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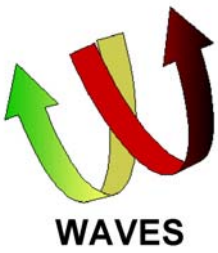
WATER AVAILABILITY, VULNERABILITY OF ECOSYSTEMS AND SOCIETY IN NORTH-EAST BRAZIL



Final Report

Working Area: Water Availability and Management
Working Group: Large-Scale Hydrological Modelling

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1. SUMMARY

The main objective of the project 'Large-Scale Hydrological Modelling' within Brazilian-German research programme WAVES (Water Availability and Vulnerability of Ecosystems and Society in the North-East of Brazil) was to develop a hydrological model for the quantification of water availability over a large geographic domain of a semi-arid environment in the Brazilian Federal States of Ceará and Piauí.

The hydrological model WASA (Model of *W*ater *A*vailability in *S*emi-*A*rid Environments) has been developed, which is a deterministic, spatially distributed model being composed of conceptual, process-based approaches that respect specific features of semi-arid hydrology. Water availability (river discharge, storage volumes in reservoirs, soil moisture) is determined with daily resolution. Scaling concepts have been developed and applied to link processes and data across scales. All model parameters of WASA can be derived from physiographic information of the study area. Thus, model calibration is primarily not required. Sub-basins, grid cells or administrative units can be chosen as spatial target units. One version of the model has been provided as a component of the semi-arid integrated model SIM of the WAVES project.

Model applications of WASA for historical time series generally resulted in a good model performance when comparing the simulation results of river discharge and reservoir storage volumes with observed data for river basins of various sizes in the study area. The mean water balance as well as the high interannual and intra-annual variability was in general reasonably represented by the model. Limitations of the modelling concept were most markedly seen for sub-basins with a runoff component from deep groundwater bodies of which the dynamics could not be satisfactorily represented without calibration.

Sensitivity analysis were performed that demonstrated that the simulation results of WASA are characterised by large uncertainties. These are, on the one hand, due to uncertainties of the model structure to adequately represent the relevant hydrological processes. On the other hand, they are due to uncertainties of input data and parameters particularly in view of the low data availability. Of major importance were uncertainties of rainfall data with regard to total volumes and spatial and temporal pattern of time series.

Simulations with WASA for climate scenarios until the year 2050 were run. The results show that a possible future change in precipitation volumes causes a larger percentage change in runoff volumes by a factor of two to three. In the case of a decreasing precipitation trend, the efficiency of new reservoirs for securing water availability tends to decrease in the study area because of the interaction of the large number of reservoirs in retaining the overall decreasing runoff volumes. However, the most important factor of uncertainty for scenarios of water availability in the study area is the uncertainty in the results of global climate models on which the regional climate scenarios are based. Both a marked increase or a decrease in precipitation and thus runoff can be assumed for the given data.

All results of this project were obtained in close co-operation with other German and Brazilian working groups within the WAVES project. The research resulted also in a number of reviewed publications, a PhD thesis and a Diplomarbeit.

2. FRAMEWORK AND OBJECTIVES

The joint Brazilian-German research programme WAVES (Water Availability and Vulnerability of Ecosystems and Society in the North-East of Brazil) (Gaiser et al., 2003; http://www.usf.uni-kassel.de/waves) focussed on the study of the dynamic relationships between climate variability, water availability, agriculture and quality of live in the rural semi-arid north-east of Brazil, taking into account changes in the driving forces of the system, such as climate change or population growth. The region has been struck by recurrent drought periods, which caused fatalities, economic losses and migration. One main objective within WAVES was to develop an integrated model (SIM – Semi-arid Integrated Model, see Krol et al., 2003) which works at the scale of the Brazilian Federal States of Piauí and Ceará, linking modules of water availability and water use, crop yield, agro-economy and demography. The model allows to analyse possible climate change impacts and run scenario simulations as a basis to set up integrated scenarios in order to support sustainable planning of regional development. In this context, a hydrological model for the quantification of water availability was essentially required as one component of the integrated model and as a stand-alone version.

Within this context, the general objective of this WAVES sub-project 'Large-Scale Hydrological Modelling' summarised in the present report was to ***develop a hydrological model for the quantification of water availability over a large geographic domain of a semi-arid environment***. Following the requirements within the framework of WAVES, the main tasks and goals as specified in the research proposal were as follows:

(1) Spatially distributed results on water availability are to be provided by the model for the Federal States of Piauí and Ceará in Brazil with a total area of about 400000 km^2. The spatial distribution primarily refers to sub-basins and administrative units (municipalities) (see also point 7 below).

(2) Water availability is to be assessed in terms of water volumes of river discharge, reservoir storage and soil moisture.

(3) The modelling concept should be applicable to the semi-arid environment of the study area in view of its specific hydro-climatological and physiographic conditions. The relevance of these features for the assessment of water availability is to be assessed.

(4) Temporal and spatial scaling approaches are to be developed to bridge the gap between the scale of interest of model application (e.g., sub-basins at a monthly resolution) and the scale of hydrological processes (e.g., hillslopes with an hourly temporal scale of individual rainfall events).

(5) The model performance of adequately simulating water availability has to be validated by comparison with observed data on, e.g., river discharge or reservoir storage volumes. Uncertainties in the results of model application are to be identified and assessed in the interpretation of the results.

(6) The model should be able to capture the influence of a changing environment on water availability. This primarily refers to the effects of a changing regional climate in the course of global climate change. Other changes include those of land cover and water infrastructure. Scenario simulations of future water availability are to be run with the model for given climate change scenarios or scenarios of reservoir construction.

(7) Beside of being a stand-alone hydrological model, one version of the hydrological model has to serve as a module of the integrated model SIM. Thus, adequate interfaces to adjacent modules are to be provided in terms of input/output variables and their spatial and temporal scale. For example, one important aspect is to provide results at the scale of administrative units (municipalities) which were defined as the common spatial unit of all components in SIM, another aspect is to quantify soil moisture as input of a crop production model for various soil units at smaller spatial scales within municipalities or sub-basins.

3. PROJECT STRUCTURE

3.1 Planning and Progress

The research program comprised the following working steps:

- Literature review on hydrological processes and their modelling in semi-arid environments
- Development of a conceptual model outline
- Collection of secondary data in Brazil and from International Institutions
- Programming of the model code
- Development of scaling techniques
- Preparation of data adequate for the model structure and purpose
- Model parameterization
- Delivery of an adapted model version as a component of the integrated model
- Integration of model components of water use from the integrated model
- Model application for historical time series
- Model validation at different spatial and temporal scales
- Analysis of model sensitivity and uncertainty
- Preparation of scenario data
- Scenario simulations of future water availability
- Discussion of results, presentation to policy makers

The above steps were performed iteratively during the project period. In particular, data collection and preparation took considerably more time than expected and was spread over the entire project period. Reasons were the limited access to data of Brazilian institutions, the lack of centralised data archives, large efforts in digitalizing analogue data collected in Brazil, and the necessarily parallel work of different working groups within the interdisciplinary project which resulted in a comparatively late availability of data and model components that depended on contributions from other working groups (see section on co-operation).

A first prototype version of the hydrological model that was also delivered as a component to the integrated model has been set up at the end of 1999. A distributed model version for