Temporal Flow Variations: A New Challenge for Water Management in Tanzania

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INTRODUCTION

- Despite the growing attention to a chronic crisis in country's water resources, our ability to assess and predict water availability to communities is still quite limited.
- This is a prevailing situation in Tanzania and northeast Tanzania in particular where limited, spatially non-uniformly distributed quality water resources are stressed to supply for various human and ecosystem needs leading to ever-growing conflicts between users.
- The water scarcity conflicts are worsened by climate-induced rainfall reduction and evaporation increase.
- In order to provide suitable measures to ensure adequate and sustainable water supplies, it is important to provide information on the water availability at different location in different times of the year to assist in the informed decision making process. This includes
  - Information on the seasonal changes of water resources
  - Information on changes of water resources over the years
- Past studies (MNRT, 2005; Valimba, 2005; Valimba, 2007a) have indicated changes of rainfall and hydrological extremes in northeast Tanzania. Therefore, this study intended to investigate changes of seasonal flow regime which might have occurred in relation to changing hydrological extremes to affect the management of surface water resources in the region.

SELECTION OF STUDY CATCHMENTS

- The surface water resources of northeast Tanzania are located within the three basins, the large Pangani, medium Umba and small Sigi (**Fig 1**).
- The surface water resources of Pangani are subdivided by the *Nyumba ya Mungu* (NyM) Reservoir into two main systems
  - Upstream system: drains into the reservoir and comprises
    - The eastern River Ruvu branch draining eastern Mount Kilimanjaro and eastern and northern North Pare Mountains
    - The western River Kikuletwa branch draining the western Mount Kilimanjaro and Mount Meru
  - Downstream system: drains the reservoir to main R Pangani which is fed with two major tributaries, R Mkomazi draining the west Usambara and R Luengera draining the east Usambara
- Rivers Umba and Sigi drain the Usambaras to discharge in the Indian Ocean and consequently their catchments extend from these coastal mountains to Indian Ocean coastline.
- Selection of study catchments considered
  - Unregulated catchments
  - Existence into different climatological regions
  - Availability of long flow records
- The selected catchments are shown in **Fig 1**.

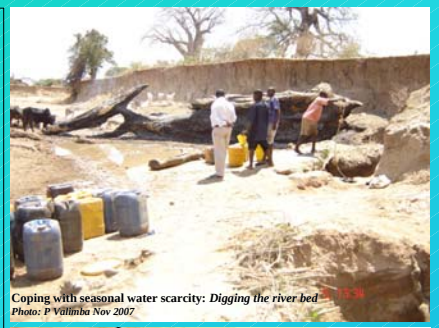
DATA AVAILABILITY AND METHODS

DATA AVAILABILITY

- The inventory of available data is given in Table 1.

METHODS

- Long-term average daily, weekly and monthly flows were used to establish flow seasonality
- Decadal (10-year) average daily, weekly and monthly flows were used to investigate changes of flow regime over the last 5 decades (1950s – 2000s)
- Linear trend analysis was used to establish direction of change of low and high flow indices (average flows, flow minima, flow maxima during month of highest flow, frequency of flows above flood flow (Q5) and low flow (Q70) indice)
- The study uses hydrological year (1st October – 30th September) and the starting day and week were 1st October and 1st - 7th October respectively
- Only available observations were used and no record extensions were involved. In-record filling was used to fill missing observations.



Coping with seasonal water scarcity: ***Digging the river bed***
Photo: P Valimba Nov 2007

Fig 1: Location of selected flow gauging stations for the study.

Table 1: Inventory of streamflow records and availability of daily data in selected catchments.

Sno.	Code	River	Location	Lat	Long	Area (km²)	Available record
1	1B4A	Umba	Mwakijembe D/S	-4.5139	38.8917	7130	Feb 1963-Sep 2002
2	1C1	Sigi	Lanconi Estate	-5.0139	38.7997	705	May 1957-Jun 1990
3	1DA1A	Luengera	Korogwe	-5.1333	38.5750	800	Aug 1953-Feb 1995
4	1DC2A	Ruvu	Tanga Road Bridge	-3.5250	37.4667	3368	Jul 1952-Dec 1991
5	1DD1	Kikuletwa	Blw Weruweru conf	-3.5167	37.2833	2849	May 1952-Feb 2005

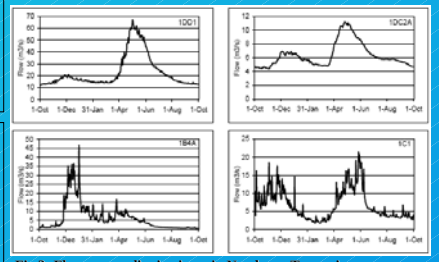


Fig 2: Flow seasonality in rivers in Northeast Tanzania.

Table 2: Changes (%) in average monthly flows in selected rivers in Northeast Tanzania relative to the 1950s averages.

Month	1DD1			1DC2A			1C1		
	1960s	1970s	1980s	1960s	1970s	1980s	1960s	1970s	1980s
Oct	58.9	76.5	148.9	17.3	7.7	6.9	54.1	24.4	61.9
Nov	160.6	80.5	132.2	42.7	21.3	18.0	138.4	0.6	46.1
Dec	96.3	49.5	117.0	67.5	33.8	55.2	-41.7	-53.0	-36.2
Jan	94.4	80.6	102.9	58.6	29.7	16.0	-33.1	15.1	-31.7
Feb	39.7	67.7	69.2	5.1	18.7	-15.6	-24.3	-40.6	-52.5
Mar	83.9	90.1	102.6	34.5	17.1	-17.6	-33.8	-70.6	-73.6
Apr	90.1	121.6	60.1	143.3	71.7	40.6	7.9	4.7	-4.6
May	9.2	16.9	22.5	30.0	13.1	32.4	4.7	9.1	24.2
Jun	29.5	47.6	48.4	8.6	0.6	-0.5	31.7	0.7	-18.4
Jul	47.8	74.1	76.1	-2.3	-12.1	-8.6	-12.6	-22.4	-2.8
Aug	39.3	67.9	102.5	-3.9	-15.7	-5.9	-52.4	-63.2	-37.5
Sep	9.5	38.5	61.6	-2.3	-13.8	-11.3	-24.0	-34.3	-13.4

FLOW SEASONALITY

- Average flows indicate spatially variable patterns of seasonal flow variations (Fig 2):
  - Predominance of bimodal flow regime in catchments upstream of the NyM reservoir (1DD1, 1DC2A) with a slight peaks in November and a main peak May following the short (October-December) and long (March-May) rains respectively.
  - Slightly bimodal in catchments (Umba, 1B4A) draining the northern part of Usambaras and Pare Mountains with the main peak December following high rainfall during the short rains.
  - Predominance of bimodal flow regime in coastal catchment (Sigi, 1C1) draining east Usambara two equally peaks in November/December and April/May resulting from the short and long rains respectively.
- The driest flows are observed in February and/or March except in the Umba basin where they are experienced in September/October.

CHANGING FLOW SEASONALITY

HIGH AND MEDIUM FLOWS

- Average high (April and May/December) flows indicated:
  - Increasing high flow peak in April/May (1DD1, 1DC2A, 1C1, Fig 3)
  - Irregular changes of medium flow peak in November/December (1DD1, 1C1, Fig 3)
  - Absence of shifting peaks (Fig 3)
  - Consistent increase of average May flows at 1DD1, 1DC2A and 1C1 (Fig 3) of 4-33% relative to 1950s averages (Table 2) and December flows at 1B4A (Fig 3)
  - Declining average April flows after the 1960s increase (Table 2)
  - Average flow changes were contributed by a combination of persistent reduced/augmented high flows and attenuated/amplified low peak (Fig 4)
- Time series analysis of high flow indices (Fig 5) indicated:
  - Declining high flow peaks at 1DD1
  - Relatively unchanged high flow peak at 1DC2A
  - Amplifying high flow peak at 1B4A and 1C1.

LOW MEDIUM FLOWS

- Average low (February and March/ September and October) flows (Figs 3, 4) indicated:
  - Relatively no changes of low flow regime in catchments with low flows in September/October (1B4A) and February/March (1DD1)
  - Consistent declining and shifting low flows at 1C1
- Time series analysis of low flow indices (Fig 6) indicated:
  - Amplifying low flows at 1DD1 and 1B4A.
  - Declining low flows at 1DC2A and 1C1.

CHALLENGES TO WATER RESOURCES MANAGEMENT

Among the implicated challenges of the identified seasonal flow regime changes to water resources management include:

- Provision for dynamic nature of flow regime in water allocations for various uses
- Provision for dynamic nature of flow regime in reservoir inflow estimations

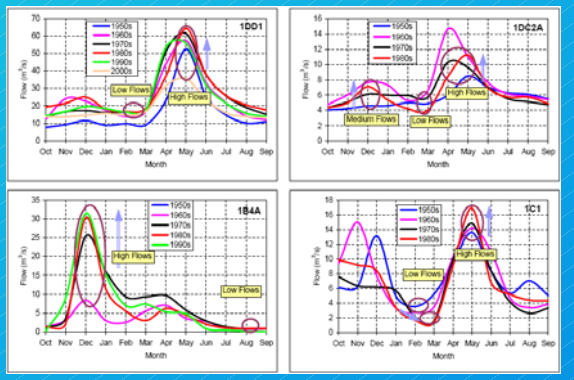


Fig 3: Changing monthly flow seasonality in selected catchments in northeast Tanzania. Allows show the nature of change (increase: up; decrease: down).

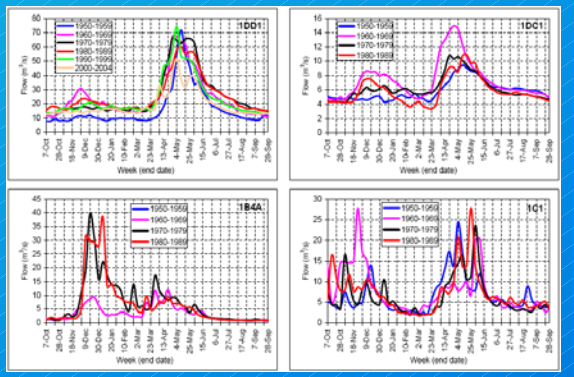


Fig 4: Changing weekly flow seasonality in selected catchments in northeast Tanzania.

CONCLUSIONS

- This study has indicated the spatially variable patterns of seasonal flow variations in northeast Tanzania with flow peaking in April/May in most parts of northeast Tanzania and in December in rivers draining the northern part of the Eastern Arc Mountains.
- The study has also indicated augmenting high flows in May and low flow reduction and/or shifting occurrence from February to March.
- The changes were contributed mainly by persistent high/low flows and sometimes by augmenting/declining high flows.

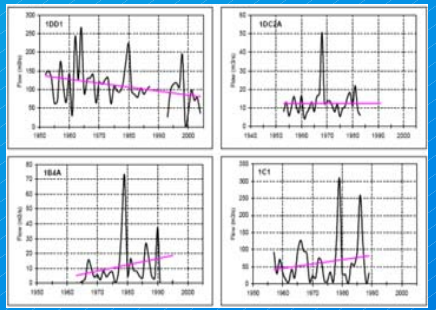


Fig 5: Multi-year variability of maximum May flows in selected catchments in northeast Tanzania.

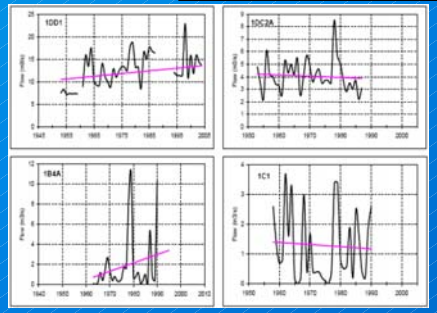


Fig 6: Multi-year variability of minimum March flows in selected catchments in northeast Tanzania.

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