Journal of Hydrology (2006) 331, 18–29

available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/jhydrol

Estimating rainfall and water balance over the Okavango River Basin for hydrological applications

Julie Wilk [a,*], Dominic Kniveton [b], Lotta Andersson [c], Russell Layberry [b], Martin C. Todd [d], Denis Hughes [e], Susan Ringrose [f], Cornelis Vanderpost [f]

[a] *Department of Water and Environmental Studies, Linköping University, S-581 83 Linköping, Sweden*
[b] *Department of Physics Chemistry and Environmental Science, University of Sussex, Falmer, Brighton, UK*
[c] *Swedish Meteorological and Hydrological Institute, 601 76 Norrköping, Sweden*
[d] *University College of London, 26 Bedford Way, WC1H 0AP, London, UK*
[e] *Institute of Water Research, Rhodes University, Grahamstown, South Africa*
[f] *Harry Oppenheimer Okavango Research Centre, Private Bag 285, Maun, Botswana*

Accepted 12 April 2006

KEYWORDS
Rainfall estimates;
Satellite data;
Raingauge;
Co-kriging;
River basin;
Okavango

Summary A historical database for use in rainfall-runoff modeling of the Okavango River Basin in Southwest Africa is presented. The work has relevance for similar data-sparse regions. The parameters of main concern are rainfall and catchment water balance, which are key variables for subsequent studies of the hydrological impacts of development and climate change. Rainfall estimates are based on a combination of in situ gauges and satellite sources. Rain gauge measurements are most extensive from 1955 to 1972, after which they are drastically reduced due to the Angolan civil war. The sensitivity of the rainfall fields to spatial interpolation techniques and the density of gauges were evaluated. Satellite based rainfall estimates for the basin are developed for the period from 1991 onwards, based on the Tropical Rainfall Measuring Mission (TRMM) and Special Sensor Microwave Imager (SSM/I) datasets. The consistency between the gauges and satellite estimates was considered. A methodology was developed to allow calibration of the rainfall-runoff hydrological model against rain gauge data from 1960 to 1972, with the prerequisite that the model should be driven by satellite derived rainfall products from 1990 onwards. With the rain gauge data, addition of a single rainfall station (Longa) in regions where stations earlier were lacking was more important than the chosen interpolation method. Comparison of satellite and gauge rainfall outside the basin indicated that the satellite overestimates rainfall by 20%. A non-linear correction was derived by fitting the rainfall frequency characteristics to those of the historical rainfall data. This satellite rainfall dataset was found satisfactory when using the Pitman rainfall-runoff model (Hughes, D., Andersson, L., Wilk, J.,

* Corresponding author. Tel.: +46 13 284463; fax: +46 13 133630.
E-mail address: julwi@tema.liu.se (J. Wilk).

0022-1694/$ - see front matter
doi:10.1016/j.jhydrol.2006.04.049

Savenije, H.H.G., this issue. Regional calibration of the Pitman model for the Okavango River. Journal of Hydrology). Intensive monitoring in the region is recommended to increase accuracy of the comprehensive satellite rainfall estimate calibration procedure.

Introduction

The assessment of water resources of large river basins over southern Africa is often complicated due to limited data availability. Nevertheless, sustainable planning of water resources in the region requires information on the present spatial and temporal variability of rainfall, as well as the hydrological response to development policies and climate change (Hellmuth and Sanderson, 2001). In this context, it has been demonstrated that hydrological models can be a valuable tool, providing a common platform for experts, decision-makers and stakeholders. Consequently, the use of models for policy making has increased in the last decade (Alkan Olsson and Andersson, submitted). The availability of geographical and climatological data, with emphasis on rainfall information, is often more critical than the choice of complexity of the hydrological model used for the success of a model application (Gan et al., 1997).

The Okavango river basin spans three riparian states: Angola, Namibia and Botswana. Streamflow is mainly generated in Angola where the Cuito and Cubango rivers rise (see Kgathi et al., this issue for an overview). They then join and cross the Namibia/Angola border, before flowing into the wetlands of the Okavango alluvial fan in Botswana (Fig. 1), known commonly as the Okavango Delta. The area of the basin that generates water to the delta is 165,000 km^2, of which 82% is situated in Angola. While much work has been undertaken on the ecology and hydrodynamics of the Okavango Delta (McCarthy and Ellery, 1998), little is known of the overall basin dynamics, especially the headwaters in Angola. This is partly due to the lack of rainfall and flow measurements during and after the Angolan civil war of 1975–2002. The Okavango River basin is situated far away from heavily populated areas and is thus relatively pristine. However, there are concerns that the resettlement of displaced communities in the Angolan part of the basin might change this (Green Cross International, 2000). Moreover, it is likely that any future developments will occur against the background of climate change (Andersson et al., this issue). Integrated water resource management to assess present hydrological conditions and the impacts of potential developments and climate change on the river flow requires relevant hydro-climatological and geographical information, with sufficient resolution in time and space.

This paper describes the development and evaluation of such fundamental data for application in hydrological modeling of the Okavango River (Hughes et al., this issue) and delta (Wolski et al., this issue). Accurate estimation of rainfall is the primary requirement for hydrological modeling. This is particularly challenging for the Okavango basin since almost all the river flow is generated in the highlands of

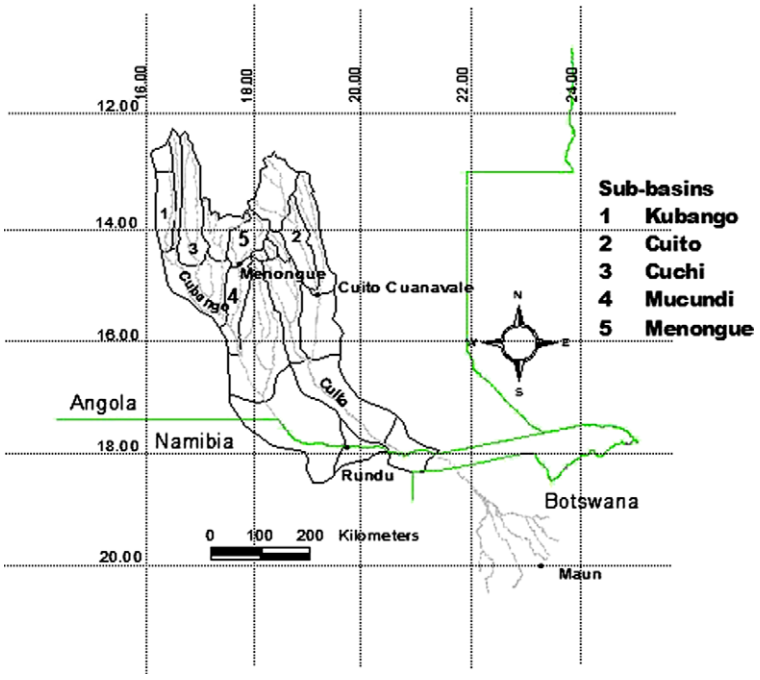

Figure 1 The Okavango River Basin showing selected sub-basins.