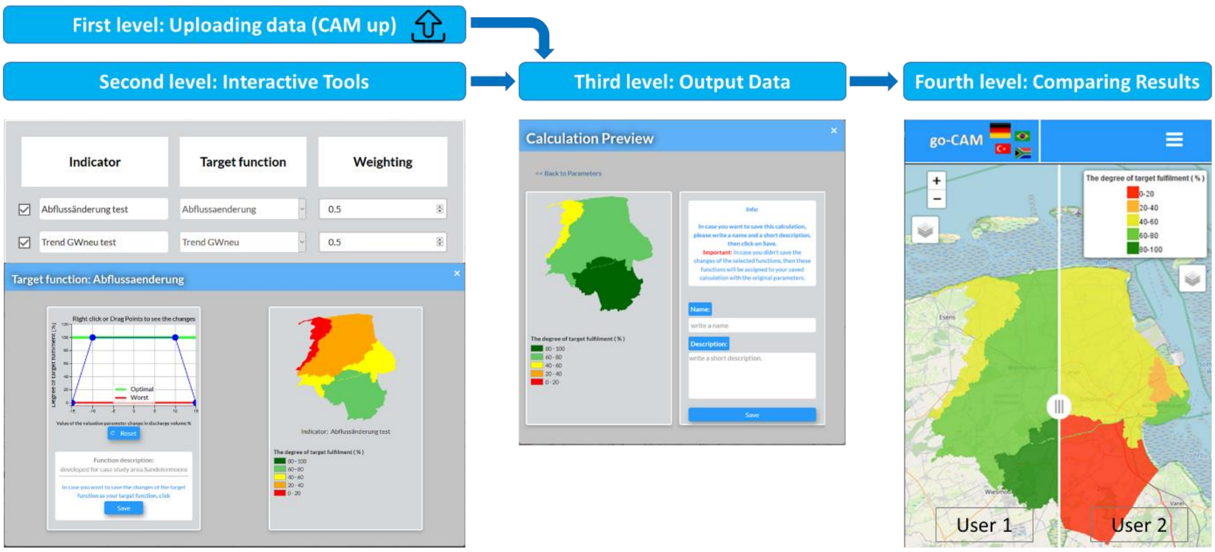


**Figure 2:** Four levels of go-CAM dialogue platform.

## OUTLOOK & 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 and maps (also based on other SDG 6 targets) 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.