Assessing the Impact of Climate Change on the Water Balance in Semi-Arid West Africa: a SWAT Application

Elke Verbeeten[1], Anne Barendregt[2]

[1]Center for International Forestry Research
elke.verbeeten@scarlet.nl

[2]Freelance consultant in Water Management
anne_barendregt@hotmail.com

Abstract. This paper discusses the application of the Soil and Water Assessment Tool (SWAT) in the evaluation of the impacts of climate change on hydrological services provided by dry forests and savannah ecosystems in Burkina Faso, West Africa. Preliminary results demonstrate that erratic and intensive rainfall leads to higher peaks of discharge in the rainy season. This results in a decline of water availability and less groundwater recharge. Under such climatic conditions the sediment load also increases, affecting the water quality. Although general trends are clear, the quantitative impact of climate change yet has to be established. An evaluation of uncertainty and sensitivity of input parameters is now undertaken. Then the most sensitive and uncertain input datasets will be revised to improve the accuracy of predicted outputs. However, the first results are promising. SWAT seems to be an appropriate tool for evaluation of climate change impacts on the water balance.

1 INTRODUCTION

Water scarcity is a real threat for people's livelihood in semi-arid regions, in particular decreasing groundwater tables and surface water during dry seasons (Falkenmark and Rockstrom, 2004). The objective of this study is to increase understanding of how climate change influences hydrological services provided by dry forests and savannah ecosystems in semi-arid regions of West Africa. The results indicate how the water availability might be affected in the near future (Neitsch et al., 2002; Bellot et al., 2001; Wit and Stankiewicz, 2006).

The watershed used for evaluation of impacts on the water balance is the 1100 km^2 Korsimoro watershed, in semi-arid Burkina Faso. The annual precipitation rate is about 600 mm. Some 45 % of the area is under cultivation, whilst forests and (semi-)natural vegetation cover another 50 %. The natural vegetation in the area consists of types of savanna and steppe: grasslands with sparse trees and shrubs (IGN-FI, 2005).

Florian Probst and Carsten Keßler (Eds.): GI-Days 2007 - Young Researchers Forum.
IfGIprints 30. ISBN: 978-3-936616-48-4

This paper discusses preliminary water balance modelling results from the Korsimoro watershed and continues with an identification of factors influencing model performance and uncertainty. In the discussion major improvements of the datasets, and therefore of model output, are identified.

2 MATERIALS AND METHODS

For evaluation of the water balance the Soil and Water Assessment Tool (SWAT) has been applied. This is a physically-based, distributed parameter watershed-scale model developed to predict the impact of land use changes, expected climate changes and management practices on large, complex watersheds. SWAT divides the study watershed into sub-basins and identifies hydrologic response units (HRU) within each sub-basin, based upon elevation, land cover and soils. All model calculations are performed at the HRU level. The model indicates how runoff and infiltration changes affect the water balance quantity and quality at a watershed level (Nietsch et al., 2002). It uses daily to yearly time steps. For this simulation, daily time steps have been used, and only stream flow and sediment load have been evaluated. SWAT has a GUI for use within ArcView. Recently, also an ArcGIS version has been released. We used this ArcSWAT version 1.0.3.

The main inputs for SWAT are meteorological data, river discharge, elevation, land use and soil physical parameters. Other input data have been used with default values. After the first run with a “warm-up period” of three years sensitivity and uncertainty analyses will determine the most influential parameters. These parameters will then be revised. Subsequently, calibration and (automatic) validation will be executed, in which respectively hydrology and sediment load will be calibrated.

3 RESULTS

Preliminary results demonstrate that more erratic and intensive rainfall leads to higher peaks of discharge in the rainy season, resulting in a decline of water availability. Under such climatic conditions the sediment load also increases, affecting the water quality.

Although first results are promising, it is important to consider sensitivity and uncertainty in input parameters. By establishing uncertainty and sensitivity, efforts can be focused on reducing the uncertainty of those sensible parameter estimates and thus reducing the uncertainty of the model output (Shirmohammadi, 2006). This process is now being executed.

Global datasets do not comply for modelling at the high resolution we worked with. In Burkina Faso the detailed datasets are often not readily available. In general, datasets missed important metadata, such as geographic projection, accuracy, application scale or attribute information. This has hampered quality control and increased uncertainty in the input datasets.

Especially the soil dataset posed a problem, since input parameters requested by SWAT had to be derived for each FAO soil type. This increased the uncertainty of soil parameters considerably.

4 DISCUSSION

Awareness of sources of uncertainty and their effects on modeling results helps in evaluating model performance and identifying the most sensitive parameters. Shirmohammadi (2006) identifies four sources of uncertainty in model results. These are due to input variability, model algorithms, model calibration and validation data, and spatial and temporal scale. We focussed on input datasets.

Critical input parameters are precipitation, digital elevation model, land use data and soil characteristics. Errors in these values can have significant impact on the accuracy of model output (Shirmohammadi, 2006; Harmel et al., 2006). When concentrating on the most sensitive datasets, resources are used most efficiently. Therefore, with the present datasets improvement should be focused on:

- soil data, to ameliorate the behaviour of different HRU's;
- the default Land Cover/Plant Growth database, since incorporating local species improves important parameter values such as potential leaf area index and maximum rooting depth;
- high resolution climate scenarios, to incorporate spatial and temporal variability.

5 CONCLUSION

Although general trends are clear and qualitative conclusions can be drawn, the quantitative impact of climate change, including information about uncertainty, yet has to be established. This can only be done after proper evaluation of the input data, reducing uncertainty, detection of the most influential parameters and amelioration of especially these sensitive datasets. Nevertheless, the first results are promising and SWAT seems to be an appropriate tool to evaluate the impacts of climate change on the water balance.

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