WATER RESOURCES ASSESSMENT IN THE BILATE RIVER CATCHMENT - PRECIPITATION VARIABILITY –

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Abstract

The river Bilate is located in the Southern Ethiopian Rift Valley and drains parts of the Western Ethiopian Highland and the Rift Valley. Rainfall variability and intensity in the catchment follows a semi-humid to semiarid tropical bimodal distributed precipitation pattern. Variability is caused by alternating dry and rainy seasons, as well as long-term influences, like the El Niño effect, which is overlapping with regional orographic effects.

The analysis of precipitation data of 15 meteorological stations shows no regular distribution of amount and intensity of precipitation. Even meteorological stations located in similar relief positions and at similar altitudes differ in precipitation sums, duration and intensity. Thus, daily or hourly precipitation values are not comparable between stations, monthly precipitation sums also differ strongly. Rainfall events are local storms of short duration (1-5 h) and high intensity (up to 30 mm/h).

Related time series of discharge data from relevant catchment areas are in insufficient conditions. Five river gauging stations in the catchment show more or less huge gaps in their recordings. Only for short time spans data are available at all stations simultaneously. Therefore, analysis is quite difficult, since flow velocities and cross sections of the gauging stations have not been controlled for a long time and available rating curves are unreliable. However, rainfall-runoff analysis is almost impossible, results may only be used for rough evaluation of computed area precipitation.

Precipitation amounts in the catchment are generally dependant on altitude. The comparison of the distribution of monthly average precipitation at different stations shows that the dependency on altitude is more pronounced in the rainy than in the dry season. On the other hand, precipitation patterns during the dry seasons of wet years do not seem to depend on altitude at all.

The extreme variability of daily and monthly precipitation amounts all over the catchment area essentially limits the exact assessment or even prediction of water resource availability. In addition, the long-term variations of precipitation – overlapping with the seasonal variability – cannot be predicted accurately as well, due to lack of reliable data.

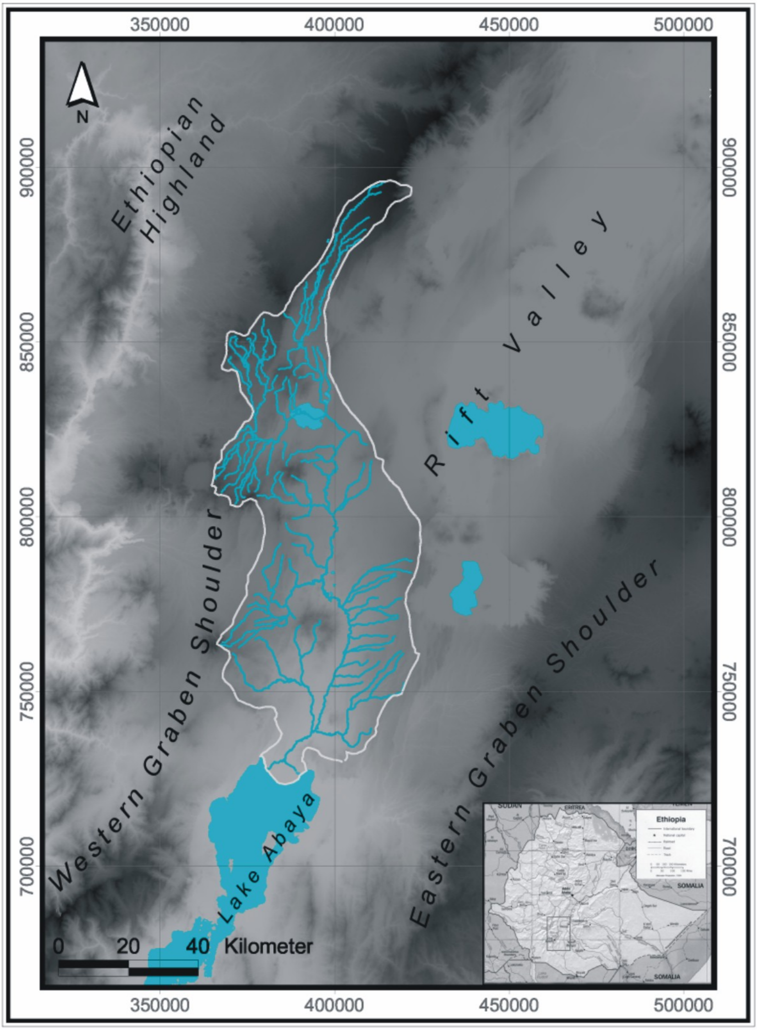

Figure 1 Relief , watershed and drainage pattern of the river Bilate

1 Introduction

Information on water resources availability in Ethiopia are generally based on studies carried out by GEMACHU in the 70ies, documented in the National Atlas of Ethiopia (NMAS, 1978). Furthermore, various basin studies were carried out in relation to the river basin mask plans. In the 80ies and 90ies certain amounts of gauging stations were established. Because of limited facilities and personnel of the meteorological and hydrological services, most data are ether non reliable or were never processed.

Row data – these are analogous recording sheets stored at several places – are made available upon request. Most basin studies were carried out on historical data, new gauging stations were rarely established. Old stations were normally not renewed, only with regard to larger projects like reservoir and hydropower generation new measurements were taken.

The southern Rift Valley was not a priority area for development. Therefore, demands were low. Consequently, the assessment of water availability in Ethiopia is strongly limited by quality and length of time series of recorded precipitation data.
In the catchment area of the Bilate River, Southern Ethiopian Rift Valley, an appraisal of precipitation sums on monthly basis has been carried out. The catchment of the river Bilate is part of the quasi-endorheic Lake Abaya-Chamo Basin and extends to approximately 5.500 km². Altitude varies from 1200 m a.s.l. in the southern part up to 3.300 m a.s.l. in the north.

15 meteorological stations are distributed within and around the catchment area on different altitudes recording daily precipitation sums. For all stations daily precipitation sums are available, only two stations offer records of hourly precipitation. Shorter time intervals are not documented. Time series of data are very insufficient, inconsistent and show several gaps of recording especially after 1991. Comparison of parallel measurements is limited because of these incomplete data.

2 Methods

Daily precipitation data of 15 meteorological stations have been analysed. Daily sums have been added to establish monthly totals and have been compared with recorded monthly sums. Since both values differ by more than 50 % within the stations and the time period of recorded daily data is available for two years only, the monthly data have been used for further analysis and modelling.
The area distribution of the meteorological stations is patchy: most stations are located on the Graben Shoulder or the Highland, only few stations are situated in the Rift Valley. The elevation of the stations ranges from 1199 m a.s.l. to 2380 m a.s.l. with a cluster at the altitude in approximately 2000 m a.s.l.

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Table 1 Meteorological stations (Coordinates from UTM projection, Zone 37 N, Map Datum Adidan)

Station	**Easting**	**Northing**	**Altitude [m a.s.l.]**
Aje	429170	806475	1858
Alaba Kulito	399846	807264	1781
Aleta Wendo	436008	729679	1922
Anchaga	374532	812196	2191
Awassa	442781	782805	1775
Bedessa	382948	759924	1606
Bilate State Farm	384920	730000	1199
Bilate Tena (Dimtu)	403593	765578	1495
Boditi	372888	768077	2079
Butajira	431275	898460	2098
Hosaina	373677	834025	2157
Humbo Tebela	364209	740462	1588
Shone	384986	789446	1980
Sodo	360987	754927	1869
Wilbareg	403265	855525	2001
Fonko	386038	845926	2380

The total sums of each month have been averaged over the time period from 1970 to 1996 for all stations. These mean monthly precipitations have been correlated with the altitude for each month. The correlation formula applied on the digital elevation model lead to an area wide precipitation excluding consideration of local influence on precipitation variability.

In a next step, the aberration of computed rainfall sums versus the existing rainfall sums at each station has been calculated. These point values of the differences have been interpolated over the area by using the kriging method. Both, the kriged values of the differences and the computed precipitation sums have been added to get the most realistic area wide precipitation (PRUDHOMME, 1999).

GOOVAERTS (2000) described, that "geostatistical prediction technique[s] (kriging) provide[…] better estimates of rainfall than conventional methods". For a high resolution sampling density, which is not available in the catchment of the Bilate River, kriging does not show significantly greater predictive skills than simpler techniques (BORGA & VIZZACCARO, 1997). Additional, the integration of the regression of rainfall versus elevation into the digital elevation model is a straightforward approach (GOOVAERTS, 2000).
Since the time series of the discharge data of the five river gauging stations have huge gaps over several years, only a little amount of data could be used for analysis. Only two gauging stations are located at the Bilate River. Three stations are gauging different tributaries. The data of the two main stations show no significant correlation.

On the contrary, data of the down stream gauging station show sometimes less discharge volume than the up stream data. Water removal for irrigation can be neglected in the area between these two stations and natural causes for large amounts of regular leakages from the river are not known. Although TENALEM (2003) reports water level drop downs of lakes in the Rift Valley caused by neotectonic events.

The uncertainty of the data originates from inadequate flow measurement techniques and untrustworthy supervision of the gauging station. WHALLEY ET AL. (2001) highlight the problems of reliability on flow measurement. It is known that flow rating curves of Ethiopian river gauging stations were often depending on few measurement only. In order to get any reliable analysis, only data of selected years have been used and averaged over the longest possible time span. No data have been substituted using known methods due to the high variation of discharge data during known time periods. Discharge volumes have been computed for each sub-catchment and for the catchment gauged by the station Tena Bilate (Dimtu).

3 Results and Discussion

Precipitation is generally depending on altitude in the Lake Abaya-Chamo-Basin (BEKELE 2001). Comparisons of the distribution of monthly average precipitation show, that the dependency on altitude is more pronounced in the rainy than in the dry season.
The average of monthly precipitation over 26 years (1970 – 1996) can be described by an exponential formula (Tab. 2).

Tab. 2: Average precipitation versus altitude [mm/month]

a) February: $\text{precipitation} = 0.0129 \cdot \text{altitude}^{1.1069}$
b) August: $\text{precipitation} = 0.0011 \cdot \text{altitude}^{1.5793}$

Precipitation patterns during the dry seasons of wet years do not seem to be depending on altitude at all. The extreme variability of daily precipitation totals in the catchment area essentially hinders the exact assessment or prediction of the availability of the resource water.
Only long term prediction can be estimated without considering the duration and intensity of effective rainfall. Therefore, the volume of monthly average rainfall can only roughly be used for estimation of water availability for cultivation or traditional water harvesting.

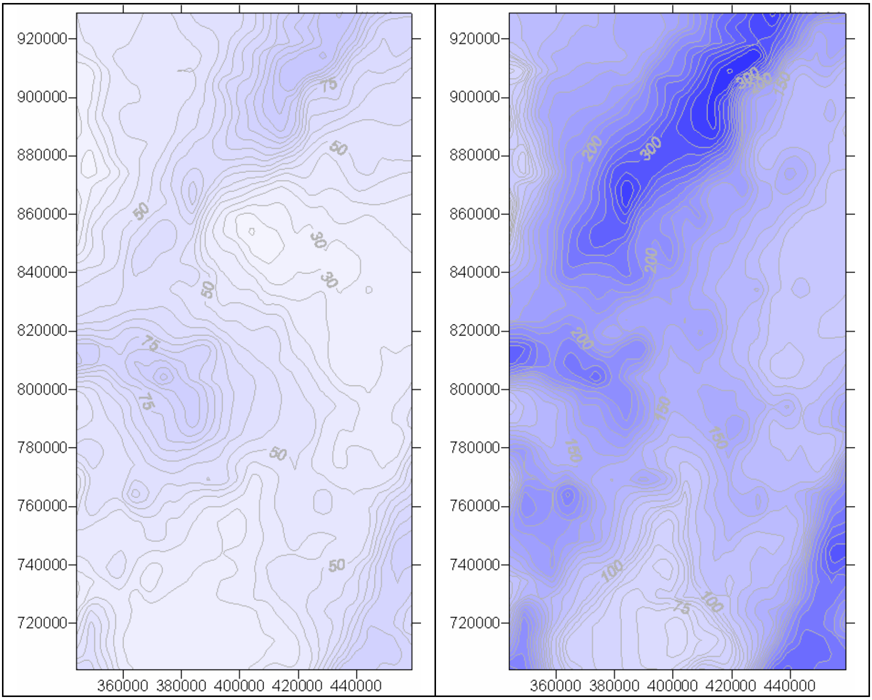

Figure 2 Average precipitation pattern 1970 – 1996 [mm/month]: left: February (dry season), right: August (rainy season)

Average monthly precipitation pattern for the time period from 1970 to 1996 is displayed in figure 2. Rainfall volumes computed for the different gauging stations vary from 51,4 mio m³ (27 mm/m²) in February to 295,3 mio m³ (155 mm/m²) in August for the catchment gauged by the station Bilate Tena (Dimtu) with an area of 1895 km².

The rainfall patterns (Fig. 2) high lightens the relative higher amount of rainfall in the mountainous regions compared to the Rift Valley. Rainfall data related to the area of the gauging station Batena, situated in the northern part of the catchment in the Western Ethiopian Highlands show extremely changing volumes during the year. They vary from 1.1 mio m³ (8 mm/month) in February to 36.3 mio m³ (264 mm/month) in August for an area of 137.9 km².

Discharge totals of the year 1992 can be compared with precipitation volume and show some, but no distinct correlation. In general, precipitation volumes of selected catchment areas are much higher than the volumes of related discharge. The typical bimodal distribution of discharge over the year can be observed, both in the small catchment of Batena and the catchment of Bilate Tena (Dimtu) station.

Discharge is reacting on precipitation with a time lag of approximately one month after the dry season at Batena station and Bilate Tena (Dimtu) station. In the rainy season the time lag is missing entirely at Batena station, whereas at Bilate Tena (Dimtu) station the time lag is at least one month. Furthermore, the reaction of the discharge to precipitation is more smooth due to the large catchment.

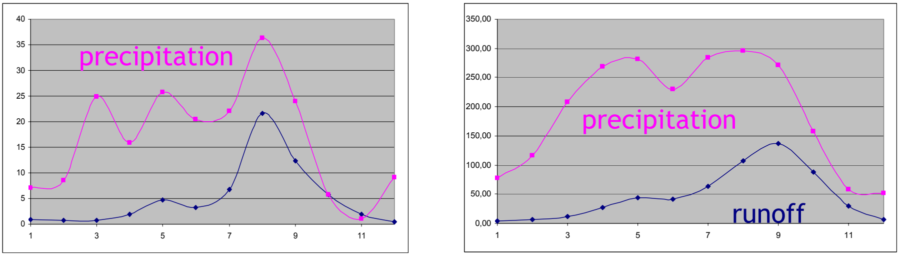

Figure 3 Volumes of precipitation versus discharge in 1992 [mio m³]: left: Batena station and chatchment (137.9 km²), right: Bilate Tena (Dimtu) station and chatchment (1895 km²)

4 Conclusion

The precipitation time series show the average precipitation of all meteorological stations used for the computation of the geographic precipitation. 1992 was a year of high total rainfall. The amount of rainfall differs monthly as well as annually, as the correlation of rainfall-altitude is dependent on the amount of rainfall. For this reason and because only few meteorological stations exist, the geographical rainfall computation was done manually and has to be considered carefully.

The volume of rainfall (catchment area north of gauging station Dimtu) in contrast to the volume of discharge (gauging station Dimtu) differs strongly: Discharge volume is only ¼ of the precipitation volume. But the potential evapotranspiration is ~2,000 mm and thus at least as high as the annual precipitation.
The extreme variability of daily and monthly precipitation totals in the catchment essentially hinders the exact assessment or prediction of the availability of the resource water. In addition, the long-term variability of precipitation – overlapping the seasonal variability – cannot be predicted accurately.

5 Literature

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