

EVOLUTION AND IMPACT OF HYDROLOGICAL EXTREME YEARS IN THE LANGE BRAMKE BASIN, HARZ MOUNTAINS, GERMANY

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Introduction

Small basins play a mayor role for hydrological process, and analytical studies since they feature the advantage that changes in discharge determining factors are better comprehensible than in large basins. In forest environments the changing environmental conditions are even less, and are further minimized in basins with pure plantations. These basins are therefore appropriate for studying governing process pattern and for the study of environmental changes, both being indispensable for the proper management of water resources as an essential partial complex of ecosystems.

The Lange Bramke basin, being a small monocultural forest catchment, will dispose of a 60 years discharge data series in 2009, hence it fulfils inter alia the qualification as a study object for hydrological trends and extremes as well as for hydrological forecast.

In this presentation trends in precipitation and discharge conditions in the Lange Bramke basin, based on data from 1988 to 2007 and compared with data from 1968 to 1987, will be highlighted and a deduction will be drawn for the water supply and flood-control situation in the Harz mountains.

Study site

The Lange Bramke basin, which is situated in the Harz mountains (Germany) covers an area of 0.76 km² and an altitude range from 540-700 m a.s.l. 90% of the area is forested with Norwegian spruce that was reforested in 1951 after the complete clearance of the basin following the Second World War. The basin is build up of an unsaturated zone (UZ) made of forest soils on silty materials of solifluidal origin rich in skeleton that covers the weathered and fractured/fissured bedrock that serves as a fractured rock aquifer (FRA). Parallel to the Bramke stream a narrow and shallow (<2 m thickness) porous aquifer (PA) is developed that consists of boulders, debris and gravels. The hydrological study concept applied in the Lange Bramke catchment as well as the available instrumentation is described by Herrmann and Schumann (2008) in a paper presented in the same conference.

The catchment serves as an inflow to the Oker reservoir that is part of the water supply network of the Harz Wasserwerke. It also serves as a flood-control reservoir for the Harz foreland.

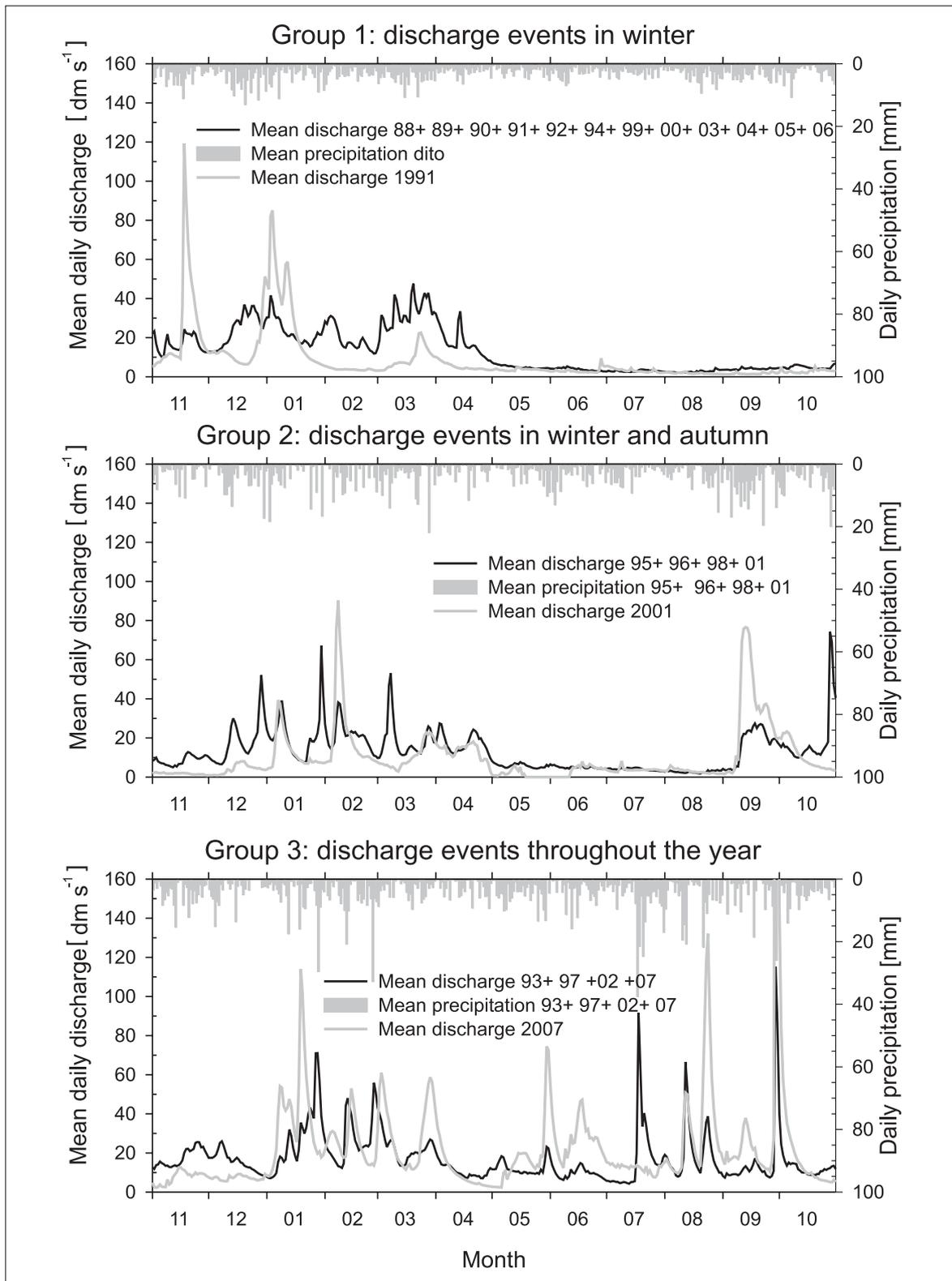


Figure 1. Categorisation of hydrological discharge behaviour of the Lange Bramke basin. Displayed are mean discharges and the respective precipitation, based on daily mean data, for the three groups as well as one hydrological extreme year of the respective group (1: minimum year 1991, 2: maximum year 2001, 3: maximum year 2007)

Results

Discharge, precipitation and piezometric data and correlations of the hydrological years 1988 to 2007 were analysed for the Lange Bramke catchment. In this context, the hydrological behaviour of the catchment can be categorised into three groups: Group 1 (G1) with considerable discharge events only during Winter period; Group 2 (G2) with considerable discharge events during Winter and in Autumn; Group 3 (G3) with considerable discharge events throughout the year. The groups are illustrated in Figure 1. From 1988 to 2007 G1 was applicable for 12 years, while 4 years could be categorized as G2 and G3 respectively. This is noteworthy since from 1968 to 1987 the distribution is different with G1: five; G2: three; and G3: twelve cases. The figure also displays that the mean annual precipitation sum for G1 (1165 mm) is lower than for G2 (1273 mm) and that G3 tops the groups with a mean of 1639 mm. The yearly mean discharge amounts follow the trend, though less distinct (G1: 528 mm; G2: 533 mm; G3: 708 mm). The precipitation distribution is the most balanced for G1.

The execution of Mann-Kendall trend analysis for yearly precipitation sums displays no overall trend. The pattern changes, however, if an analysis is based on half-yearly data, divided in Winter (November to May) and Summer (June to October) half-terms. The Winter term displays a clear negative trend while the Summer term displays a positive trend, indicating that the total amount of Summer precipitation increases presently. This is mainly caused by a changed precipitation distribution during the past 12 years that results in a reversal from Winter- exceeding Summer precipitation to Summer- exceeding Winter precipitation in hydrologically extreme years (e.g. 2002 and 2007). This situation is shown in Figure 2.

In principle the runoff ratio in the Bramke catchment is high in Winter and relatively low in Summer with 68% and 21% (mean for 1988-2007) respectively. Both runoff ratios show a positive trend in the past 20 years, the Summer slope with 0.10 lower than the Winter slope with 0.51. This trend may have two origins: (a)

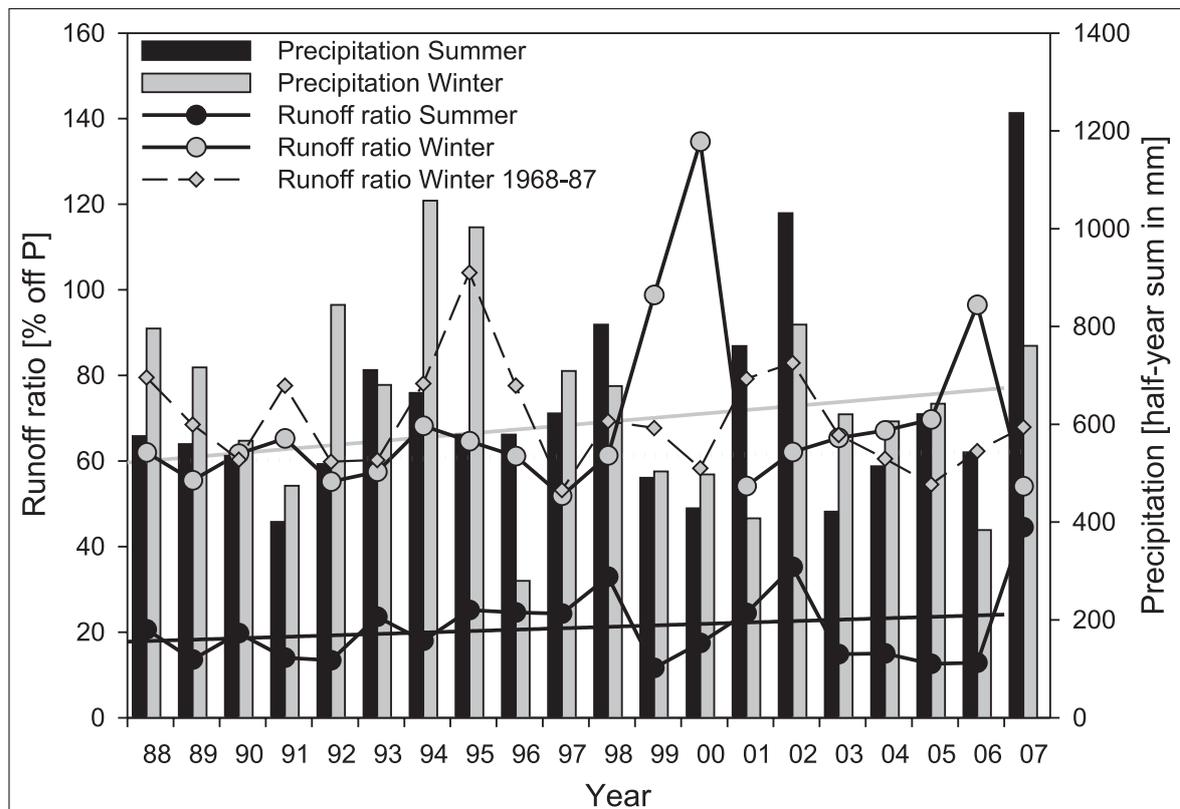


Figure 2. Half-yearly precipitation sums (Winter: Nov.-May; Summer: June-Oct.) for the hydrological years 1988-2007 and runoff ratios for the same periods and for Winter 1968-87. Further shown are the trend lines for the runoff-ratios in Summer (1988-2007) and Winter (1988-2007). The dotted Winter trend line represents the situation without the extremes 1999, 2000 and 2006

The evapotranspiration decreases or (b) the precipitation falls less balanced, i.e. extreme precipitation events (with high intensities and amounts) and therefore extremely high discharge events are on the increase. Latter is definitively the case for the Summer where hydrological years of the type G3 are getting fewer but with more pronounced events and with absolute Sommer event discharge maxima in 2002 and 2007. Furthermore, it can be observed that the dry Sommer period typical for the type G3 is not only more frequent but also starts earlier, i.e. the dry period takes shape from May to October (see Figure 1) while in the hydrological years 1968 to 1987 the dry period started distinctively only in June/July and lasted until October.

The Winter situation reveals that in comparison to the period 1968 to 1987 (see Figure 2), the runoff ratio decreases slightly from 69.4% to 68.3%. Trend analysis considering the whole Winter period 1968 to 2007 displays that actually a slight negative trend (slope -0.13) exists. If the period 1968 to 1988 is compared to the 1988 to 2007 period without the years 1999, 2000 and 2006, the runoff ratio proportion changes to 69.4 to 61.0. The high runoff ratios in Winter do have their origin in melt events of accumulated snow covers, in extreme years topped by precipitation falling onto the melting snow cover. Decreasing Winter runoff ratios hence indicate a decline in snow accumulation during the past 40 years that account for high Winter discharges during melt events. It can be stated that in the period 1988-2007 the runoff ratios are generally lower and more equalized but are also subject to few outstanding maximum extremes.

The influence of the observed piezometric levels in the catchment on discharge behaviour still needs to be studied in detail. So far can be stated, that the piezometric levels during Winter exceed those in Summer by around 0.2 m at a stream-close-well (HKLQ) and that the piezometric levels follow throughout the year the course of the discharge hydrograph. Notable is the fact, that from the analysis of stable isotopic and tritium data for selected discharge events it is known, that direct runoff is only 12% of total on the average. In some cases i.e. during Winter rain on snow melt events, event water corresponds even to less than 1% of the actual rain or meltwater input. This means that the high runoff ratios in the Bramke catchment do not indicate high event water proportions but that the high runoff ratios are still generated by a process that follows the three major successive stages (1) Infiltration with saturation of top soils and percolation; (2) Rise of groundwater table, corresponding to an increase of groundwater potential; combined pressure transmission and mass transfer (3) Groundwater exfiltration in faults and PA to stream channel as described in (Herrmann *et al.* 2006).

Conclusion

Results indicate decreasing precipitation amounts in Winter and decreasing runoff ratios for the Winter season resulting in less Winter input to the Bramke reservoir. The mean runoff ratios for Winter are 68% (including extreme years) and 61% in the more balanced years. During the past twelve years, Summer precipitation is increasing and a trend towards Summer precipitations exceeding the Winter precipitations exists. This is caused by hydrological extreme events that gain weight in the past years. At the same time, years with long low discharge periods extending from May to October occur more frequently and these periods begin up to two month earlier than before the eighties and hence also last longer.

It can be concluded that the hydrological situation in winter becomes more equalised, though this period is also subject to outstanding maximum extremes. The Summer period becomes less predictable and definitely extremer concerning drought and flood situations. This may cause problematic situations during Summer for the drinking water supply since the reservoirs do gain discharge water less reliable during summer and low flow periods are elongated. Equally the storage level after the Winter period must not be beyond limit since the occurring outstanding extreme Summer discharge events with an increasing trend in runoff ratios may otherwise cause floods in the Harz forelands if the flood-control assignment of the reservoirs is not maintained.

References

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