Comparison between the United States Soil Conservation Service (SCS) and the two models commonly used for estimating rainfall-runoff in south-eastern Botswana

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Abstract

The United States Soil Conservation Service (SCS) curve number method is used to estimate rainfall runoff from three sub-watersheds in South-Eastern Botswana. This approach uses the NASA Endeavour Shuttle Radar Topography Mission (SRTM) DEMs, digital soil data from the Botswana Ministry of Agriculture, rainfall data from the Department of Meteorological Services and land-use data derived from Landsat ETM+ imagery. Runoff predicted from the SCS method is compared with the runoff calculated using the Pitman and Monash models and the gauged runoff. The Thagale River system watershed produces a mean annual volume of 7.2 Mm^3 while the Notwane and Metsimotlhabe runoff volumes are 19.9 Mm^3 and 17.8 Mm^3 respectively. The SCS Model is found to be either over- or under-estimating the mean annual runoff volumes found using the other two models. It is concluded that more mean annual runoff volumes should be established for the whole country using the three models and a correlation analysis made in order to determine the superior model. The SCS Model uses a lot of Earth Observation (EO) and other data found in different government departments, hence this encourages collaboration. It is further observed that the SCS Model is quick to produce results, does not require stream gauging and can also easily be updated as the land use/land cover changes.

Keywords: Botswana, SCS, curve number, watershed, Dems, soil, rainfall, land use and HEC-1

Introduction

Botswana is a totally landlocked country lying between latitudes 18°S and 27°S and longitudes 20°E and 29°E in Southern Africa. Botswana covers about 528 000 km^2 with a generally uniform topography varying from 600 m in the northeast of Tuli Block where the major rivers converge into the Limpopo River, to about a local maxima of 1 400 m. Botswana climate is described as arid to semi-arid with generally low and erratic rainfall. Rainfall varies from about 250 mm in the south-west (Kgalagadi desert) to 650 mm in the north. The temporal distribution of rainfall within a year is consistent with two distinct seasons namely, a dry winter season extending from May to August and a rainy summer period extending from November to March.

Because of the aridness of the country, the government of Botswana has invested heavily on studies to evaluate potential of water resources in the country. These studies are meant to indicate the water resources that could be developed to meet the ever-increasing water demands for domestic, industrial and agriculture use (BNWMP, 1991; NAMPAD, 2000). The ultimate aim of water resources prediction models must be to improve decision making about a hydrological problem, such as water resources planning, flood protection, mitigation of pollution, or licensing of abstractions (Beven, 2005). It is crucial that the watershed runoff or inflows, which are used as inputs for the modelling of water resources, are accurate as erroneous values could have serious implications.

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There are numerous rainfall-runoff models available (lumped or distributed, deterministic or stochastic, fuzzy) (Beven, 2005; Wainwright and Mulligan., 2005). The major constraint to using these models is mainly lack of data (rainfall, rainfall intensity and distribution, discharge data, evapotranspiration losses, water table, soil moisture profiles, spatial patterns of near surface soil moisture, fine resolution digital elevation or terrain maps (DEM and DTM), GIS maps of vegetation types, soil types and geology).

Description of the study area

Figure 1 shows the map of Botswana; the study area is composed of several small rivers around the city of Gaborone which drain into the Limpopo River.

The objective of this study is to estimate mean annual runoff volumes for South-Eastern Botswana using the SCS Curve Number Model. These mean annual volumes shall then be compared to mean annual volumes determined using the Pitman and Monash models. The river gauge flow data that were used to calibrate the two models for the Notwane and Metsimotlhabe watersheds shall also be compared to the output from the SCS Model.

Watershed

A watershed is normally defined in terms of the watershed outlet point. Its boundary is defined by identifying all points within an area from which rainfall will contribute water to the outlet. When using a hydrological model, the following watershed characteristics are required; drainage area, watershed or channel length, the shape of the watershed, the slope of the watershed or channel, the drainage pattern, time of flow parameters, land-