Hydrological changes from 1960 to 2004 in the Blue Nile Basin, Ethiopia: A statistical approach

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Introduction

- The Blue Nile Basin is the main source of the Nile water and feeding subsistence farming households in the Ethiopian highland.
- Historical hydrological changes are valuable bases for present and future water resource development in the Basin.

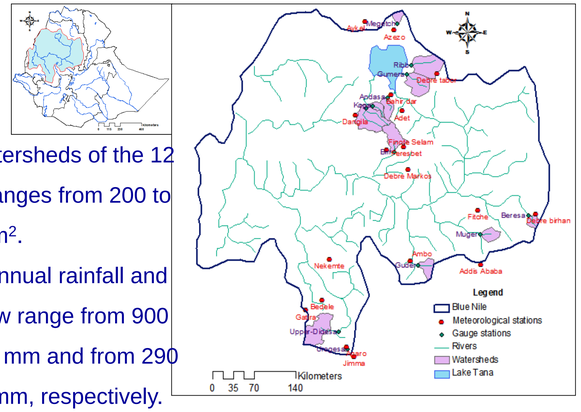
Objective

- To identify and analyze the possible trends and step-wise changes in hydrological regime of the rivers of the Blue Nile since 1960.

Study site

- For the study 12 rivers were selected in the Blue Nile Basin, considering data quality (Figure 1).

Figure 1. Location of the Blue Nile Basin and 12 study rivers with their respective watersheds



- The watersheds of the 12 rivers ranges from 200 to 1800 km^2.
- Mean annual rainfall and total flow range from 900 to 2000 mm and from 290 to 950 mm, respectively.

Discussion and conclusion

- There are significant differences in the hydrological regime between the three periods, but only in *ca* 15% of the total tested cases.
- The results could not be generalized at the Basin scale as they are specific to each rivers.
- Thus, specific watershed characteristics need to be considered for temporal changes of hydrological regime in the Basin.
- The more frequent stepwise changes in P3 might indicate more abruptly land-use changes between those periods.

Methodology

Data

- The time series were divided in to three periods as 1960-1975 (P1), 1975-1991 (P2) and 1992-2004 (P3) (Figure 2).
- Annual rainfall (P), annual total flow, Qt [mm yr^{-1}]; runoff coefficient, C [the ratio of Qt to P]; high flow, Qh [mm yr^{-1}]; low flow, Ql [mm yr^{-1}] and low flow index, LFI [the ratio of Ql to Qt] were considered.

Analysis

- Partial least square – discriminant analysis (PLS-DA) was applied to see if the hydrological parameters were significantly different among the three periods.
- Trends in the whole time series and in each of the three periods were tested using Spearman's rho test. Step-wise change between medians was made using Wilcoxon signed-rank test.

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Results

- The hydrological regimes were significantly different between three periods (R^2 = 0.76) (Figure 2).
- 11 out of the 12 rivers showed significant changes (34 trends out of 258 test cases and 36 step-wise changes out of 246 test cases) (Table 1).
- 50% of the step-wise changes were seen from P2 to P3, most frequent change was seen in C.
- Changes were river specific.

Figure 2. Partial least square (PLS-DA) graph for the classification of three periods [1960-1975 (P1), 1976-1991 (P2) and 1992-2004 (P3)]. The broken line ellipses showed the classification.

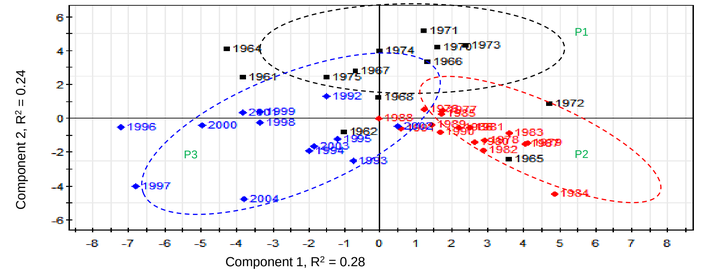

Table 1. Number of rivers that have significant changes in trends and step-wise changes in each period and in each hydrological parameters in the three periods. *NS* indicates no significant test exists, "+" signs increment, while "–" decrement at $p \leq 0.05$

Rivers	Trend in				Step-wise change from		
	Whole time series	P1	P2	P3	P1 to P2	P1 to P3	P2 to P3
P	2–	1–, 1+	1–	NS	1–	NS	NS
Qt	1+, 1–	NS	NS	NS	1+, 3–	1–	5+
Qh	1–	NS	NS	2–	3–	2–	1+, 1–
C	2+	1–	1+	3–	1+	3+	4+
Ql	1+, 2–	1+	4+		1–	1+	1+, 2–
LFI	1+, 1–	2+	2+	3–	1–	1+	2+, 1–
Total	**12**	**6**	**8**	**8**	**11**	**8**	**17**

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