Okavango Basin - Hydrology

Table 1: General information and key figures.

Other names	Countries	Region
Kawango	Angola, Namibia, Botswana	Southern Africa
Tributaries west (Cubango Catchment)	**Tributaries east (Cuito Catchment)**	**Cities**
Cubango, Cutato, Chuchi, Cacuchi, Celei, Cuebe, Cueio, Cuatir	Cuito, Cuanavale, Lussinga, Longa, Cuiriri	Menongue (Angola), Rundu (Namibia), Maun (Botswana)
Source	**Source location**	**Source elevation**
Bié Plateau (Central Plateau of Angola)	Close to Tchicala Tcholohanga (other names: Vila Nova, Chicala Choloanga) near the village/settlement of Lumbula	1,850 m approx.
Source coordinates	**Mouth**	**Mouth elevation**
12°42´40.76´´ S 16°03´50.48´´ E	Between Seronga (east) and Ikoga (west) into the Okavango Delta (Botswana)	Outlet of the Panhandle between Seronga and Ikoga: 980 m; Maun: 940 m (Delta outlet)
Mouth coordinates	**Length**	**Basin**
18°50´40.76´´ S 16°03´50.48´´ E	Cubango: 1,260 km approx., Cuito: 920 km approx., Okavango (including the Delta until Maun): 1,860 km approx.	165,000 km² approx. (until the entrance into the Panhandle at Mohembo)
Discharge average		
304 m³s⁻¹ approx (Station Mukwe, 10/1949 - 09/1998)*		

* for flow characteristics, see Figure 3

The Okavango River has its origin in the semi-humid highlands of Angola and drains the endorheic Okavango River basin through the arid and semi-arid eastern parts of Namibia into Botswana where it drains into a wetland, also known as the Okavango Delta (Fig. 1). The Okavango River basin upstream of the Delta covers an area of about 171,000 km² (Mohembo). About 95% of the streamflow entering the Delta is generated by two main tributaries, namely the Cubango River (108,000 km²) and the Cuito River (57,470 km²), both located in Angola. The ephemeral Omatako River originates in Namibia and joins the Cubango River near Rundu, but has not contributed to runoff from the Okavango for over 50 years.

The Cubango River (flow length of 1,260 km) has its source in the eastern part of Huambo Province close to the village of Tchicala Tcholohanga (1,850 m above sea level (a.s.l.), whereas the Cuito River (flow length of 920 km) rises between Cangoa and Sachiambe (1,430 m a.s.l.) in the western part of Moxico Province (Fig. 2). After the confluence of both rivers south of Dirico the river becomes the

Fig. 1: The Okavango Delta in August 2009 (photo: J. Helmschrot).

"Okavango River" (Cubango River in Angola and Kavango River in Namibia). Flowing in a southeasterly direction, the Okavango River passes the gauging stations Mukwe and Mohembo where historic annual discharge of about 10 km³ finally spills through the Panhandle and subsequently into the Okavango Delta at an elevation of 980 m a.s.l. The different

flow regimes and associated main runoff generation mechanisms of both tributary basins (active drainage area) are strongly controlled by both climatic conditions and landscape characteristics, including geological and soil conditions as well as topography. According to the strong precipitation gradient in the basin, where the highest annual precipitation is in the

Fig. 2: Okavango River Basin including all main tributaries and the Okavango Delta with its entrance at Mohembo gauging station and outlet at Maun (data source: NIWR, ORI; background: MODIS 16-day BRDF-adjusted NBAR data (MCD43A4) courtesy of EOSDIS-NASA).

northeast (1,200-1,300 mm, Huambo) and the lowest annual precipitation is in the southwest (<500 mm, Rundu and Maun) (FAO 2001), almost all discharge is generated in the headwaters during the rainfall season between October and March. The hilly landscape of the Cubango and parts of the Cuito headwaters are dominated by igneous and metamorphic rocks forming granitic, sometimes shallow soils, supporting surface runoff and rapid subsurface flows rather than baseflow generation. In contrast, most of the flat north-eastern and

southern parts of the Cubango basin as well as wider parts of the Cuito basin are covered with thick-layered sedimentary formations from the Kalahari group. These areas affected by sandy deposits show a moderate topography allowing for high percolation rates and groundwater recharge. The river morphology also notably controls the discharge of both basins (Fig. 3, Fig 4.). Abrupt incised valleys also promote rapid runoff generation in the upper Cubango and explain the sharp increase of the hydrograph with the beginning of the rainy

season. The wider valleys of the Cuito basin with their densely vegetated swampy bottoms, floodplains and meanders decelerate the runoff and provide moderate hydrographs with significantly higher baseflow contributions than observed in the Cubango system.

The different flow regimes are also reflected in observed runoff volumes. As shown by daily data for the period between 1945 and 2000, the mean annual runoff of the Cubango at Rundu is 165 m³s⁻¹ with the highest runoff in April (393 m³s⁻¹) and the lowest runoff in October (38.9 m³s⁻¹).
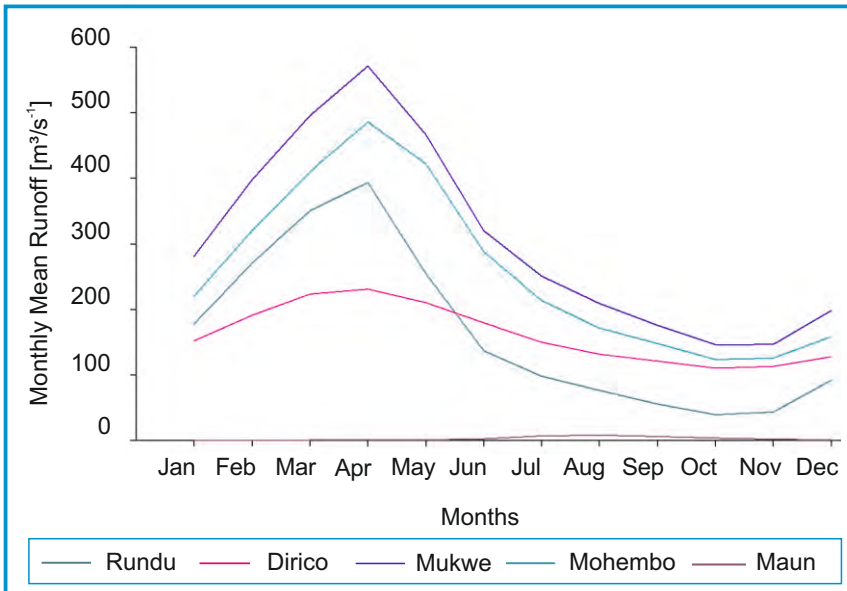
Fig. 3: Monthly mean discharge values describing the inner-annual flow characteristics and flood pulse pattern at representative gauging stations (Mukwe: 1949-1998, Rundu: 1945-2000, Dirico: 1962-1975, Mohembo: 1974-2002, Maun: 1980-2000) along the Okavango River (data source: NIWR, GRDC, ORI).

Similar timing can be observed for the Cuito at Dirico. However, the moderate runoff peak in April (230.7 m³s⁻¹) and a significantly higher runoff during low flow conditions in October (110.2 m³s⁻¹) are a result of the retention functions and sustained water release from the wetlands and floodplains. The analysis of upstream-downstream effects showing varying water travel times in both tributaries underpin differences in the runoff generation mechanisms. Analysis of runoff events observed at the gauging stations at Mumba (upstream of Cubango) and Rundu (Fig. 5; 500 km downstream) shows that the travel time of an individual peak is up to 10 days in the Cubango River. In contrast, the travel time of the flood peak between Cuito Cuanavale (upstream of Cuito) and Dirico (270 km) is four times longer. However, the relatively low travel times and high wetland storage functions favour the retention of sediments and
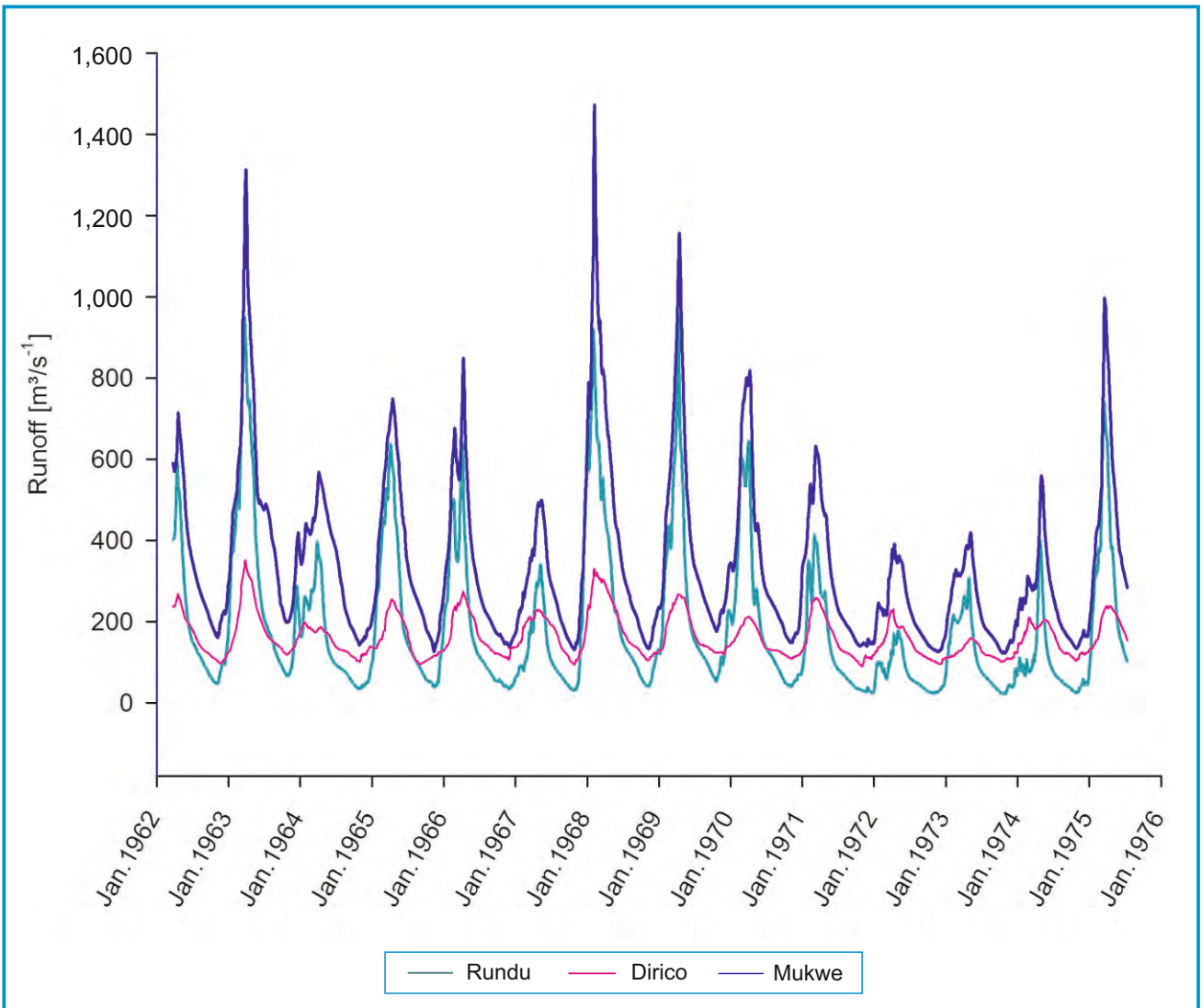

Fig. 4: Daily runoff at Rundu (Cubango), Dirico (Cuito), and Mukwe (Okavango) stations between 1962 and 1975 (data source: NIWR, GRDC).

nutrients from leached sandy soils and, thus, cause clear, nutrient poor river water.

At the Mukwe gauging station, which is close to the confluence of both tributaries, the mean annual runoff increases up to 304.7 m³s⁻¹. The discharge reaches its maximum of 571.3 m³s⁻¹ in April and drops to 145.2 m³s⁻¹ during low flow conditions in October. The mean daily runoff volume at Mukwe is $26.3*10^6$ m³ (1949-1998) which equals 57 mm*a⁻¹*m⁻² of the catchment. Before entering the Delta, the Okavango also loses water between Mukwe and Mohembo through evaporation, groundwater losses, and water extraction. The mean daily runoff entering the Okavango Delta at Mohembo is 6% less than the runoff at the gauging station at Mukwe. Consequently, the mean annual daily runoff at Mohembo (1974-1998) is 263 m³s⁻¹. The highest difference in monthly streamflow occurs in January and is 21% lower compared to the runoff in Mukwe (281 m³s⁻¹).

The Okavango Delta is situated in two sets of parallel faults, oriented perpendicular to each other, underlain by deep Kalahari sands. With mean annual precipitation and potential evapotranspiration of 450 mm and 2,000 mm respectively, it receives almost all of its water as a flood pulse from its headwaters in the Angolan highlands. The flood pulse peaks in Mohembo around April/ May. Due to the nearly flat topography (slope ratio in metres of 1 in 3,500), the flood takes about three to four months to traverse the Delta, a distance of about 250 km, reaching the seasonal Thamalakane River, the main outlet from the Delta, in July/ August. This only happens when sufficient water flows into the Delta in Mohembo, coupled with local precipitation and antecedent soil moisture in the Delta. Almost 95% of the inflow is lost to evapotranspiration in the Delta. The total flooded area of the Delta varies annually, depending on the total inflow volume at Mohembo and the previous year inflow. It ranges between approximately 6,000 km² of permanent swamps, and 12,000 km² due to the flooding of seasonal and occasional floodplains.

Mainly because of civil war in Angola, which ended in the early 2000s, and the high prevalence of insect-borne diseases

Fig. 5: Gauging station at Rundu (photo: H. Göhmann).

in the Delta, the river basin, together with the Delta, has been minimally impacted by anthropogenic activities. However, with the end of the war in Angola and the eradication of the insect-borne diseases in the Delta, the basin is facing increasing pressure due to land use/land cover changes, water abstractions, and pollution. These all have the potential to negatively impact the flow distribution of the basin. Their impact will be exacerbated by the impacts of climate change.

Acknowledgements

Reference

FAO (Food and Agricultural Organization of the United Nations) (2001): FAOCLIM 2.0 A World-Wide Agroclimatic Database. – Food and Agriculture Organization of the United Nations: Rome, Italy.

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