Deutscher Tropentag 1999 in Berlin
Session: Research and Management of Ecosystems and Natural Resources incl. Forests

WARIG - a modular water balance model in the focus area of Picos, Piauí - WAVES-program in Northeast Brazil -

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Abstract

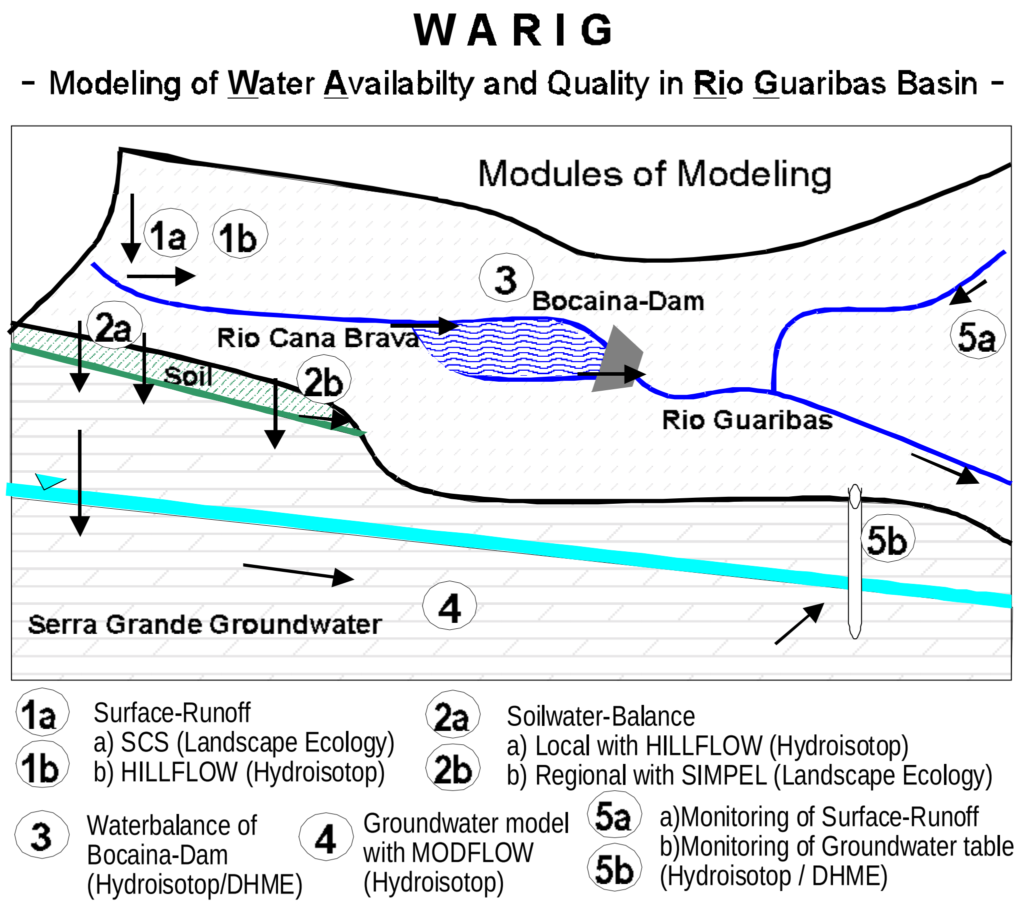
The city of Picos and the Rio Guaribas Basin in the State of Piauí/Brazil is one of the focus areas within the international WAVES-program. With the investigation in focus areas on meso- and microscale level the statewide, macroscale WAVES-models are evaluated and calibrated. The description and modeling of different water flows in the Rio Guaribas Basin is performed by combining different models or working tools for each water compartment, so-called different modules within the WARIG-concept (WARIG- Modeling of **W**ater **A**vailability and Quality in **Ri**o **G**uaribas Basin). In addition, the description of the actual water budget and the simulation of future water budgets support the regional development of the investigation area. Further on, results will be up-scaled and transferred to other areas with less data density.

Keywords: Northeast Brazil, Waterbalance, Watermanagement, Surface Runoff.

Introduction

The Brazil-German scientific program WAVES (Water Availability, Vulnerability of Ecosystems and Society in Northeastern Brazil) is aimed at helping to understand the interactions between water availability, ecosystems and human systems in the dry zone of Northeast Brazil. Within the program a description of water availability and water demands as well as the simulation of future developments is performed for the area of the two Brazilian states Ceará and Piauí and for focus areas. Investigations in focus areas on meso- and microscale level should proof and optimize the statewide, macroscale WAVES-models. The Rio Guaribas Basin with the city of Picos in the State of Piauí/Brazil is the main investigated focus area within WAVES. The description and modeling of different water flows in the Rio Guaribas Basin is performed by using different models or working tools for each water compartment, the so called different modules shown in Figure 1. The description of the actual water budget and the simulation of future water budgets aid the regional development of the area. Further on, results can be upscaled and transferred to other areas.

Figure 1: Structure and involved working groups of the water balance method WARIG



Within WARIG

- modeling of surface-runoff,
- modeling of the soil-water balance at single characteristic localities,
- modeling of the soil-water balance in regional scale,
- continuos measurements of the water volume in the Bocaina-dam,
- modeling of groundwater flow and
- continuos measurements of precipitation, surface water flux and groundwater level

are the main parts of the investigation. WARIG is developed by the WAVES Working Groups Watermanagement and Waterresources/Hydroisotop Schweitenkirchen-Germany, Landscape Ecology/Technical University TU Munich-Germany, Department of Hydrometerology DHME-SRH/Teresina-Brazil and Agro-Ecosystem-Soil Science/University of Hohenheim-Germany. All modules are stand-alone-modules which are connected via a GIS-based regional 100x100 m net. Here, basic data like digital morphology or land use are present, but also the data transfer and presentation format is located here. Calculated data like distribution of rainfall with regard to interception, soil types (CN-values), surface-runoff, groundwater-flow are generated by the different models with spatial input-data. The model results are proofed and calibrated by field measurements. However, what are the main reasons and targets of WARIG ?

- WARIG is the micro- and mesoscale validation of the macroscale statewide model HYMO within WAVES and support the mesoscale integrated model MOSDEL
- WARIG includes a groundwater model, which is important for the area

- The Guaribas-basin is an exemplary area for the future water management of the Piauí government and water authority (Soares Filho, 1997; DHME-SEAAB, 1997).

Methodology

The water flux in the investigation area is observed, described and simulated with different tools and by different working groups, see Figure 1. Different applied water budget models (rainfall-runoff model) were checked. Especially hydrological models yet applied in the drought polygon were of interest. Sarmento (1997) used MODHAC (Modelo Hidrológico Autocalibrável) (Lanna & Schwatzbach, 1988) to simulate the runoff in the Acaraú-catchment area in the north of Ceará. Billib (1997) used a stochastic model for the generation of synthetic streamflows in NE-Brazil. Applied European rainfall-runoff models were proofed also.
The results of the screening of hydrological models is: often expansive software requires detailed input-data in small areas and is often specialized on technical questions under humid conditions. Often only partly the water budget is described, the groundwater part is not taken into consideration. The selected method presented here of combining different standard models and monitoring tools is a scientific based planning tool. The results are as good as the input data and the calibration, which is often lacking consistent parameters. However, a 4800 km^2 area is well described and the method allows future simulation within clear defined scenarios. The obtained results support the decision, to work with a low sophisticated, flexible, easy to handle, good visible and cheap method.

Module 1a: Modeling surface-runoff with a flow-model of the US Soil Conservation Service (SCS) (USDA, 1972). Results are:
- the spatial and temporal analysis of the surface-runoff in comparison to the rainfall
- the spatial and temporal difference between the rainfall and the surface-runoff as an input in the soil water models.

Module 2a: Mesoscale spatial soilwater model for the whole area with SIMPEL (Hörmann, 1997). Calculating of the storage was changed following Glugla (1969). Results are:
- the spatial and temporal analysis of evaporation and transpiration
- the spatial and temporal analysis of interflow and groundwater recharge

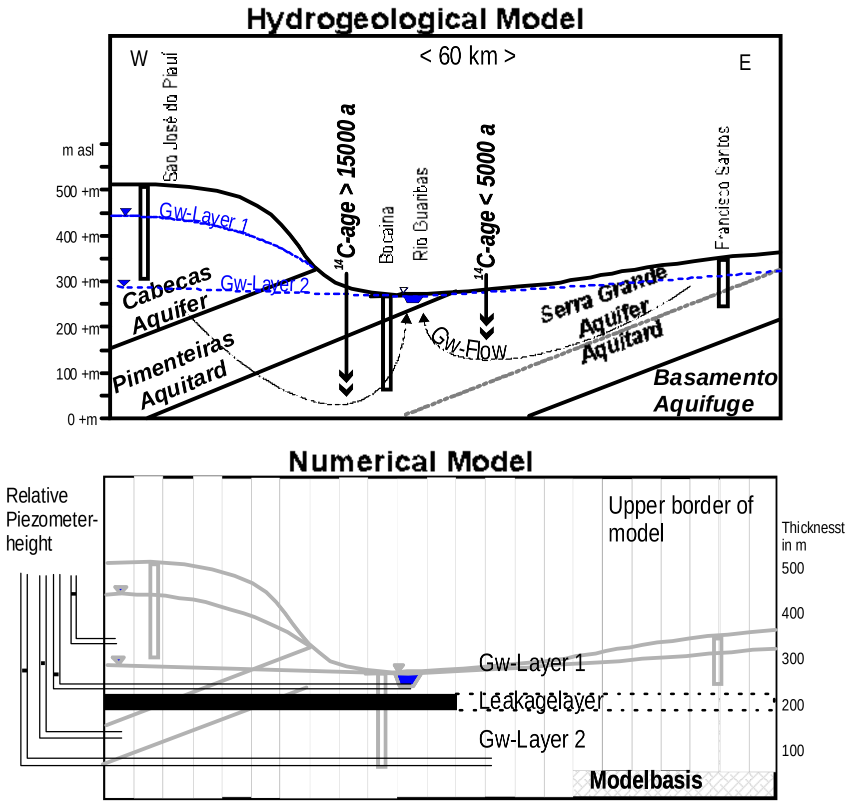
Module 1b + 2b: Microscale soilwater model (HILLFLOW) (Bronstert, 1994) at 8 locations, characteristic in morphology, geology and soil. Results are:
- temporal detail analysis of surface-runoff at specific locations (e.g. slopes or deep soils)
- temporal detail analysis of soil water budget at specific locations
- data for calibration of regional surface-runoff –model and soil model

Module 3: Continuos measurement of the watertabel of the Bocaina-dam as an indicator for the stored water volume. Results are:
- temporal calculation of the water volume and volume changes (quant. of evaporation)
- calibration of surface-runoff and interflow by calculating the change of volume

Module 4: Modeling groundwater balance with the USGS groundwater model MODFLOW (McDonald & Harbaugh, 1988) in the version Processing Modflow (Chiang & Kinzelbach, 1993) (see Figure2). Results are:
- analysis of groundwater availability, regarding the needed depth of exploration.

Module 5: Monitoring of the water flux in the rivers and the watertable in the groundwater by using measurements of precipitation, of flux and watertable at both, surface- and groundwater following the suggestions of DVWK (1991). Results are:
- basic data for modeling and model calibration

Figure 2: Hydrogeological model with ^{14}C-dated groundwaters and the translation into a numerical groundwater model with MODFLOW



Results

Precipitation
14 precipitation stations within the area were proofed on both, the West/East distribution of rainfall and the influenece of the areas height above sea-level. The results show no gradient from East to West. The average precipitation is about 804 mm to 654 mm during the last 20 years. The analysis of monthly rainfall doesn't show differences too. The measurement stations of Picos (195 m asl.) and Itainópolis (200 m asl.) and the stations São José do Piauí and Dom Expedido Lopes (400 m asl.) were compared to proof the influence of the height: no significant differences were recognized. In consequence of no W-E and height-gradient a spatial distribution of rainfall for the WARIG-area isn't possible. For the modeling we calculated only with the rainfall data of the precipitation station Bocaina in the center of the investigation area (Figure 1).

Surface-Runoff
The results of surface-runoff over a period of two years was calculated in a 100x100 m net. High values were shown for example in outcrop of the geological formation of Pimenteiras

and in areas of steep slopes. Low values were shown in the river valleys and at the plains of the Chapada. The water balance of precipitation and average surface-runoff show, that about 3 % (10-20 mm) of the yearly rainfall are calculated as surface-runoff.

Soilwater Balance

The soilwater balance was visualized as groundwater recharge over a period of one year in a 100x100 m net. High values were shown for example at steep valleys. The outcrop of Serra Grande Sandstone with sandy soils east of the Rio Guaribas Valley is characterized by high recharge, which is probably correct. Low values are shown in the river valleys or at the Chapada plain. The water balance of precipitation and groundwater recharge show, that less than 10 % (< 60 mm) of the yearly rainfall are calculated as groundwater recharge, which seems to be to high.

First simulations carried out with the surface-runoff model and the soilwater model with precipitation data from dry years demonstrate, that only the intensity of rainfall is responsible for surface-runoff and groundwater recharge. With 400 mm instead of 690 mm precipitation there is no change in surface runoff (10-20 mm) and groundwater recharge (40 mm). However, if the future regional climatic simulation will result in a change of rainfall intensities, even a small change can have a long-term impact.

Groundwater Model

The groundwater balance model within the WARIG-Project is a 2-layerd regional-scale groundwater model comprising the most important aquifer of the Guaribas-basin, the Serra Grande – aquifer, the covering mudstone layer of the Pimenteiras – aquitard and the covering sandstone aquifer Cabeças (Figure 2). The investigation is aiming at evaluating the groundwater balance to estimate the vulnerabilities of the resources and the possible long-term withdrawl for future water supply. As input data for the model, the groundwater recharge was calculated via the surface runoff model and the soilwater model, the flux for aquifer and aquitard was estimated from water balance calculations. Spatial distribution of hydraulic parameters has been based on hydrogeological aspects and on data from CPRM (1997). In absence of detailed watertable measurements the calibration of the model was performed by using isotope data, especially carbon-14. It is shown clearly, that groundwater with an age of more than 15.000 a is flowing from the west to the Rio Guaribas, crossing the Cabecas and the Pimenteiras. Groundwater, which is flowing from the east, the outcrop area of the Serra Grande, is only < 5.000 years old. That is a distinct demonstration for the flowsystem in the area.

Monitoring

One target of the continuos measurements of the watertable of the Bocaina-dam was the calibration of simulated surface-runoff by comparing the water flux volumes with the stored water volume in the dam. A comparison was carried out for the rainy period from November 1998 till May 1999. One mm precipitation corresponds with 1000 m^3/km^2. Heavy rainfall is documented at the end of November, in January and February. The comparison of precipitation and surface-runoff shows, that surface water flux starts only after heavy rainfall or after long rainy periods. A precipitation in the area of approx. 40 million m^3 results in surface-runoff from about 1 million m^3. The normal situation is a water loss in the dam of about 100.000 m^3/per day by evaporation and technical outflow (1800-3.600 m^3/h or 43000-86000 m^3/day). Rain events mostly correspond directly with an increase in water volume in the lake. The volume of surface-runoff and the volume change in the lake is in a similar order of magnitude and herewith, the model is calibrated. However, actually the problem exists, that the lake volume increases after moderate rains, but the surface-runoff model doesn't calculate water flux. It is believe, that the model has to take into consideration more intensively the direct surrounding of the lake.

Conclusion

WARIG observe and describe the water budget in an high resolution. This is important in an area with significant climatic variability and a high sensitivity of the water balance due to this climatic changes. So, it is different for groundwater recharge and surface-runoff if 40 mm precipitation is falling in one day or in two days. In the Guaribas basin (and in whole northeast Brazil), changes in the intensity of precipitation or changes in the temporal distribution of precipitation will results in a small, probably no measurable, change in groundwater recharge and surface-runoff.

Acknowledgments
The authors thank the German Ministry of Science and Education (BMBF) and the Brazil Conselho Nacional de Desenvolvimento Científica e Technológico (CNPq) for financial support of the program WAVES. The Departamento Nacional de Obras Contra as Secas - Teresina (DNOCS) and the Companhia de Pesquisa de Recursos Minerais – Teresina (CPRM) is thanked for access to their data. The observers in the field is thanked for assistance.

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