Derivation of upstream precipitation values for main water supply schemes in the SMMRB

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Several water intakes from rivers and streams for drinking water supply exist in the the Sio-Malaba-Malakisi River Basin in the border region between Kenya and Uganda. These include

- Lirima Gravity Flow Scheme (1)
- Manafwa - Tororo Gravity Flow Scheme (2)
- Malaba Kenya (5)[1]
- Malaba – Tororo (7)
- Busia – Mundika Water Supply (Sio) (15)

The numbers in brackets refer to the (sub-) watersheds assigned to the single water intakes and are shown in Figure 1. Table 1 and Table 2 give basic statistics of the watersheds and water intakes.

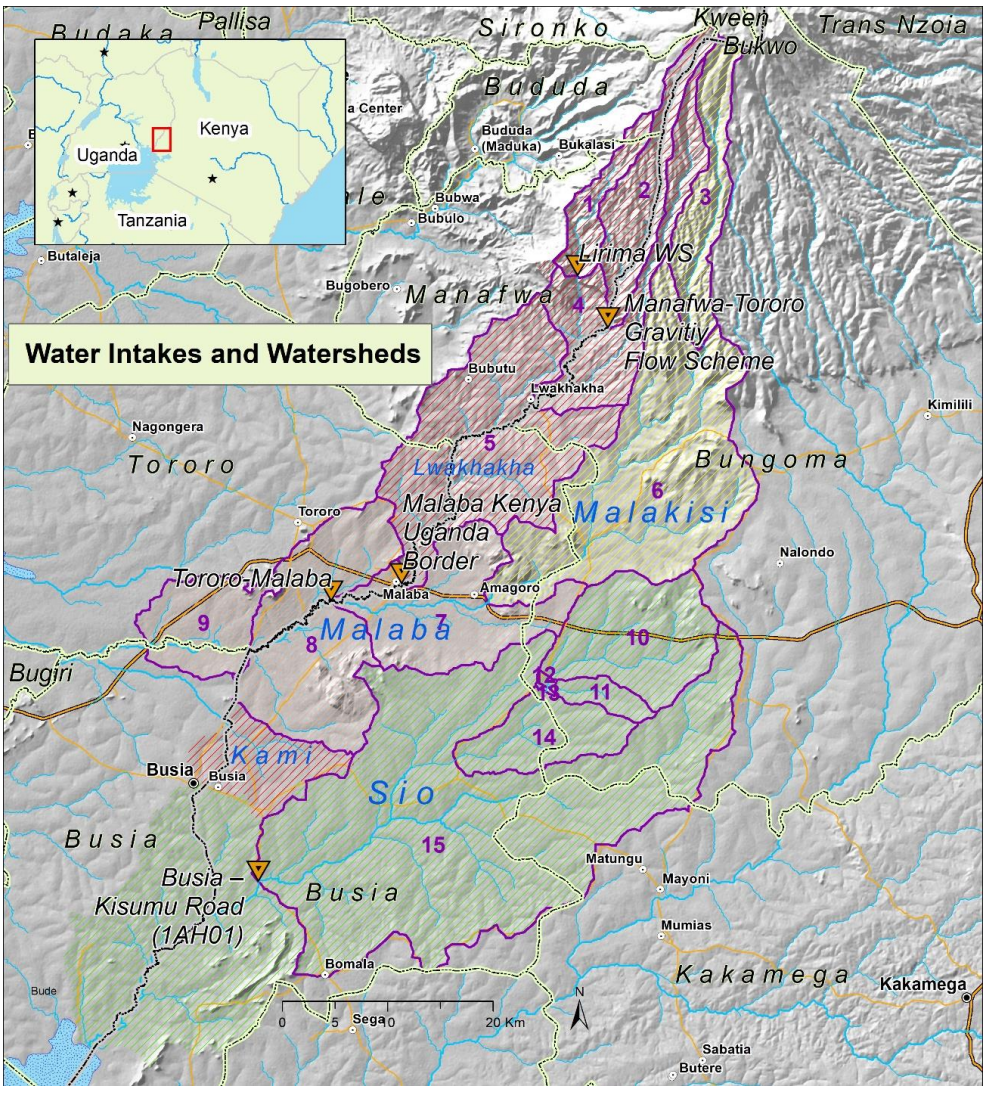

Figure 1: Location of water intakes in the SMMRB, including delineated sub-watersheds

[1] The location of Malaba-Kenya is not verified and results should be take with caution.

Table 1: Statistics of delineated sub-watershed and watersheds, including upstream areas

ID	River	*Sub-watershed*					*Watershed, including upstream areas*				
		Area (km²)	**Elevation (m)**	**Slope (°)**			**Area (km²)**	**Elevation (m)**	**Slope (°)**		
		-	mean	mean	min	max	-	mean	mean	min	max
1	Lwakhakha	43.0	2566	13.0	0.1	41.3	43.0	2566	13.0	0.1	41.3
2	Lwakhakha	93.5	2849	12.6	0.1	48.2	93.5	2849	12.6	0.1	48.2
3	Malakisi	92.4	2934	13.0	0.1	39.7	92.4	2934	13.0	0.1	39.7
4	Lwakhakha	138.4	2057	9.6	0.2	57.7	275.0	2406	11.2	0.1	57.7
5	Lwakhakha	297.9	1352	3.9	0.0	29.8	572.9	1858	7.4	0.0	57.7
6	Malakisi	370.0	1568	5.7	0.0	43.1	462.3	1841	7.1	0.0	43.1
7	Malaba	168.2	1215	2.3	0.0	26.1	1203.4	1761	6.6	0.0	57.7
8	Malaba	225.6	1179	2.7	0.0	33.2	1429.0	1669	6.0	0.0	57.7
9	Malaba	90.0	1129	1.7	0.0	34.0	1519.0	1637	5.7	0.0	57.7
10	Naliwatsi	147.1	1346	2.3	0.0	19.4	147.1	1346	2.3	0.0	19.4
11	Naliwatsi	22.4	1302	1.7	0.0	4.9	22.4	1302	1.7	0.0	4.9
12	Naliwatsi	2.0	1253	1.5	0.1	3.4	171.5	1339	2.2	0.1	3.4
13	Naliwatsi	0.8	1253	1.7	0.3	3.9	172.4	1338	2.2	0.0	19.4
14	Naliwatsi	83.5	1257	1.5	0.0	4.2	255.8	1312	2.0	0.0	19.4
15	Sio	753.9	1256	1.8	0.0	25.0	1009.7	1270	1.8	0.0	25.0

Table 2: Summary statistics of water supply watersheds

ID	River	*Watersheds of water intakes*					*Water supply scheme*	
		Area (km²)	**Elevation (m)**	**Slope (°)**				**Elevation (m)**
		-	mean	mean	min	max		Intake (approx.)
1	Lwakhakha	43.0	2566	13.0	0.1	41.3	Lirima Gravity Flow Scheme	1912
2	Lwakhakha	93.5	2849	12.6	0.1	48.2	Manafwa - Tororo Gravity Flow Scheme	1571
5	Lwakhakha	572.9	1858	7.4	0.0	57.7	Malaba Kenya	1142
7	Malaba	1203.4	1761	6.6	0.0	57.7	Malaba – Tororo	1118
15	Sio	1009.7	1270	1.8	0.0	25.0	Busia – Mundika Water Supply	1161

For analysing the potential connection or correlation between raw water at the intakes and precipitation, mean catchment precipitation values were derived for the upstream areas of each intake. In a first step, the orographic watersheds (Figure 1, Table 1) were derived in ArcGIS using layers from the MERIT Hydro dataset (Yamazaki et al., 2019) as a basis. Also the locations of the water supply schemes were used as (sub-) watershed outlets or pour points (Table 2). Using these (sub-) watersheds and Google Earth Engine (Gorelick et al., 2017), mean daily areal precipitation values for the period 1981-2019 were extracted from the CHIRPS Daily v2 dataset (Funk et al., 2015). “Climate Hazards Group InfraRed Precipitation with Station data” (CHIRPS) is a 30+ year quasi-global rainfall dataset. CHIRPS incorporates 0.05° resolution satellite imagery (infrared Cold Cloud Duration (CCD) observations) with in-situ station data to create gridded rainfall time series for trend analysis and seasonal drought monitoring.

For watersheds of water intakes, which constitute of several upstream sub-wastersheds, e.g. Malaba-Tororo, area weighted means were of monthly precipitation was calculated for the period 1981-2019. Derived from this data, Figure 2 and Table 3Table 1 show the long-term precipitation climatology for the watersheds. The seasonality in the areas are quite similar, showing to rainfall peaks around April and October. The Sio catchment (Busia water supply), being the wettest with a mean annual precipitation of 1836 mm, shows a more distinct peak in April and higher sums in the long rainy season from March to May/June.

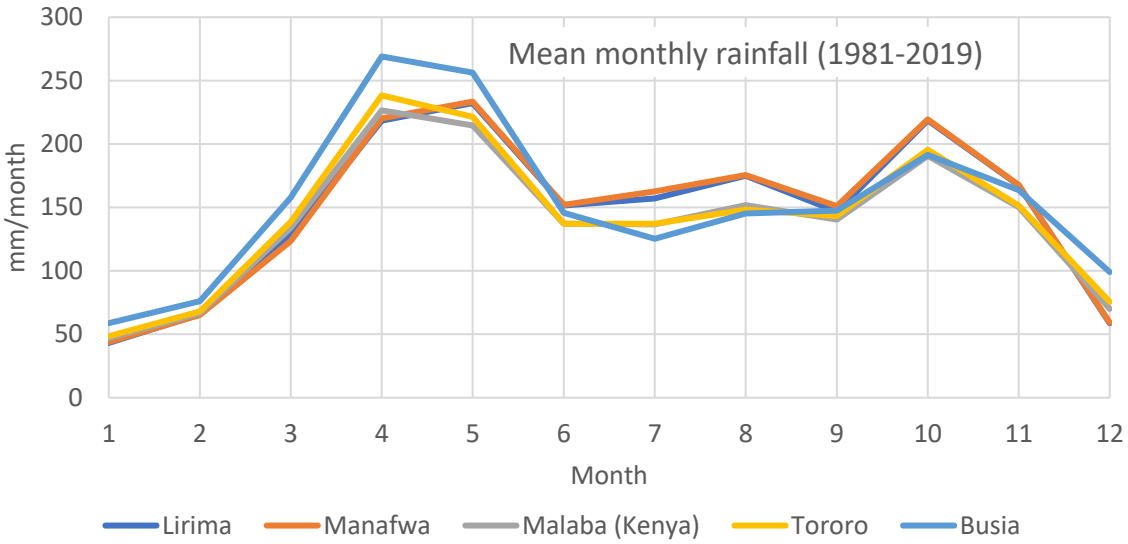

Figure 2: Long-term mean monthly precipitation (1981-2019) for the watersheds upstream of the water intakes

Table 3: Long-term mean monthly and annual precipitation in mm evaluated for the period 1981-2019 for the watersheds upstream of the water intakes

Rainfall for water supply scheme watersheds (mm)

Month	Lirima	Manafwa	Malaba (Kenya)	Tororo	Busia
1	43	44	47	48	59
2	66	65	67	68	76
3	128	124	134	139	158
4	219	220	227	238	269
5	232	233	215	221	256
6	152	152	137	137	146
7	157	163	137	137	125
8	175	176	152	148	145
9	147	151	140	143	147
10	219	219	191	195	192
11	168	168	150	152	164
12	59	59	70	76	99
1-12	1763	1774	1665	1703	1836

Figure 3 shows the time series of precipitation for the years 2017-2019. Compared to the long-term mean monthly values, the years 2017-2019 showed drier and wetter conditions (Figure 4). The mean annual sums for the years was around 10 to 15% higher, compared to the long-

term average. 2017 and 2018 showed significantly higher sums in the rainy season around April. In contrast, the year 2019 was mostly much drier in the long rainy season, but showed extremely higher precipitation values beginning with September 2019.

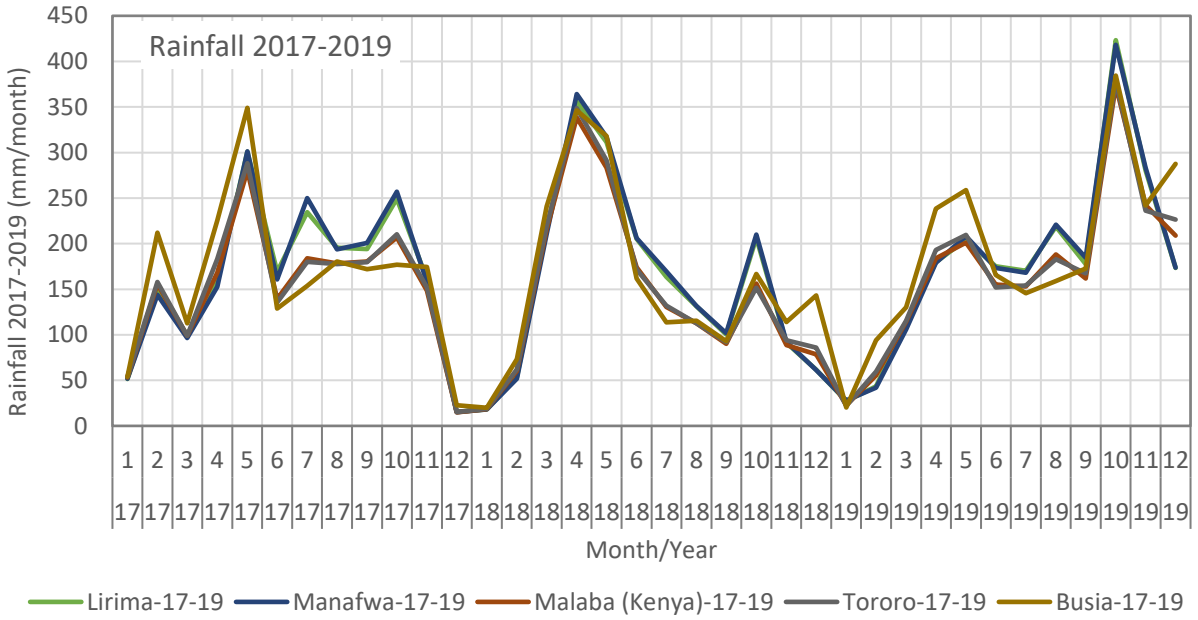

Figure 3: Rainfall in the years 2017-2019

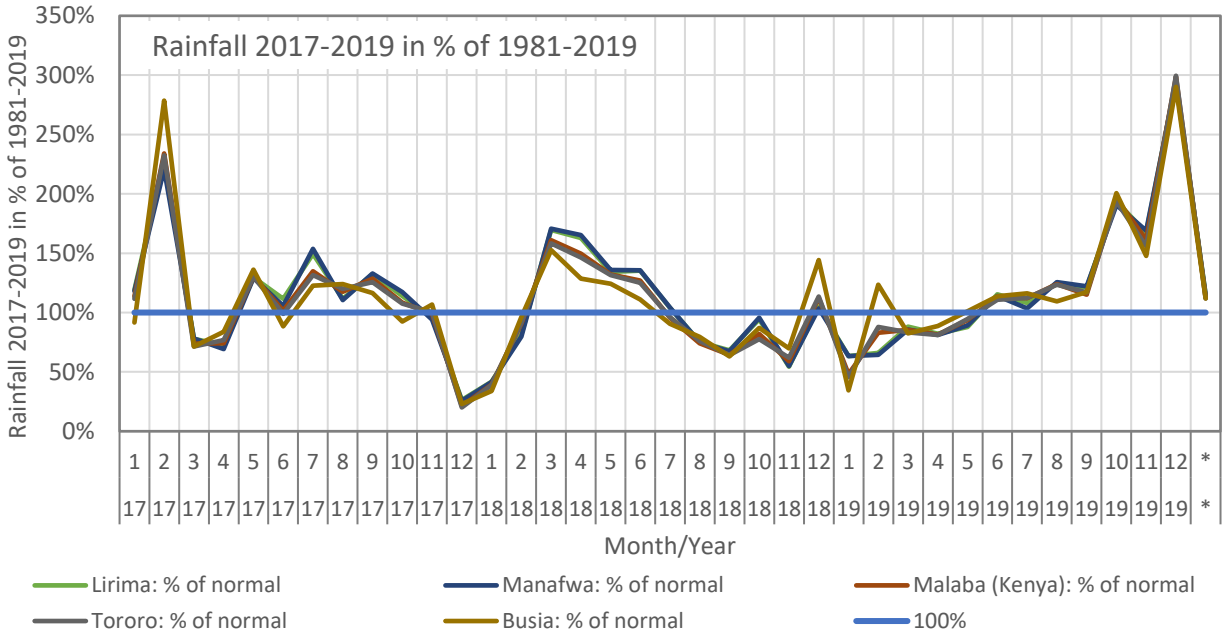

Figure 4: Monthly rainfall in the years 2017-2019 in comparison to long-term mean monthly values in the period 1981-2019. The value marked with an asterisk (*) indicates values for the years 2017-2019. Values above 100% indicate wetter conditions in 2017-2019 an vice versa.

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