Annex 2 Feasibility Study | Appendix 4

Water Balance Analysis

For FAO-GCF project ''Climate Resilient Agriculture in Somalia''

2024

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. Introduction

1.1. Purpose

Somalia is prone to frequent droughts and flooding and the country is characterized by high mean annual temperatures and low annual rainfall totals. High variability in rainfall also impacts the country's agricultural output and food security. The purpose of this project was to evaluate the hydrologic water balance for two districts located in different agroclimatic regions.

Data availability in Somalia post-civil war is very limited. The FAO Somalia Water and Land Information Management (SWALIM) began collecting historical data during the early 2000s and were able to locate the pre-war records for both meteorological and hydrometric stations. SWALIM also began to reestablish meteorological stations and hydrometric stations at key locations in the mid-2000s. However, due to the security situation in Somalia, improved automatic weather stations were only installed post-2014 for majority of the country.

1.2. Scope

The objective of this report is to complete a water balance assessment of two districts within the country: Afgooye district and Odweyne district. The two districts are distinctly different in terms of altitude, agro-ecological zone, rainfall patterns, and soils. The climate zone in Odweyne is classified as arid while the climate for Afgooye is semi-arid. The two locations were selected as representative areas for the arid and semi-arid climate zones.

Afgooye district is located along the banks of the Shabelle River and is one of the key agricultural hubs in the country. The Afgooye district area is 3,929 kilometer square and situated between the towns of Balad along the northeastern limits and Awdhegle along southwestern limits. The southern limit for the district extends to the Indian Ocean and abuts the Mogadishu city limits. There are both rainfed and irrigated agricultural fields within the district. Refer to Figure 1 for a location map. Figure 2 is a vicinity map of Afgooye district and includes the contributing watershed.

Conversely, Odweyne district, located in the northwest of the country, is mostly arid. The district is situated in the Togdheer region, in the valley just south of the mountainous area. Odweyne district area is 8,351 kilometer square and extents from Sheikh along the northern boundary to the Somali national boundary limits to the south. There are numerous ephemeral streams and agro-pastoralist communities along the alluvial plains that practice both rainfed and irrigated agriculture. Refer to Figure 3 for a vicinity map of Odweyne. Odweyne district is part of the larger Ogaden basin that outfalls into the Indian Ocean. Odweyne district is an administrative boundary that does not correspond to a hydrologic divide. Figure 3 also includes an inset showing the elevation range within the Odweyne district limits.

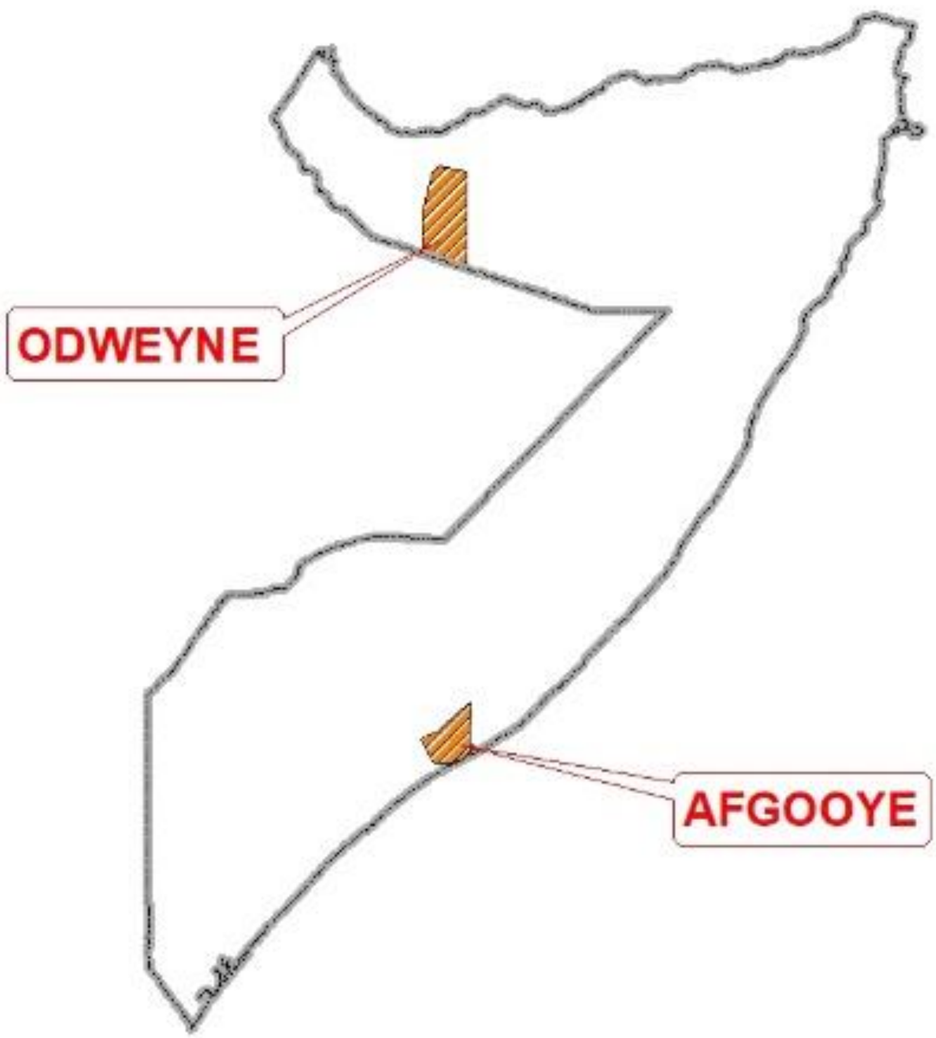


Figure 1: Location Map

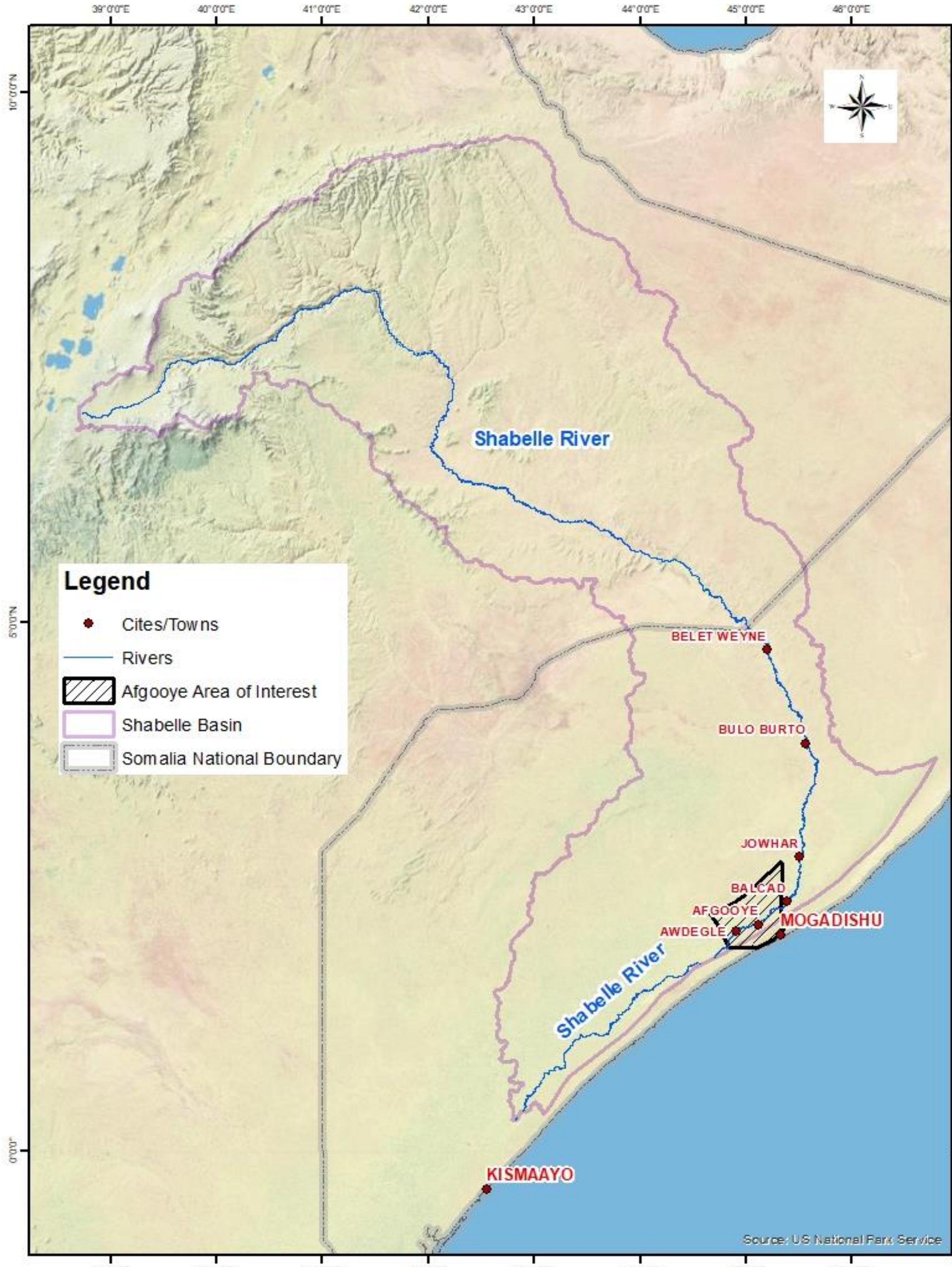


Figure 2: Afgooye District Area of Interest

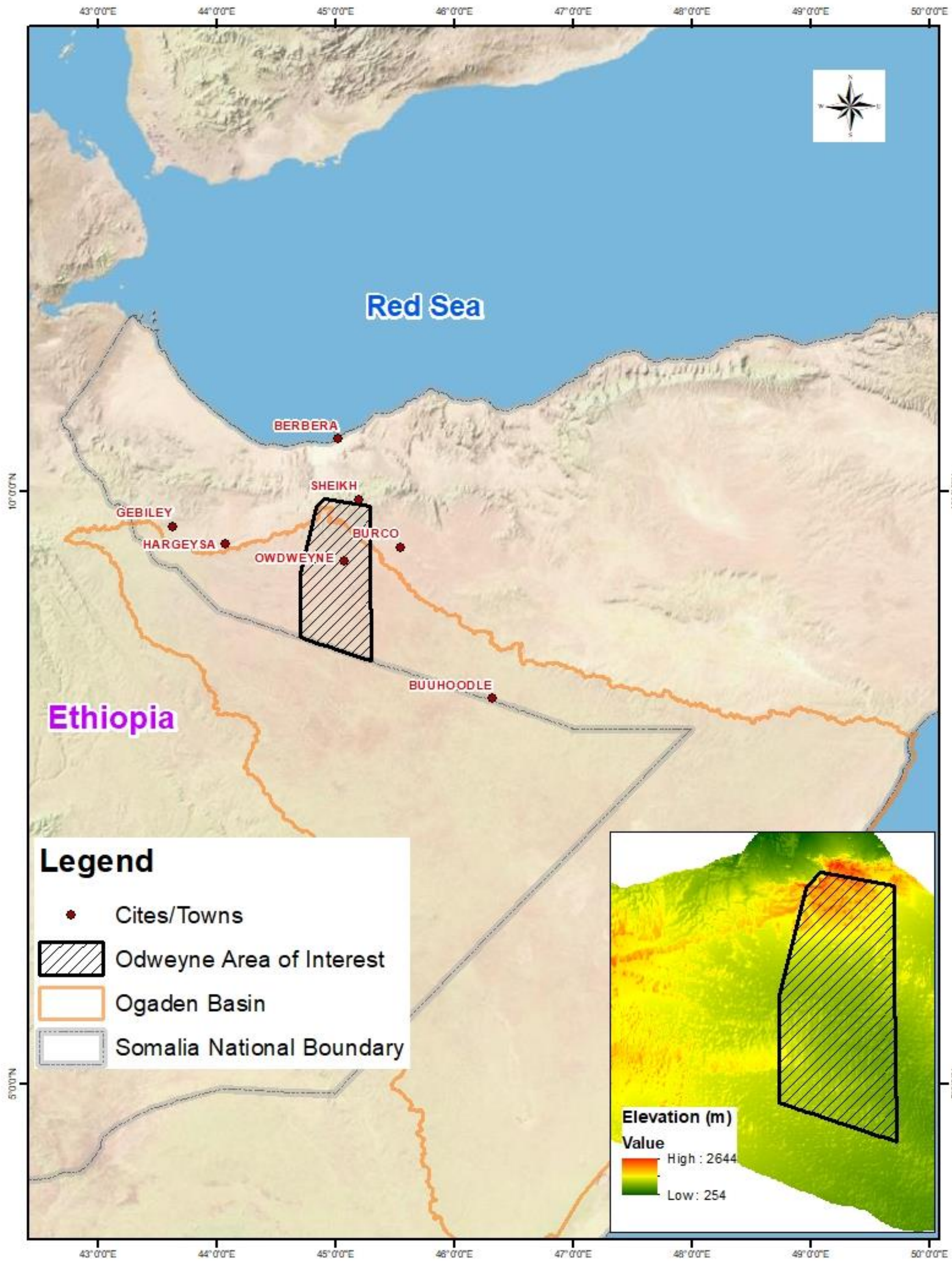


Figure 3: Odweyne District Area of Interest

2. Literature Review

SWALIM has completed numerous reports pertaining to water resources assessments and land use/land cover classifications. Additionally, soil surveys and hydrogeological surveys have been conducted. Several reports were reviewed in this analysis as part of the data collection effort. Technical Report No. W-01 and Technical Report No. W-11 are the primary documents referenced in this analysis. Technical Report No. W-01, completed in 2007, focused on the overall climate of the country (Muchiri, 2007). Project Report No. W-11, titled "Water Resources of Somalia," provided comprehensive information on the available water resources nationwide, including water uses and demand (Basnyat, 2007).

The full list of publications reviewed are outlined below:

- W-11 – "Water Resources of Somalia" (Basnyat, 2007) was the main report used in this analysis for reference. The report included a countrywide hydrologic assessment and detailed water demand for main cities.
- W-01 – "Climate of Somalia" (Muchiri, 2007) provided a summary of climate data for the entire country and included long-term mean values for rainfall, temperature, potential evapotranspiration, and other climate parameters.
- W-20 - "Hydrogeologic Survey and Assessment of Selected Areas in Somaliland and Puntland" (FAO SWALIM, 2012). This report included detailed hydrogeologic testing for select areas of interest, including evaluation of groundwater recharge and flow.
- W-22 "Water Demand Assessment for the Juba and Shabelle Rivers." (Petersen 2012)." This project included water demand analysis for areas along the Juba and Shabelle rivers.
- Hydrometry Project of Somalia – Mott McDonald & Partners (MacDonald, 1990). This report provided a compilation of stream flow data for all stations along the Juba and Shabelle rivers. For most stations, daily data was available from 1963-1989.
- Climate Hazard Assessment (FAO/OCB, 2022). This assessment included evaluation of future climate impacts using regional models and assessment of short-term and longer-term potential impacts.

3. Climate/Background

The climate condition in Somalia is influenced by the northward and southward movement of the Inter-Tropical Convergence Zone (ITCZ). The ITCZ passes over Somalia twice a year, corresponding to the two rainfall seasons: the Gu and Deyr. The Gu season occurs from late March to June when the ITCZ moves northward over the area, while the Deyr season occurs from October to November as the ITCZ moves southward (W-01 Muchiri, 2007).
Within the country, there is variability in the rainfall totals for the two rainy seasons, as well as in their duration and onset. In addition to the Gu and Deyr seasons, there are also light showers along the coastal areas during the Haggai season between the two rainy seasons (July –

September). The northwestern part of the country, west of Hargeisa, also receives rainfall during the Haggai season. Jilaal is the dry season in most of the country, occurring from December to mid-March.

Somalia's weather is also influenced by oceanic processes such as El Niño and the Indian Ocean Dipole.

4. Methodology

The methodology to complete the water balance analysis in this report varied depending on the available data. Afgooye and Odweyne district limits correspond to administrative boundaries which do not coincide with the hydrologic basins. Afgooye district is part of the Shabelle River watershed which extends to Ethiopian highland, refer to Figure 2. Afgooye district is located along the lower reach of the Shabelle River basin before outfalling into the Juba River and ultimately to the Indian ocean. Odweyne district is located in the Ogaden basin which also originates within Ethiopia. The flow concentrates in ephemeral streams before outfalling into the Indian ocean. The methodology for the hydrologic analysis for the two districts is outlined below.

4.1. Afgooye District

Detailed hydrologic analysis was not completed due to data gaps and inconsistencies. The contributing area to Afgooye is more 200,000 square kilometers and extends to Ethiopia. Stream flow data is only available for two stations within Somalia, near the Ethiopian border. Based on the limitations, the following approach was used in Afgooye district.

i. Available measured climate data was collected and compared against global datasets. The global climate dataset used included CHIRPS, IMERG, MODIS 16 and MODIS-21. ERA-5 rainfall dataset was used in initial comparisons.
ii. Historical (1963-1990) analysis by FAO SWALIM reports such as W-01 and W-11 were evaluated and compared against recent (2005-present) climate data.
iii. Historical (1963-1990) stream flow data was compared for upstream and downstream stations.

4.2. Odweyne District

Historical analysis or data was not available for this part of the country. A Soil & Water Assessment Tool (SWAT) model was developed for the watershed.

i. DEM - Global SRTM 30 m.
ii. 6 FAO SWALIM rainfall stations within the watershed were used to determine the areal distribution of rainfall.
iii. For temperature only Burco station was used. Global datasets were used for the remaining climate inputs into SWAT model.
iv. Land cover – FAO SWALIM Odweyne and Burco land cover land suitability analysis.
v. Soil survey at 250K and 100K by FAO SWALIM were reviewed.

5. Data Collection/Analysis

The purpose of the data collection effort was to evaluate the available data and determine suitability in the water balance assessment. Climate data and physical watershed characteristics are vital in completing hydrologic analysis and water balance. Groundwater information such as baseflow, recharge rate and aquifer extents are also a vital component of the water balance analysis. For this analysis the key focus was on climate data, particularly rainfall and temperature and physical parameters that influence the response for surface water hydrology. There are no groundwater monitoring stations within the area of interest and reliable groundwater data was not available.

5.1. Rainfall

5.1.1. Afgooye District

As mentioned above, there is variability in rainfall totals and patterns within the country. Therefore, it is crucial to review the rainfall patterns for the two districts independently. To evaluate the rainfall for Afgooye and the surrounding area, SWALIM rain gauges at Afgooye, Balad, Mogadishu, and Jowhar were reviewed. Prior to the civil war, there were also other functioning nearby gauges such as Genele, which have since become obsolete. The Afgooye rainfall station was reestablished in 2005 and was functional until 2019. Within this period, there were numerous gaps in the data from 2014-2019, with significant data missing. There were also gaps from 2005-2014, and continuous data is only available for 8 years within that period. CHIRPS satellite-based precipitation data was utilized for comparison against the rainfall gauge data and to review any rainfall trends. Figure 1 compares the annual rainfall pattern between the CHIRPS satellite product and the Afgooye gauge station. CHIRPS data represents the mean over the Afgooye area of interest. Note that the red dots denote years with missing data for one or both rainy seasons. See figure 27 in the appendix for location of new and historical rain gauges.

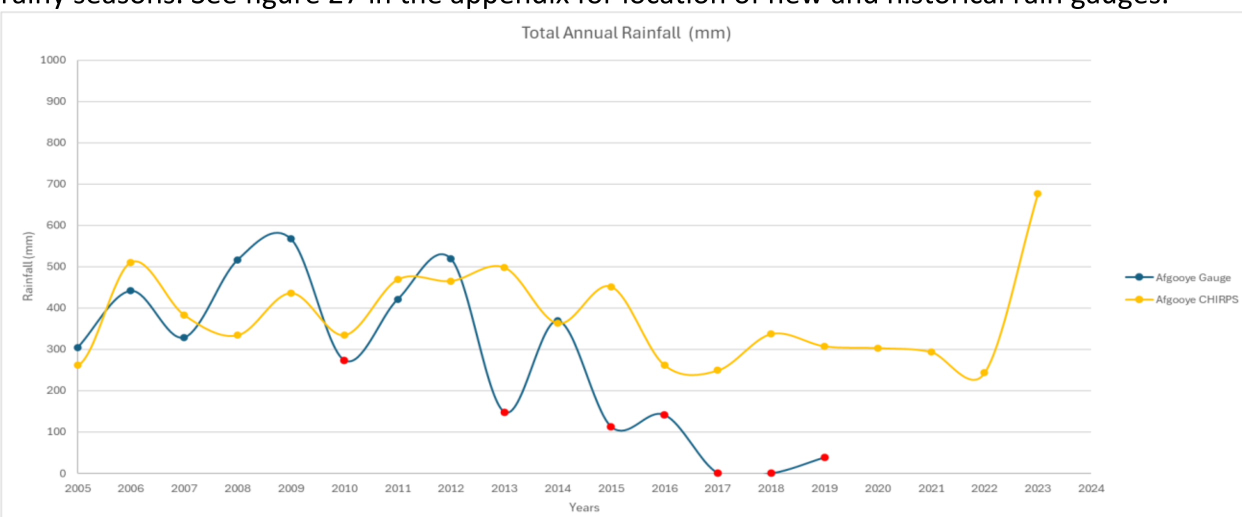


Figure 4: Annual Rainfall Comparison for Afgooye Gauge and CHIRPS Satellite[1]

[1] The differences between CHIRPS satellite and gauge station is mainly due to data missing from the gauge station for either one or both rainy seasons. For example, 2013 and 2015 is missing the Gu season. For 2017 and 2018, rainfall data is missing for the entire year.

The seasonal variation shown in Figure 5 supports the existence of the two rainy seasons in Afgooye as reported in W-01 (Muchiri, 2007) and W-11 (Basnyat, 2007). The two rainy seasons produce similar rainfall totals on average, although historically the Gu season generated higher cumulative precipitation. It is worth noting that the pre-civil war long-term mean data (1963-1990) is higher for the two rainy seasons. It is unknown whether this is related to climate patterns or data collection/input errors. Note, years with missing data for Afgooye rain gauge were removed from the analysis.

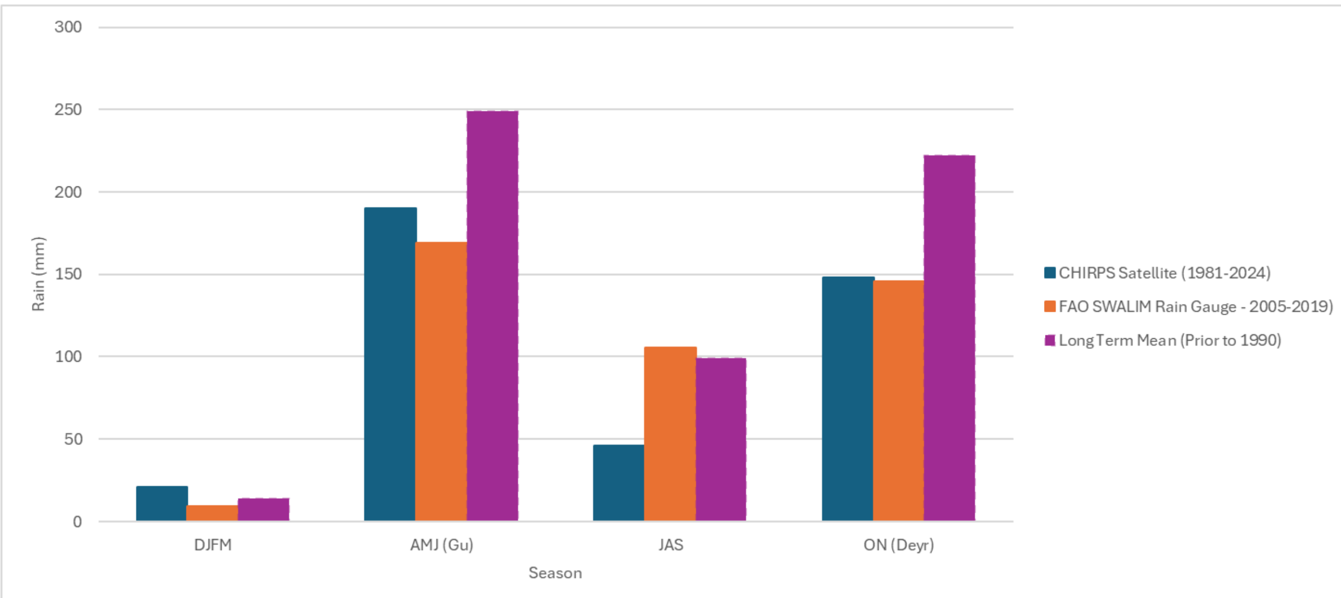


Figure 5: Seasonal Rainfall Variations for Afgooye

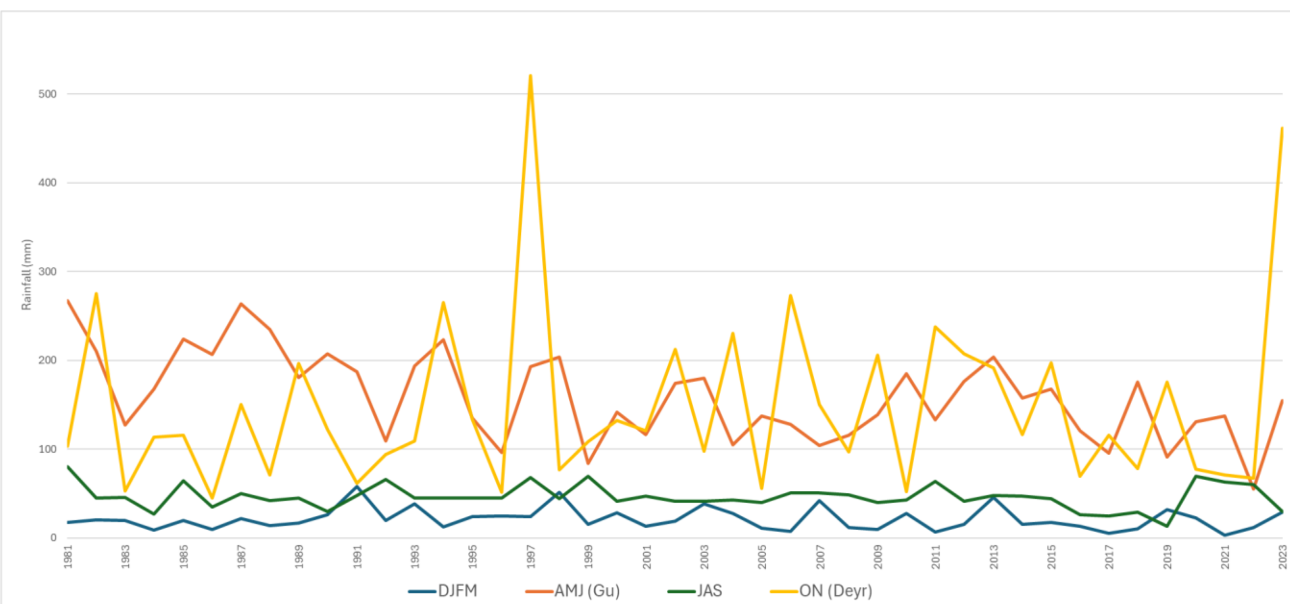


Figure 6: CHIRPS Data 1981-2023 For Afgooye

Figure 6 shows the variability in rainfall from year to year. CHIRPS satellite data from 1981 to 2023 was used in the comparison. From figures 6 and 5, it is reasonable to conclude that both Gu and Deyr produce similar rainfall totals for Afgooye District. The extreme values for 1997 and 2023 correspond to the El Nino events. The mean annual rainfall for Afgooye District is 405 mm based on long term CHIRPS data and 429 mm based on SWALIM gauge.

5.1.2. Odweyne District

The rainfall gauge at Odweyne was installed by SWALIM in 2007. Within the vicinity of Odweyne district, there are multiple rainfall gauge stations such as Burco, Gatiiley, and Waraabeye. The Gatiiley station, installed in 2019, is the closest station to Odweyne. Even though the Gatiiley station was installed recently, there are numerous gaps in the data, particularly during the rainy season. Other nearby stations were also used in the comparison, such as Sheikh, Gacan-Libah, Gebilley, and Salaxaley. Figure 7 shows annual rainfall comparison for Sheikh, Burco, and Odweyne from 2007-2023. Although Sheikh is located at a higher altitude, the station was included in the comparison due to its proximity and years of record. Similar to Afgooye, there are gaps in the data for almost all stations. For example, Sheikh is missing either partial or full annual rainfall data for 2007-2011. Besides the data gaps, another challenge is the reliability of the rainfall data since all these stations are manually operated. For example, in 2013, both Sheikh and Odweyne recorded significant rainfall for the year, over 600 mm; however, Burco, which is nearby, recorded only 305 mm. The CHIRPS satellite product also yielded 305 mm for the Odweyne district. These inconsistencies raise doubts about the reliability of the data.

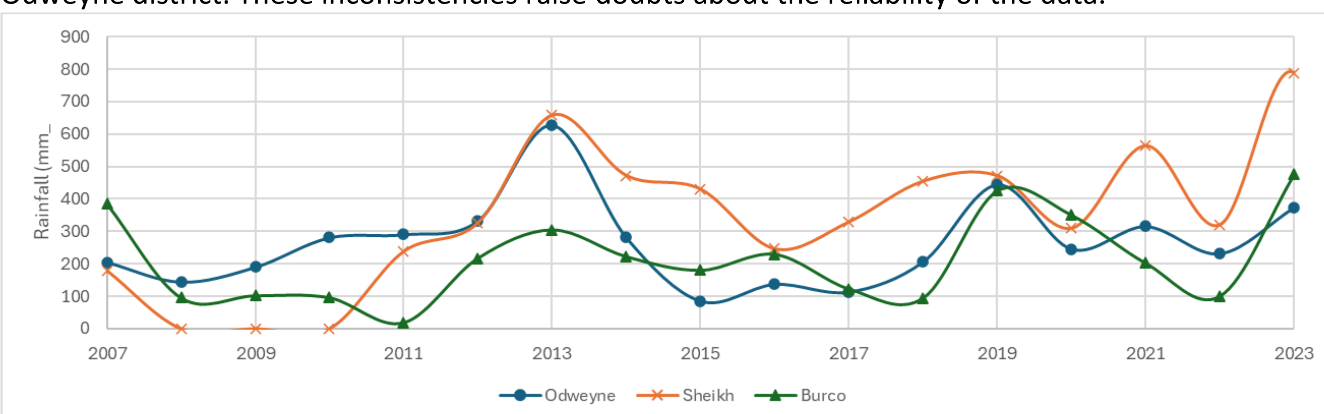


Figure 7: SWALIM Gauge Comparison Near Odweyne District

Figure 7 shows a comparison of Sheikh, Burco and Odweyne rainfall stations from 2007-2023. Sheikh station has missing data from 2007-2010 while Odweyne includes outliers for 2008 and 2015.

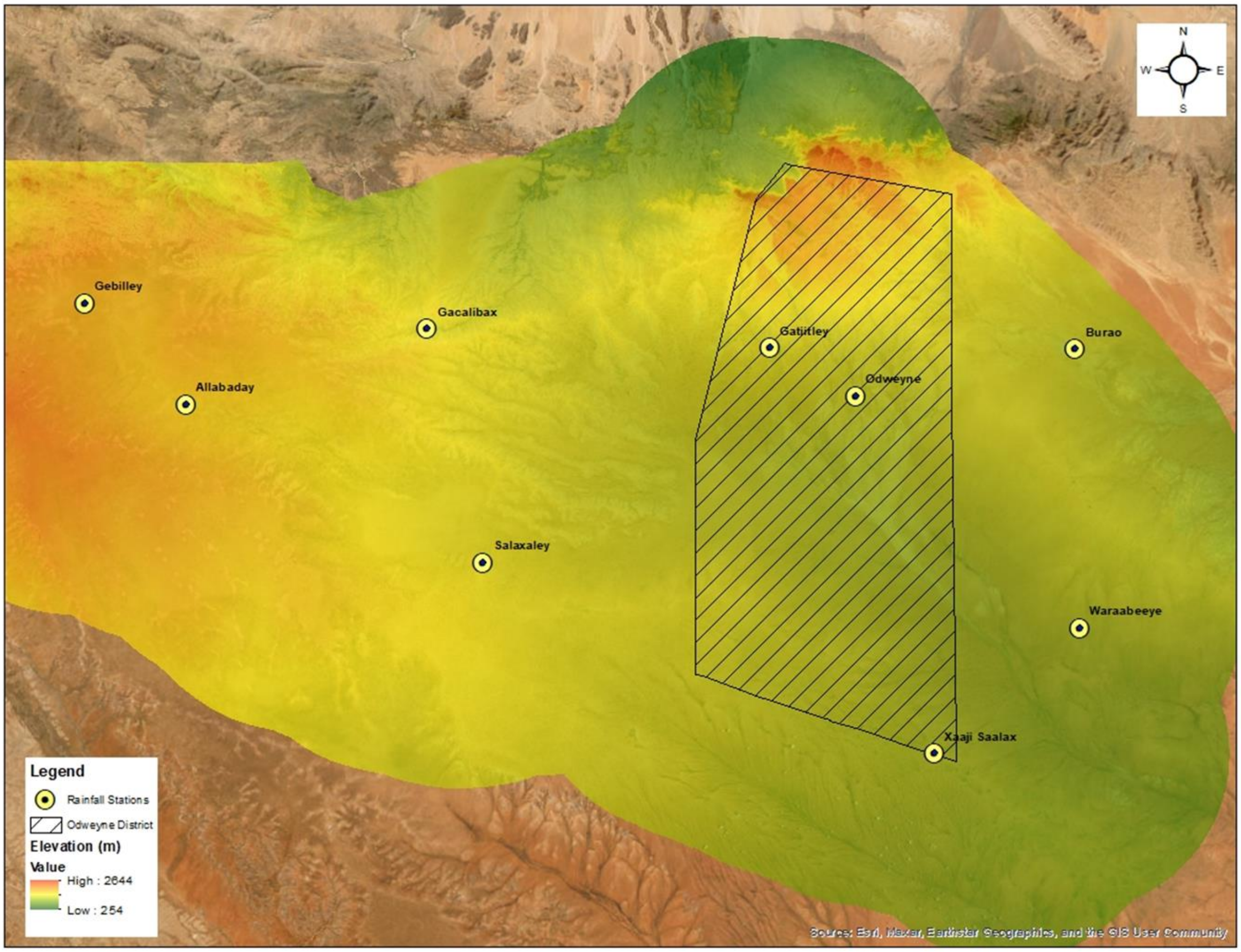


Figure 8: Odweyne District and Surrounding SWALIM Rainfall Gauge Stations

Figure 8 shows the Odweyne district rainfall stations and surrounding rainfall stations.

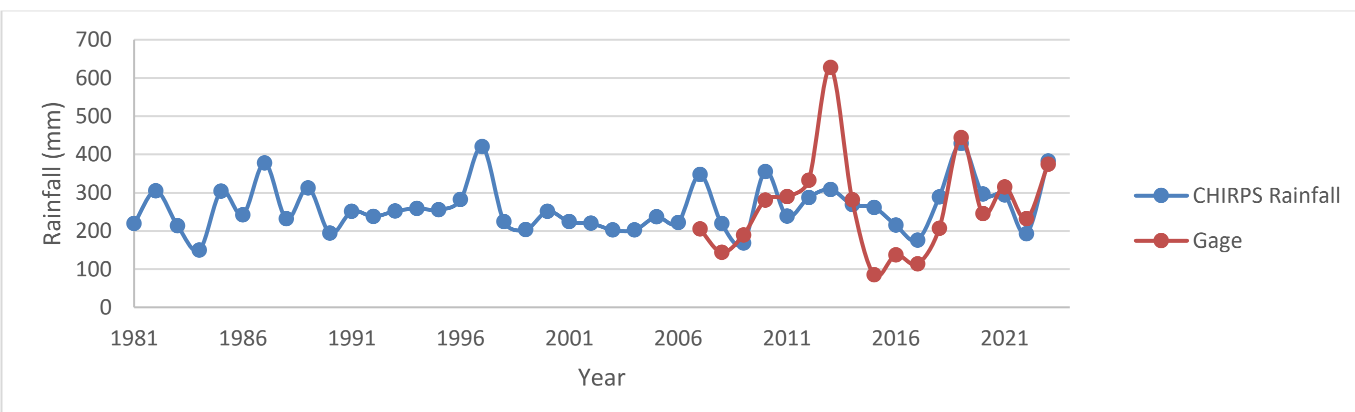


Figure 9: Annual Rainfall Comparison for Odweyne Station vs CHIRPS[2]

[2] For the outliner in 2013, CHIRPS data recorded rainfall similar to the mean for the year although the gauge for Odweyne and Sheikh both recorded significantly higher rainfall (600 mm vs 300 mm). This could be due to localized rainfall or an error in the data recording.

Figure 9 illustrates a comparison between CHIRPS data and Odweyne gauge for annual total rainfall. Figure 10 is a comparison of CHIRPS data and Odweyne gauge for the Gu rainy season.

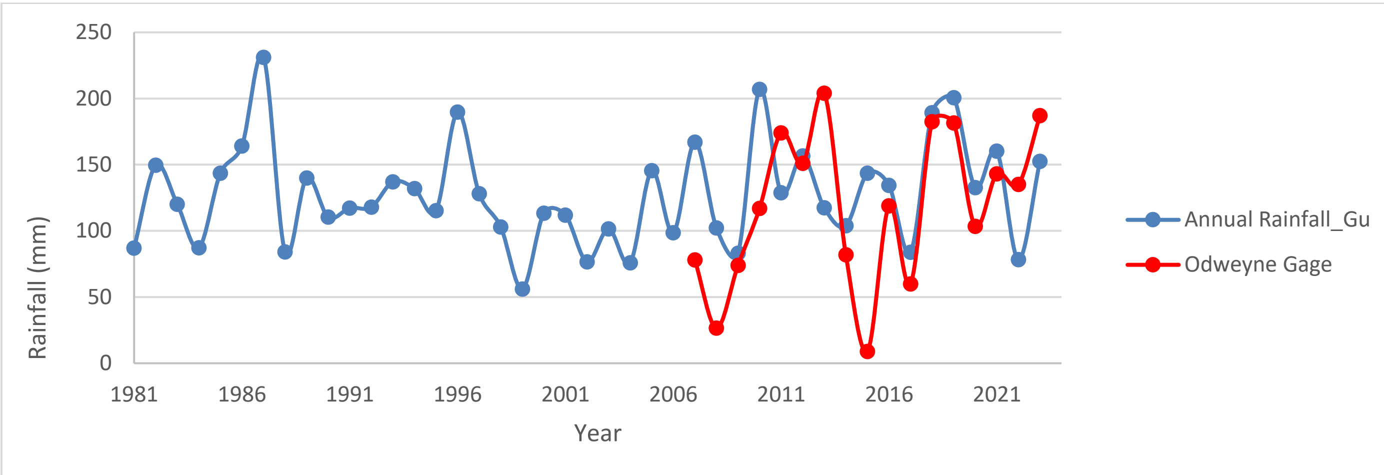


Figure 10: Comparison of Gu Season for Odweyne against CHIRPS

Figure 11 highlights the 95th percentile of all recorded daily rainfall events for the Odweyne station, corresponding to 27 mm of rainfall. The W-11 Technical Report indicates a minimum 24-hour rainfall total requirement of 5 mm for rainwater harvesting and 20 mm for surface runoff generation in smaller catchments (Basnyat, 2007). Based on that threshold, most rainfall events recorded by the Odweyne gauge did not generate runoff downstream. However, this only partially explains the watershed response, as antecedent moisture condition also a major factor in runoff generation. Therefore, consecutive days of rainfall with less than 24-hr total rainfall of 20 mm could also generate runoff.

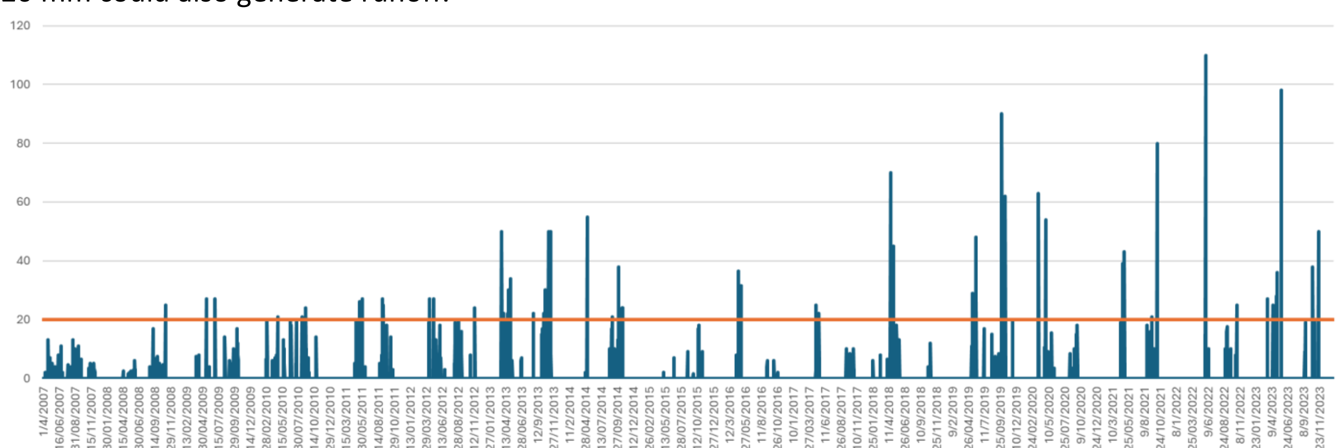


Figure 11: Odweyne Rainfall Station Daily Records

5.2. Temperature:

5.2.1. Afgooye District

Mean, minimum, and maximum daily temperatures are important parameters in determining the evapotranspiration rate for crop water requirement and water balance. SWALIM reports W-01 and W-11 include historical long-term climatic data pre-civil war, which contains monthly mean, minimum, and maximum temperature data. SWALIM has recently started to install synoptic and automatic weather gauge stations at numerous locations within Somalia. Although there is no automatic weather station at Afgooye collecting temperature data, the recently installed automatic weather station at Jowhar, located 100 kilometers away, is the closest station with recorded temperature data. The Jowhar station also collects other climatic data such as humidity, wind speed, and solar radiation. Given that Jowhar is slightly higher in altitude and Afgooye is closer to the coastal area, the differences in temperature between the two stations are deemed negligible for the purposes of this analysis. The Jowhar automatic weather station was installed in 2020, so there is only three full years of data. The mean monthly temperature for the gauge station is shown below in Figure 12. A comparison was also completed using the historical long-term mean and maximum monthly temperature data from W-01 and W-11 reports in Figure 13. Note, the long-term mean for Afgooye and Jowhar are relatively close and mean for the Jowhar station is also very close to the historical records. Another comparison was completed using MODIS terra satellite temperature product (MOD21). The MODIS data is much lower than the gauge station and long term mean.

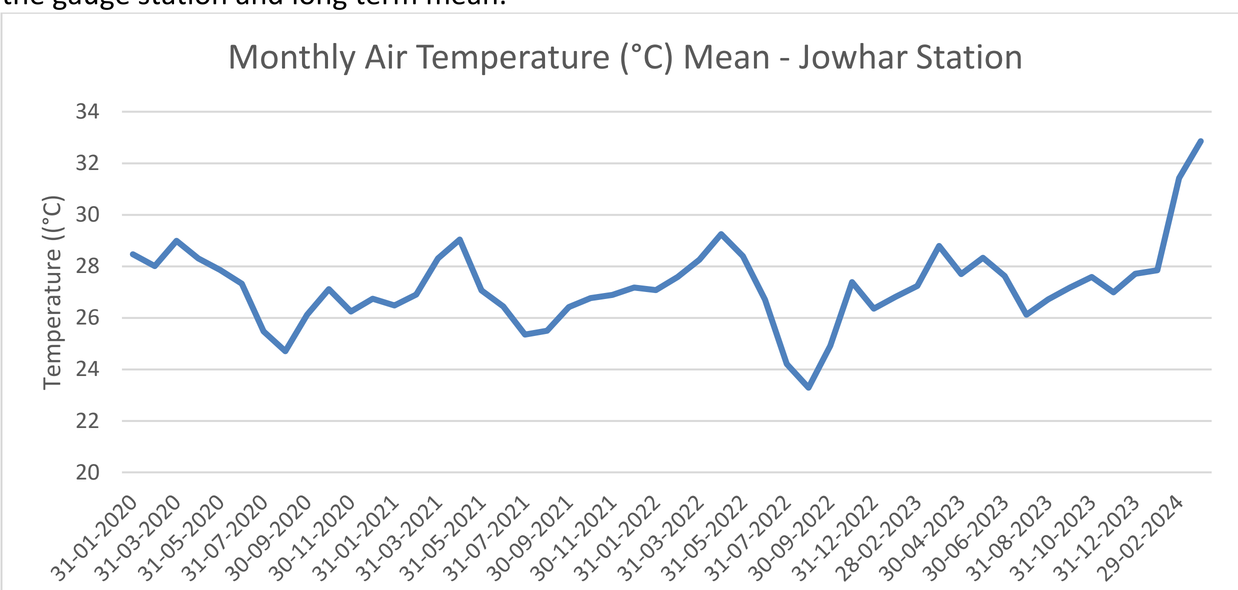


Figure 12: Jowhar Automatic Weather Station Temperature Data

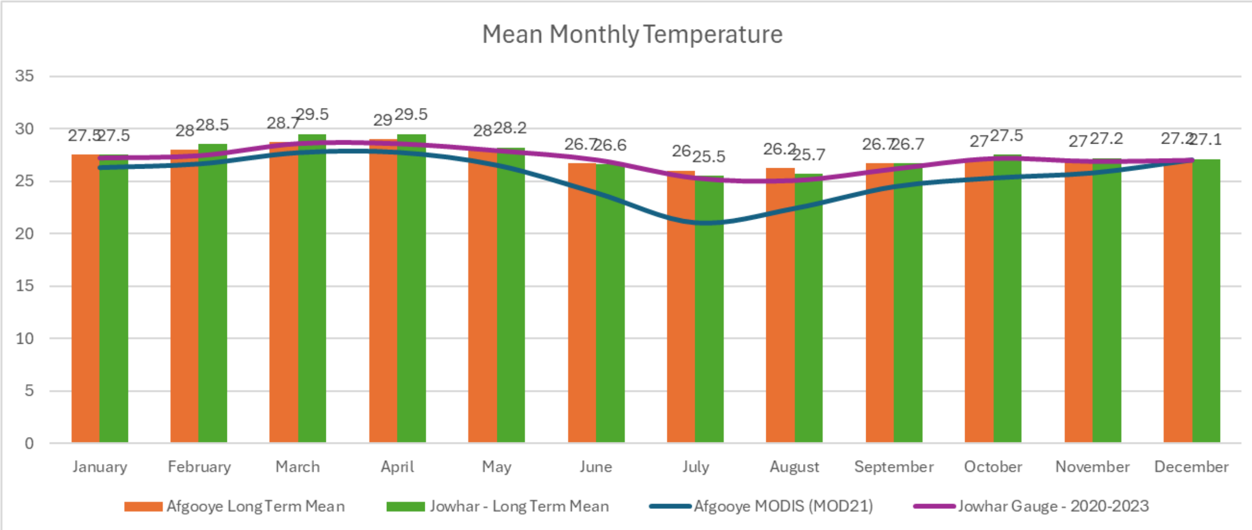


Figure 13: Mean Monthly Temperature Comparison For Jowhar Station Against Long Term Mean

5.2.2. Odweyne District

The closest automatic weather station near Odweyne is in Burco, which is approximately 55 km northeast. Additionally, there is a synoptic station at Burco owned and operated by SWALIM staff. To extract temperature information, the Burco automatic weather station was used for the period 2014-2023. The station records daily minimum, mean, and maximum temperatures. Figure 14 compares the daily maximum results to the long-term daily maximum temperature from the W-01 report. There are differences, and further investigation is warranted to evaluate any data collection issues or errors in processing. At some locations, the difference is 2°C or more, which is not possible.

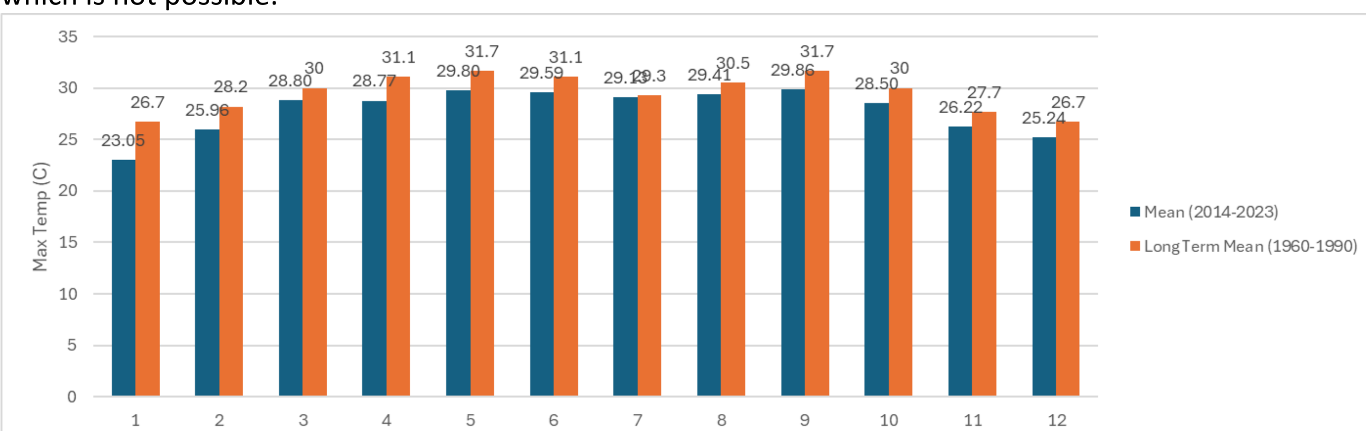


Figure 14: Burco AWS Daily Mean Maximum Temperature Against Long Term Mean

5.3. Stream flow

5.3.1. Afgooye District

Afgooye district is located at the lower reach of the Shabelle River before the confluence with the Juba River. Refer to Figure 1 location map for Afgooye district extents. The river crosses the district and flows from northeast to southwest. Prior to the civil war, there were numerous streamflow gauges along the upper, middle, and lower reaches of the Shabelle River. Currently, only the upstream stations have streamflow information (i.e., Beledweyne and Bulo Burte for the Shabelle River, see figure 2). To estimate the volume of annual streamflow at Afgooye, historical streamflow data were reviewed for Afgooye, Awdhegle, and Mahaday Weyne stations. Mahaday Weyne is located upstream of Afgooye and Awdhegle is located downstream. The data was extracted from FAO SWALIM report W-11 and the Mott Macdonald Hydrometric Data Book for the Shabelle River from 1963-1989. The study included daily and monthly flows for the stations. The Afgooye station was one of the most complete stations in the Mott MacDonald study. During the validation process, Afgooye station retained 90% of field measurements. For nearby stations (including Balad, Awdhegle and M.Weyne), numerous values were removed due to outliers.

Note, the two functioning stream gauge locations near the Ethiopian border, Beled Weyne and Bulo Burte show an increase in the magnitude of floods and river flow compared to the historical mean. This does not necessarily translate to an increase in the Afgooye stream flow, however it warrants further investigation to evaluate the potential impacts.

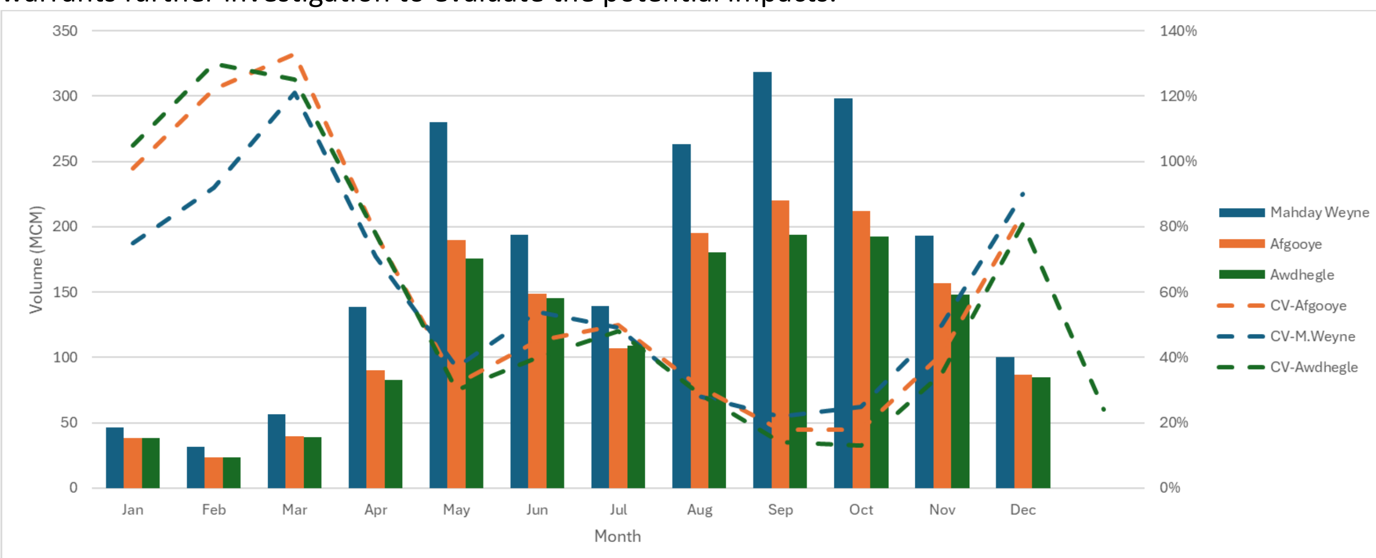


Figure 15: Monthly Flow Comparison for Shabelle River Stations

Figure 15 summarizes the variability in stream flow on a monthly basis. It is important to note that flow in the river decreases as it moves downstream although the contributing watershed area increases. This is due to the Somalian part of the catchment having little to no influence in the river flow. More than 90 percent of the river flow is generated from the precipitation in the upper catchment within the Ethiopian highlands. The decrease from Mahaday Weyne to Afgooye and ultimately Awdhegle is due to river abstractions, evaporation and river bank spillage (Basnyat 2007). Figure 15 also includes the coefficient of variation (CV) for each station as a percentage. This statistical parameter illustrates the variation of the long term (1963-1990) monthly data around the mean.

Table 1 summarizes the monthly flow and volume for the mean and 80% flow from the flow duration curve (Basnyat, 2007). The flow duration curve results for the 80% flow represents the low flow condition and the available water resources using reliable flow generated from long term flow data.

Table 1: Annual Flow Summary for Shabelle River Stations

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mahaday Weyne												
Mean (m^3/s)	17	13	21	54	105	75	52	98	123	111	75	38
Mean (MCM)	46	32	57	139	280	194	139	263	318	298	193	100
80% Flow (m^3/s)	7	4	2	5	55	30	24	68	102	79	30	12
80% Flow (MCM)	18	10	6	13	147	77	65	181	263	211	78	32
Afgooye												
Mean (m^3/s)	14	10	15	35	71	57	40	73	85	79	60	32
Mean (MCM)	38	23	39	90	190	149	107	195	220	212	157	87
80% Flow (m3/s)	4	2	1	6	54	22	23	69	97	71	24	8
80% Flow (MCM)	10	5	3	14	144	57	61	184	252	189	62	22
Awdhegle												
Mean (m^3/s)	14	10	15	32	66	56	41	67	75	72	57	32
Mean (MCM)	38	24	39	83	176	145	109	180	194	193	148	85
80% Flow (m^3/s)	2	0	0	0	43	28	18	49	70	64	33	7
80% Flow (MCM)	5	0	0	0	114	74	48	132	181	171	85	20

6. Existing Water Balance/ Water Demand:

The purpose of this report is to develop a baseline water balance for Afgooye and Odweyne districts. To achieve this, data collection effort was initiated to evaluate and review the available data. There are numerous reports and qualitative analyses completed for Somalia, all of the previous water demand analyses focus on the riverine areas (i.e. Juba and Shabelle river basins). Refer to the methodology section for the hydrologic approach for this analysis.

6.3. Water Balance:

Water balance in hydrology is based on the conservation of mass also known as the continuity equation. The inflow into the system will equal the outflow while accounting for change in water storage. There are numerous forms of the water balance equation that can either be simplified or made more complex depending on the area under consideration, the length of the period considered and other assumptions such as the omission of groundwater flows. The simplified version of the general equation is provided below. (UNESCO, 1971) (Sokolov,1974).

$$P + QSin + QGin - Qsout - QGout - E - \Delta S = 0$$

P = Precipitation
E = Evapotranspiration
Q_{Gout} = Outflow sub-surface
ΔS = Change in water storage
Q_{Sin} = Inflow Surface
Q_{Gin} = Inflow sub-surface
Q_{Sout} = Outflow Surface

6.3.1. Afgooye District

The water balance for Afgooye district was simplified based on the available data. The groundwater component of the water balance equation was not used since there were no available groundwater monitoring stations or recharge rates. For the inflow component of the water balance equation, precipitation data from the CHIRPS satellite and historical streamflow data pre-war were used. CHIRPS data was selected in the analysis due to the missing data in the rain gauge records. Streamflow data at Afgooye, Mahadway Weyne (upstream), and Awdhegle (downstream) were compared (see Table 1 above). FAO WaPOR product was used for the actual evapotranspiration. The WaPOR product solves the Penman-Monteith equation using the latest available global data and remote sensing techniques. The period of analysis for CHIRPs and WaPOR is 2018-2023. Both datasets were averaged over the district area. The stream flow data is historical data from 1963-1990 since the gauge was discontinued after 1990.

Table 2: Afgooye District Water Balance

Month	Precipitation (mm)	Stream Flow (mm) - AFGY	Stream Flow (mm) - AWDH	AET (mm)
January	0.3	0.14	0.14	16.60
February	0.1	0.08		11.04
March	8.7	0.14		8.55
April	64.4	0.32		10.83
May	59.7	0.68	0.63	15.83
June	18.5	0.54	0.52	20.75
July	24.9	0.39	0.39	20.36
August	13.2	0.70	0.64	16.03
September	5.8	0.79	0.69	12.57
October	73.8	0.76	0.69	23.24
November	81.4	0.56	0.53	33.17
December	9.5	0.31	0.30	29.87
Annual	**360**	**5.42**	**4.53**	**218.82**

The stream flow data and flow duration curve were obtained from W-11 technical report (Basnyat 2007). The stream flow data in Table 2 is divided by the contributing watershed area. Afgooye stream flow station and Awdhgle stream flow station are included for reference. Awdhegle is included to illustrate changes in the river flow downstream of Afgooye District.

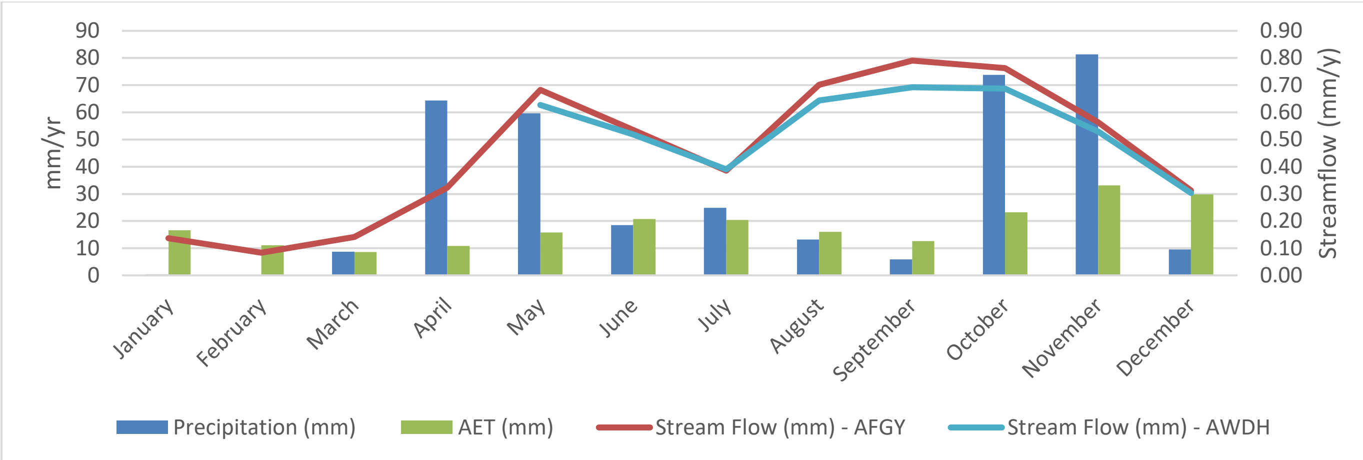
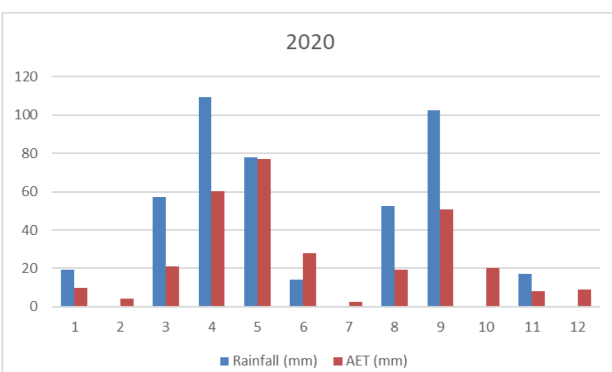
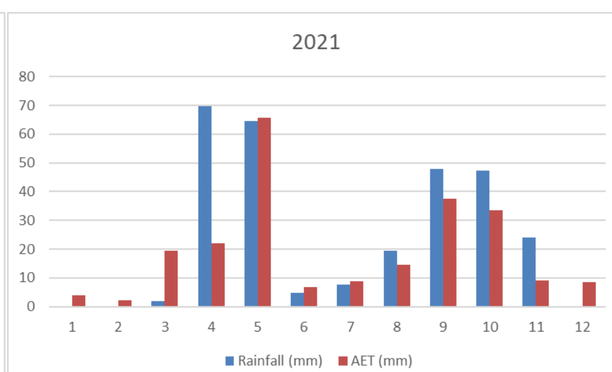


Figure 16: Afgooye District Annual Water Balance (2018-2023)

6.3.2. Odweyne District

A SWAT model was prepared for the Odweyne district due to limited hydrologic analysis or data available for the area. The SWAT model was prepared using SWALIM compiled data such as rain gauges, temperature data, land use suitability and classification, and soil survey. The DEM used for the analysis is the 30m global SRTM. Although the area of interest is the Odweyne district, the SWAT analysis area is much larger and extends outside the Somali national borders. The contributing catchment to the area of interest is part of the Ogaden Basin (See Figure 3 Location Map for Odweyne). The direction of flow for the catchment is from the northwest to the southeast. Multiple rain gauges were used in the analysis to account for the areal distribution of rainfall (see Figure 8 for all the rain gauges used). For temperature, only the Burco gauge was used in the analysis. In locations where detailed soil and land-use data were not available, global datasets were utilized. The SWAT model was run for four years, 2020-2023. See Figures 28, 29, 30 and 31 for input data into the SWAT model and sub-basins used in the model. The results of the model are shown below. Due to the lack of groundwater monitoring stations, the groundwater component was not modeled in detail for this analysis. Additionally, numerous small dams and rainfall harvesting impoundments were not included in the model as information on their functionality and volume was not available for incorporation.





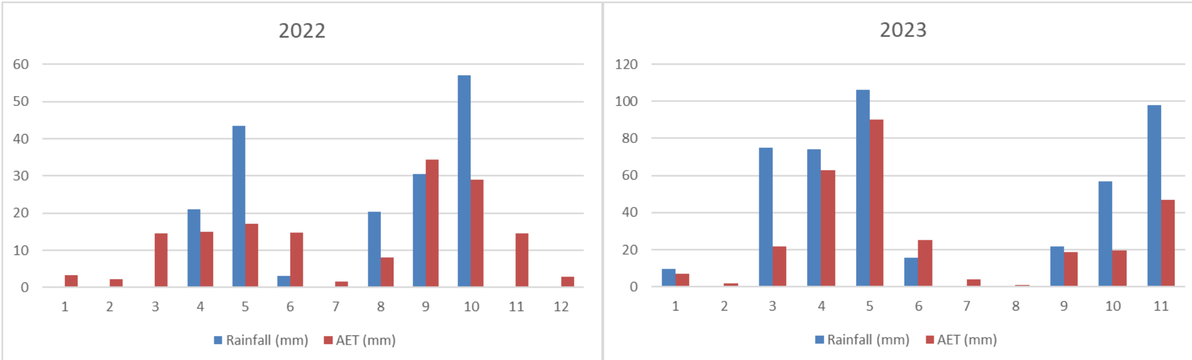


Figure 17: SWAT Model Results for Each Year of the Analysis

Tabe 3 summarizes the SWAT model annual water balance over the watershed. Summarized in the table is average rainfall over the watershed, water contained in the soil column, actual evapotranspiration (AET), potential evapotranspiration (PET) and surface runoff generated.

Table 3: Odweyne District Water Balance

Month	Rainfall (mm)	Soil Water Content (mm)	AET (mm)	PET (mm)	RUNOFF (mm)
January	7.28	19.45	6.00	166.63	0.81
February	0.00	16.78	2.67	172.73	0.00
March	33.52	20.66	19.18	227.24	8.78
April	68.65	33.98	40.04	206.42	12.14
May	73.02	26.06	62.49	233.63	14.85
June	9.43	15.08	18.70	286.33	0.96
July	1.92	12.74	4.26	289.66	0.00
August	23.05	20.10	10.82	296.63	2.70
September	50.70	26.05	35.32	265.15	7.20
October	40.32	33.84	25.67	200.69	5.18
November	34.75	37.44	19.62	184.07	9.66
December	0.00	24.07	6.68	185.31	0.00
Total	**343**		**251**	**2714**	**62**

6.4. <u>Water Demand:</u>

Quantifying the main water use categories is crucial in understanding the total demand for water and define deficits. For the purposes of this study, water use will be subdivided into three categories: livestock use, domestic use, and agricultural use. According to W-22 (Petersen 2012) and W-11 (Basnyat 2007), agriculture is the main sector that uses water in the riverine areas.

6.4.1. Livestock Use:

Livestock data from 1988 was used to determine the total of livestock within each region. The data used in this report is extracted from W-11 (Basnyat 2007) report which references the 1988 survey by the Ministry of Agriculture. Since the values were provided at a regional scale, an assumption was to use 40% of the total regional value at the district level. This assumption should be revisited as more data is collected. Tabe 4 lists the annual water demand at Afgooye and Odweyne in million cubic meters.

Table 4: Livestock Annual Water Use Summary

Livestock	Odweyne	Afgooye	Demand	Odweyne Demand	Afgooye Demand
			(l/h/d)	(MCM)	(MCM)
Cattle	20,428	17,576	25	0.19	0.16
Camel	146,964	134,428	12	0.64	0.59
Sheep/Goat	90,276	149,684	1.6	0.05	0.09
Total				**0.88**	**0.84**

6.4.2. Domestic Use:

Population data was obtained from the population estimation survey completed for Somalia by the UN agencies in 2014. For both districts, it assumed that majority of the population is rural and only 20% live in urban settings. The daily water use per person is estimated at 20 liters per day for rural areas and 50 liters per day for urban locations (Basnyat 2007). These estimates seemed reasonable although the seasonal usage or demand could be much less for certain rural areas where there is water scarcity. Tabe 5 lists the annual domestic water demand at Afgooye and Odweyne in million cubic meters.

Table 5: Domestic Minimum Water Use

Population	Odweyne	Afgooye	Demand	Odweyne Demand	Afgooye Demand
			(l/cp/d)	(MCM)	(MCM)
Urban	16,578	94,447	50	0.30	1.72
Rural	66,311	377,786	20	0.48	2.76
Total	**82,889**	**472,233**		**0.79**	**4.48**

6.4.3. Agriculture Use:

Agricultural water use accounts for majority of the water consumption in a region according to W-22 (Petersen 2012). Various crops are cultivated in Afgooye and Odweyne districts. For this analysis two common crops are used, maize and sorghum. To quantify the crop water requirements, FAO CROPWAT tool along with historical references such as W-22 and W-11 are utilized. The FAO AQUASTAT climate Information Tool was used to determine the ETo for the two districts. ETo represents the reference evapotranspiration which is multiplied by the crop coefficient to determine the actual evapotranspiration from a particular crop. Crop pattern comprising of maize and sorghum was used for both District, Table 6 summarizes the crop seasonal calendar used in the analysis. The crop planting schedule coincides with the two rainy seasons. The irrigation schedule efficiency was set to 40% based on surface irrigation with earthen inefficient conveyance canals.

Table 6: Afgooye and Odweyne Seasonal Crop Calander

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Maize -1												
Maize - 2												
Sorghum												

CROPWAT tool was also used to determine the irrigation requirement for the cropping pattern outlined. The area cultivated for both districts was obtained from existing FAO SWALIM datasets. The datasets were generated using remote sensing techniques and field validation. Table 7 summarizes the footprint of both rainfed and irrigated area for both districts. For this analysis, only the irrigated agricultural area was used since this area is cultivated annually. Tables 8 and 9 summarize the irrigation water demand for Afgooye and Odweyne districts respectively. The crop pattern for both districts assumed that 50% of the area will be planted with maize and the remaining 50% will be sorghum. Both crops will be planted during the Gu and Deyr seasons to take advantage of the rainfall.

Table 7: Agricultural Area for Afgooye and Odweyne Districts

District	Area (ha)	Type
Odweyne	503	Rainfed Crops
Odweyne	9,982	Irrigated Crops
Afgooye	20,308	Irrigated Crops
Afgooye	291,723[3]	Rainfed Crops

Table 8: Afgooye District Irrigation Water Demand

Month	Rainfall (mm)	Eff Rain (mm)	Net Irr. Req. (mm)	Irrigation Req. (l/s/ha)	Irrigation Req. (m^3/ha)
January	0.3	0.3	157	0.59	1,580
February	0.2	0.2	5.8	0.02	48
March	6.2	6.1	0	0	0
April	84.3	72.9	0	0	0
May	74.8	65.8	74.9	0.28	750
June	31.0	29.4	140.7	0.54	1,400
July	27.2	26	106.7	0.4	1,071
August	12.4	12.1	4.9	0.02	54
September	6.5	6.5	0	0	0
October	76.3	67	0.5	0	0
November	71.6	63.4	72.6	0.8	2,074
December	14.3	14	171.9	0.64	1,714
Total	**405.0**	**363.7**	**735.0**		**8,691**

[3] Source: L-09 Land Suitability Assessment of the Juba and Shabelle River (FAO SWALIM 2007). This area is based on historical satellite imagery and these locations were cultivated at least once in the past but unknown if cultivated annually.

Table 9: Odweyne District Irrigation Water Demand

Month	Rainfall (mm)	Eff Rain (mm)	Net Irr. Req. (mm)	Irrigation Req. (l/s/ha)	Irrigation Req. (m^3/ha)
January	7.3	7.2	111	0.45	1,098
February	0	0	5.5	0	0
March	33.5	31.7	0	0	0
April	68.7	61.1	0.7	0	0
May	73.0	64.5	93.8	0.35	937
June	9.4	9.3	207.2	0.80	2,074
July	1.9	1.9	158.6	0.59	1,580
August	23.1	22.2	4.6	0.02	54
September	50.7	46.6	0	0	0
October	40.3	37.7	14.6	0.05	134
November	34.8	32.8	79.3	0.31	804
December	0	0	137.5	0.51	1,366
Total	**343**	**315**	**812.8**		**8,046**

6.5. Summary of Findings:

The total demand for the two districts is summarized in Table 10 below. For Afgooye district, river flow data in Table 1 indicate water availability to meet the agricultural demand for the area shown in Table 7.

Table 10: Water Demand for Afgooye and Odweyne

Demand Use	Odweyne Demand	Afgooye Demand
	(MCM)	(MCM)
Livestock	0.88	0.84
Domestic	0.79	4.48
Agriculture	80.3	176.5
Total	**82.0**	**181.8**

For both districts the irrigation demand exceeds the available rainfall. In the case of Afgooye, the river flow is adequate to cover the irrigation demand for the area noted in Table 7. For Odweyne district, groundwater is an option to cover the remaining irrigation demand. SWAT model indicates runoff along the main ephemeral wash which could also be utilized via surface dams to store some of the runoff. The surface dams are currently in use in the area and a detailed analysis of the quantity and quality of the stored water will be vital.

7. Future Climate Condition:

The potential impacts of extreme events in the future were evaluated using the FAO Climate and Agriculture Risk Visualization and Assessment Tool (CAVA). CAVA was used to plot and evaluate moderate and high risk climate scenarios. The climate scenarios evaluated are based on the Intergovernmental Panel on Climate Change (IPCC) Representative Concentration Pathways

(RCPs). RCP 2.6 low emission and RCP 8.5 high emission were evaluated in the near term (2021-2040), mid term (2041-2060) and long term (2081-2100). A more detailed analysis is included in the Climate Impact Potential Assessment Report completed by FAO Office of Climate Change (FAO OCB 2024).

The SWAT analysis for Odweyne was rerun using the regional climate models from the FAO CAVA tool. The CAVA tool uses W5E5 gridded dataset for observed data from 1980-2015. The W5E5 dataset is based on the ERA5 reanalysis product which accounts for global observational datasets. Figure 18 illustrates the rainfall for the low emission RCP 2.6 scenario for multiple regional models. The regional models' results are relatively close to the W5E5 data. There are couple of models that predict a decrease in rainfall. Figure 19 highlights the SWAT model results for future condition scenario RCP 2.6 actual evapotranspiration. Similar to rainfall, the computed actual evapotranspiration is lower in the future condition models compared to the W5EF historical data. Figure 20 summarizes the surface runoff from the SWAT simulations for the various regional models. Compared to the WE5E gridded rainfall data, the projected scenario RCP 2.6 models indicate a slight increase in surface flow rate although there is high variability within the regional models.

Since a hydrology model was not generated for Afgooye district, an in-depth analysis was not possible to evaluate the impacts of future climate on the runoff in Shabelle river or rainfall runoff in Afgooye district.

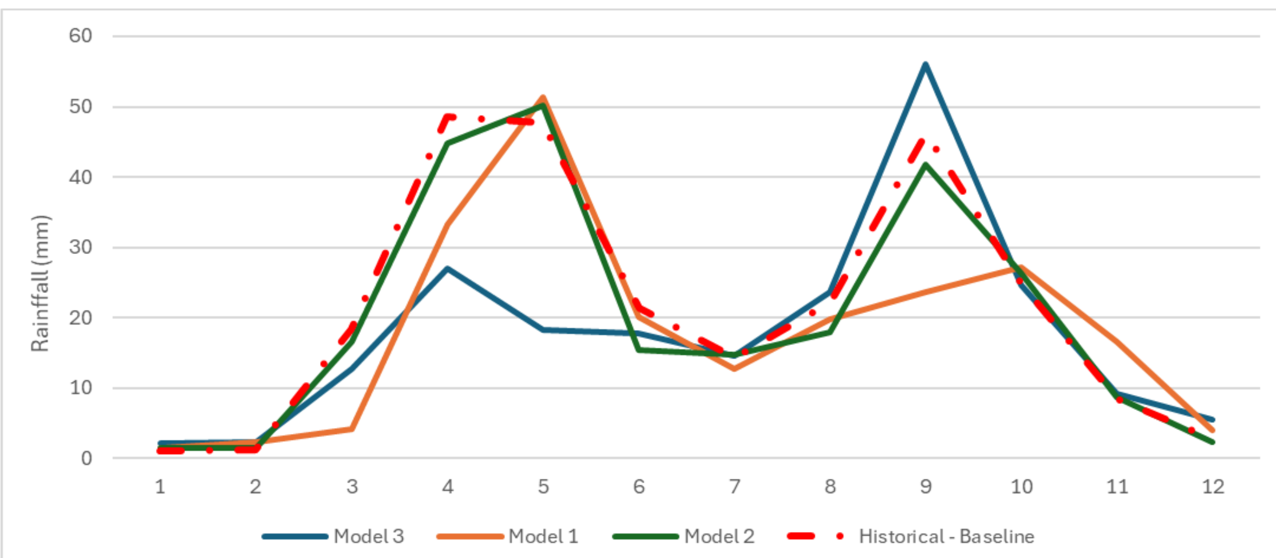


Figure 18: Rainfall for the Low Emission RCP 2.6 Regional models (2025-2099)

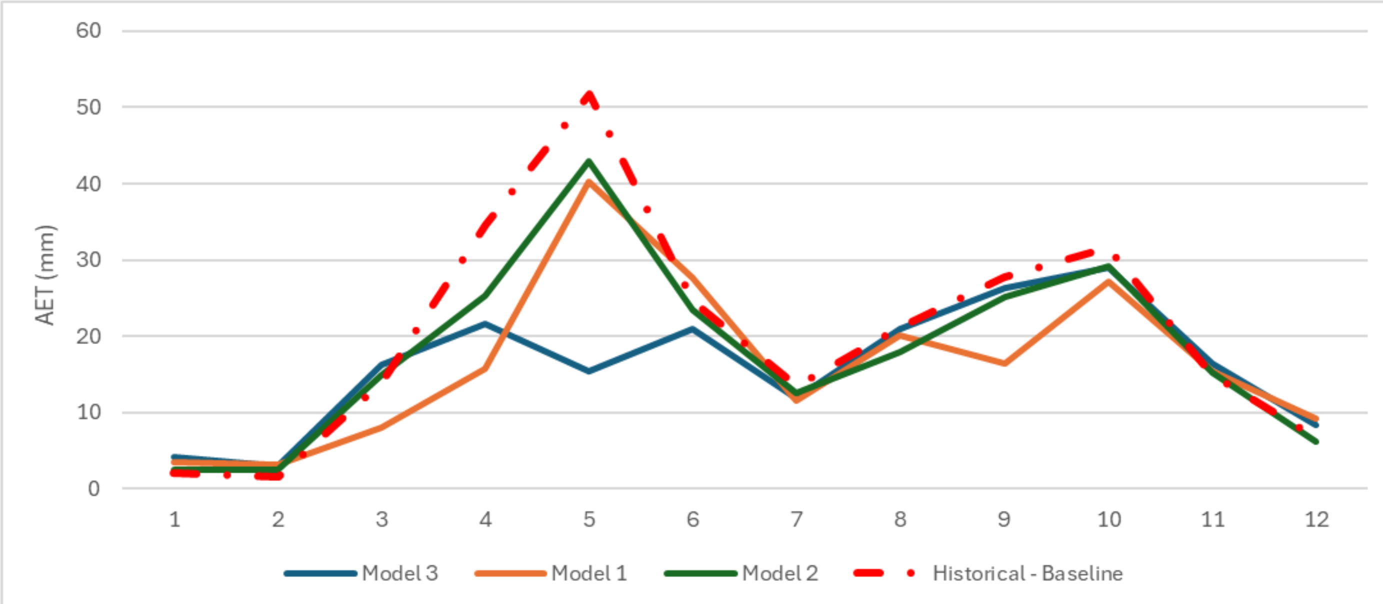


Figure 19: Actual Evapotranspiration for the Low Emission RCP 2.6 Regional Models (2025-2099)

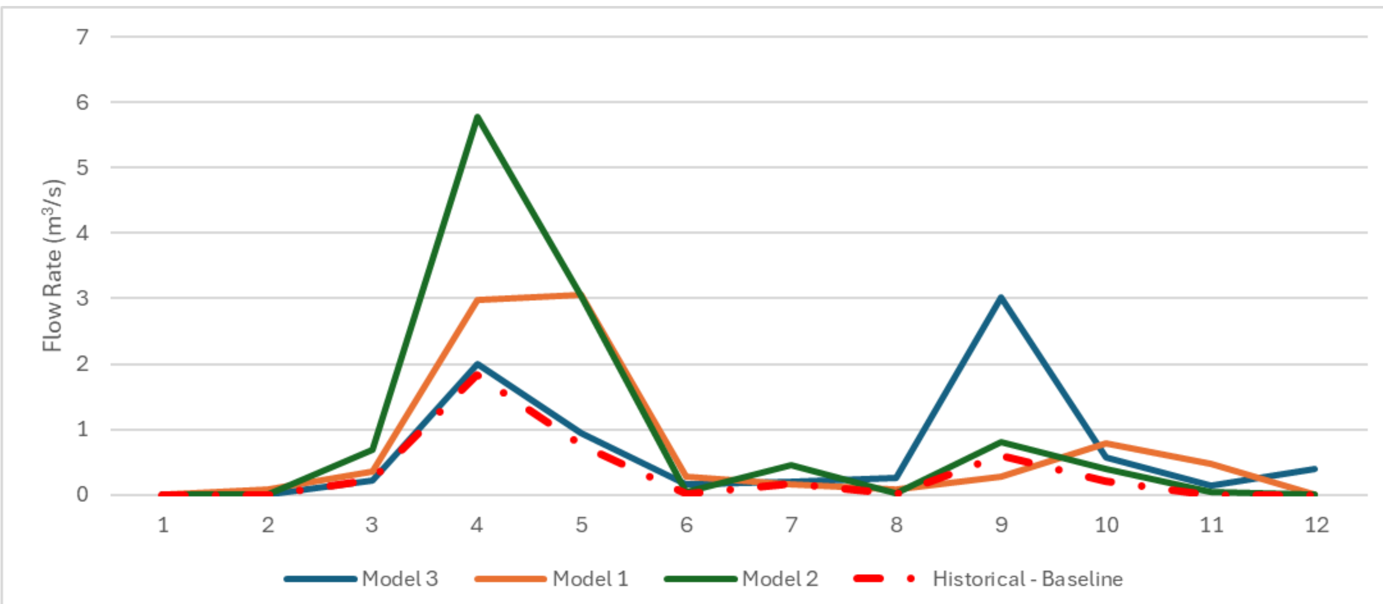


Figure 20: Flow Rate for Low Emission RCP 2.6 Regional Models (2025-2099)

The following figures (Figures 21-25) were produced using FAO CAVA tool to review the impacts of various climate scenarios. CAVA model utilizes multiple regional climate models for each scenario. The results indicate variability within the regional models. The bold line indicates the median of all regional models used for each scenario (i.e. RCP 2.6 and RCP 8.5).

Figures 21 summarize the results for Afgooye District for total precipitation for the near term, mid term and long term. Model results indicate a slight increase in precipitation in the mid term and long term for both low emission RCP 2.6 and high emission RCP 8.5. Figure 22 indicates an increase in the number of days with high precipitation (greater than 100 mm). This could potentially indicate higher risk of flooding in the medium and long term periods. High emission scenario RCP 8.5 trend indicated a larger increase in the number of high precipitation days compared to low emission scenario RCP 2.6. Figure 23 includes model results for maximum temperature for low emission and high emission scenarios. The maximum temperature results indicate a slight increase in the maximum temperatures under low emission scenario but a more pronounced increase in the high emission scenario.

Similarly, for Odweyne district there is a slight increase in total precipitation for the two climate scenarios. Figures 24 and 25 include the results for precipitation and maximum temperature using the CAVA tool for Odweyne. More detailed analysis is included in the Climate Impact Potential Assessment Report (FAO OCB 2024).

For the purposes of water balance, the projected increase in temperature will adversely impact both districts. The projected increase in temperature will potentially increase the already high evapotranspiration rate.

8. References:

- Basnyat, D.B (2007). Water Resources of Somalia. Technical Report No. W-11, FAO-SWALIM, Nairobi, Kenya.

- FAO-SWALIM (2012). Hydrogeological Survey and Assessment of Selected Areas in Somaliland and Puntland. Technical Report No. W-20, FAO-SWALIM. Nairobi, Kenya.

- Kirungu, Soldan, Alvar-Beltran (2024), Climate Impact Potential Assessment: Climate Resilient Agriculture in the Lower Shabelle in Somalia, FAO OCB.

- Muchiri, P.W. (2007). Climate of Somalia. Technical Report No. W-01, FAO-SWALIM, Nairobi, Kenya.

- Omuto, Vargas, Paron (2009). Soil Erosion and Sedimentation Modelling and Monitoring Framework for Areas in Juba and Shabelle. Technical Report No. L-16, FAO-SWALIM. Nairobi, Kenya.

- Peterson, G., and Gadain, H.M (2012) Water Demand Assessment for the Juba and Shabelle Rivers. Technical Report No. W-22, FAO-SWALIM.

- Setti, Soldan, Alvar-Beltran (2022), Climate Hazard Assessment: Climate Resilient Agriculture in the Lower Shabelle in Somalia, FAO OCB.

- Sir Mott MacDonald & Partners (1990), Hydrometric Data Book of Juba and Shabelle Rivers 1951-1989. Ministry of Agriculture, Government of Somalia.

- Sokolov A.A. (1974). Methods For Water Balance Computations. UNESCO. Paris, France.

- Ullah, Saleem (2016). Territorial Diagnostic Report of the Land Resources of Somaliland. FAO-SWALIM, Nairobi, Kenya.

- Venema, J.H. and Vargas, R. (2007). Land Suitability Assessment of the Juba and Shabelle Riverine Areas. Project Report No. L-09. FAO-SWALIM, Nairobi, Kenya.

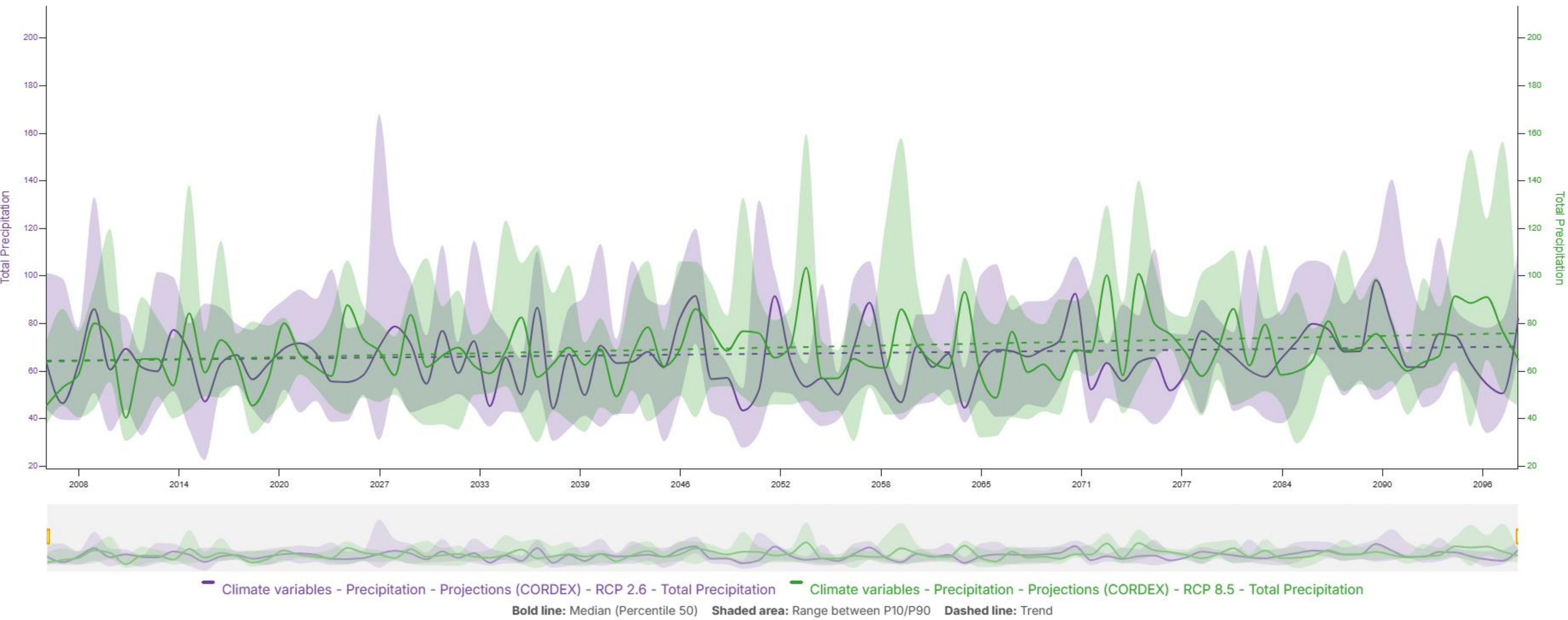


Figure 21: Afgooye Climate Model Results for RCP 2.6 and RCP 5.8 - Total Precipitation

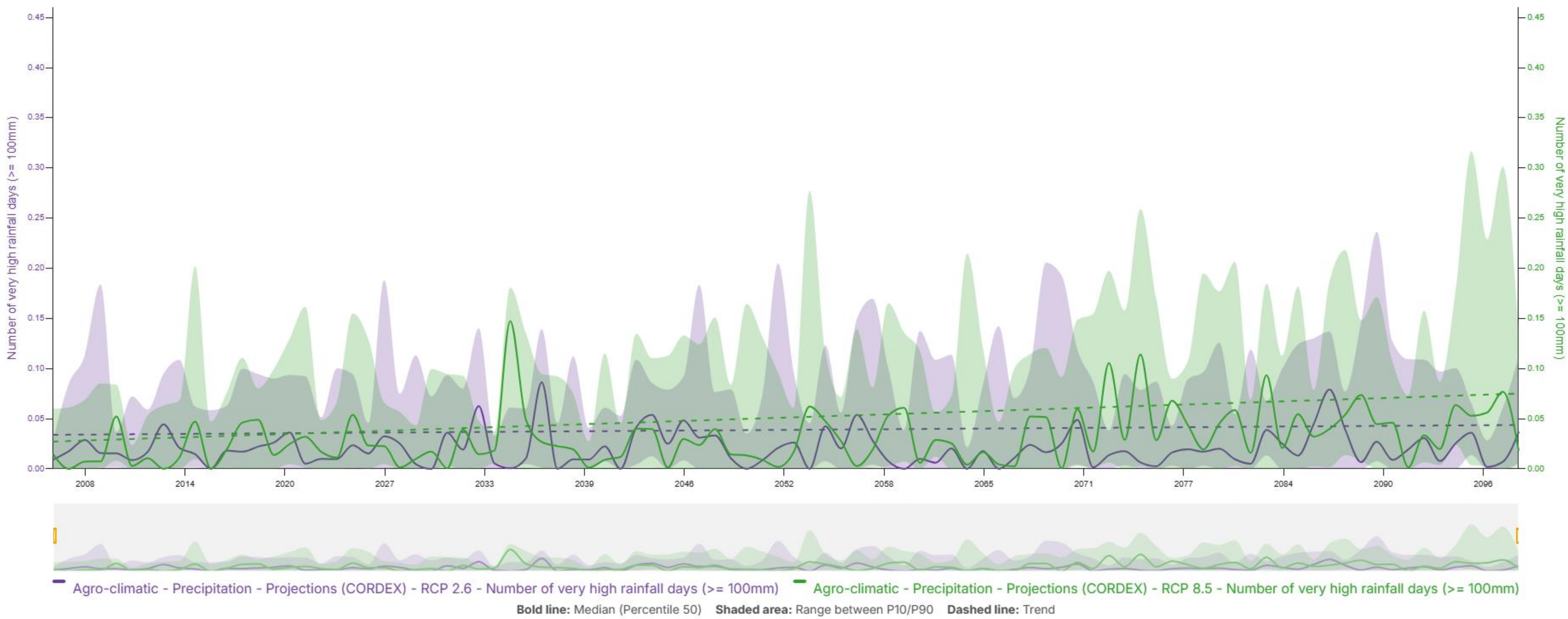


Figure 22: Afgooye Climate Model Results for RCP 2.6 and RCP 5.8 - Number Days with High Precipitation (>100 mm)

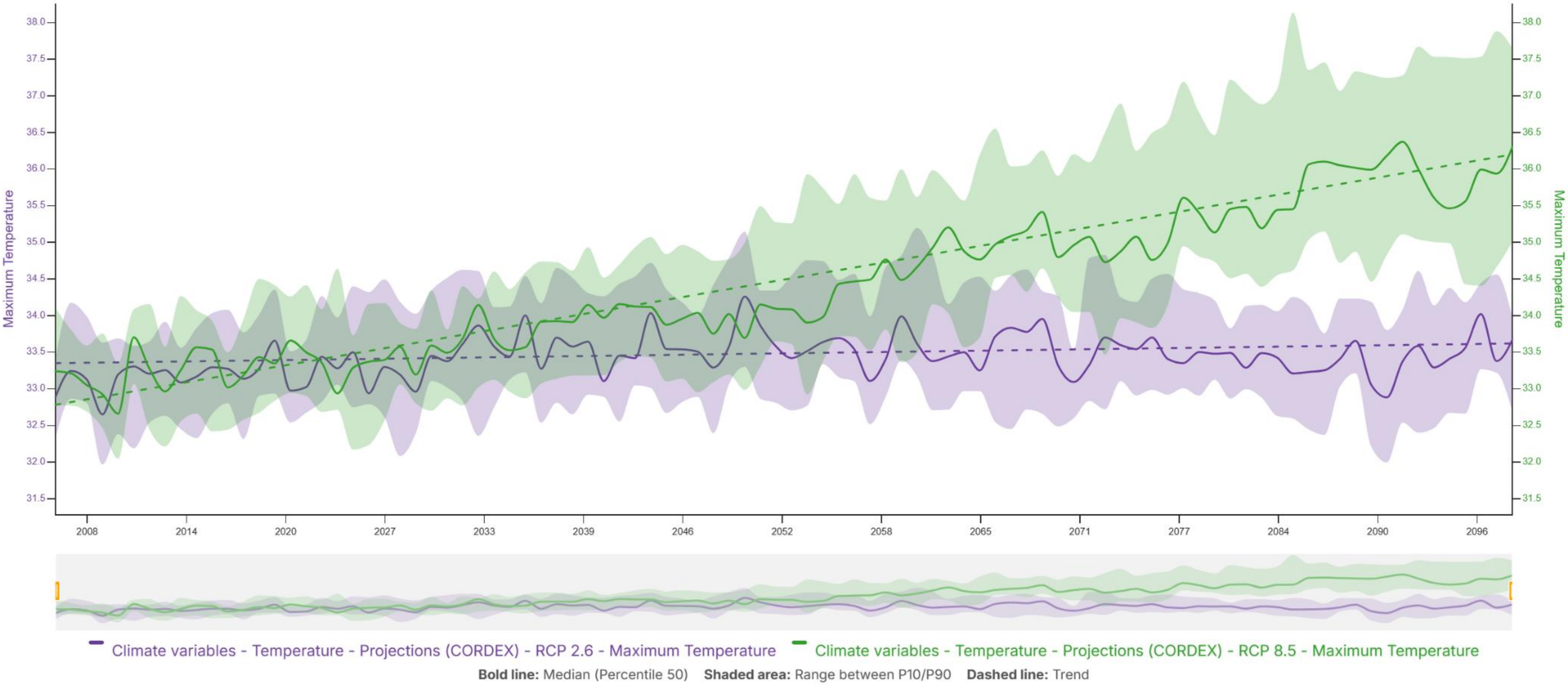


Figure 23: Afgooye Climate Model Results for RCP 2.6 and RCP 5.8 – Maximum Temperature

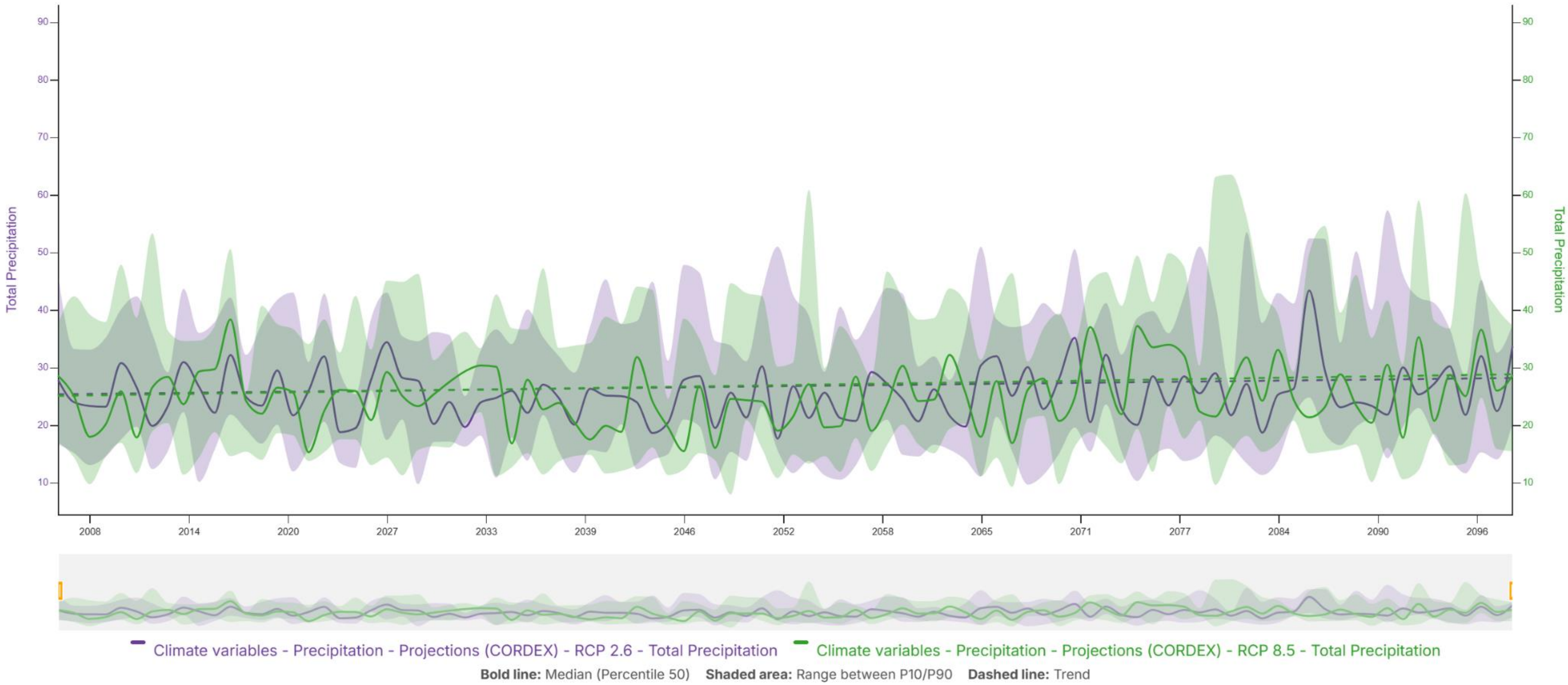


Figure 24: Odweyne Climate Model Results for RCP 2.6 and RCP 5.8 - Total Precipitation

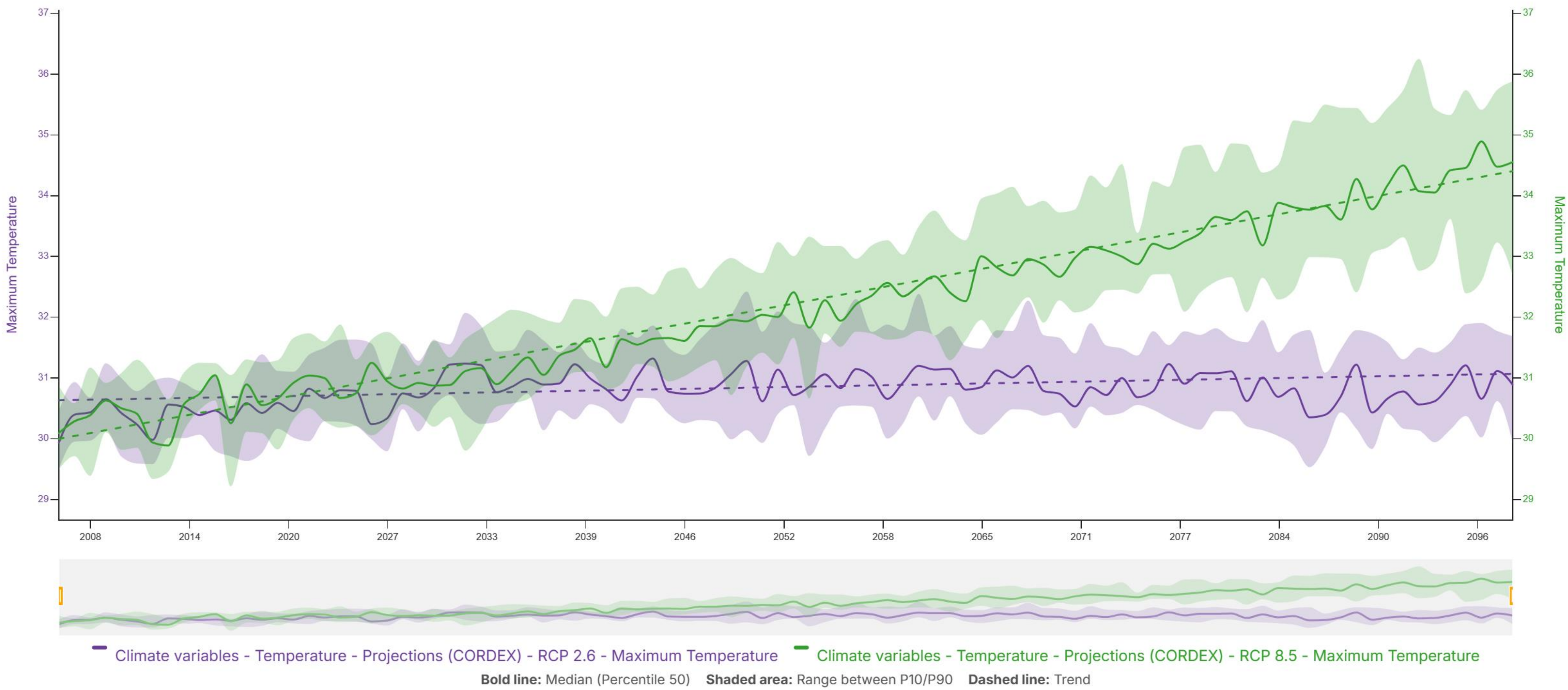


Figure 25: Odweyne Climate Model Results for RCP 2.6 and RCP 5.8 - Maximum Temperature

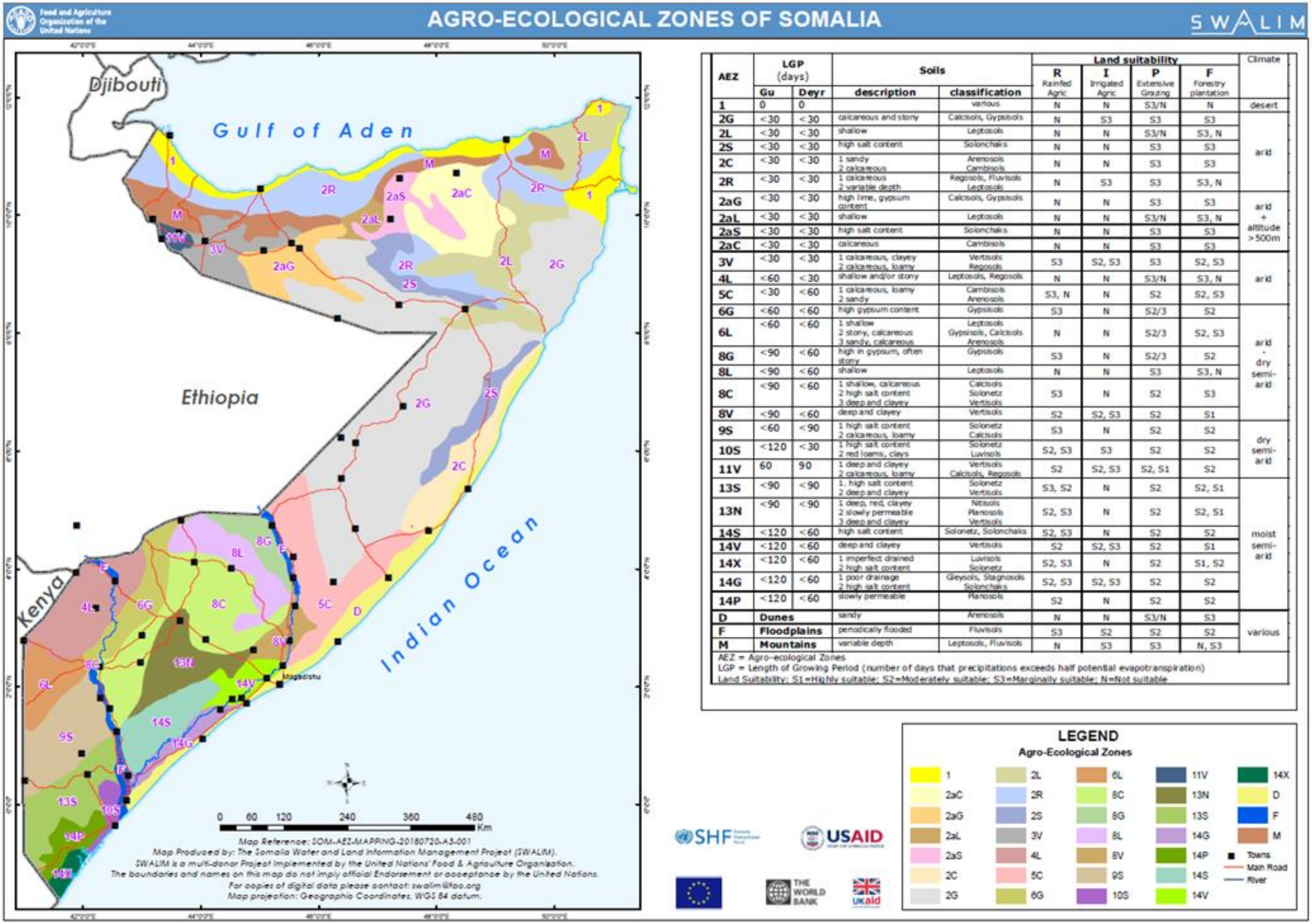


Figure 26: Agro-climate Zones for Somalia (FAO SWALIM 2020)

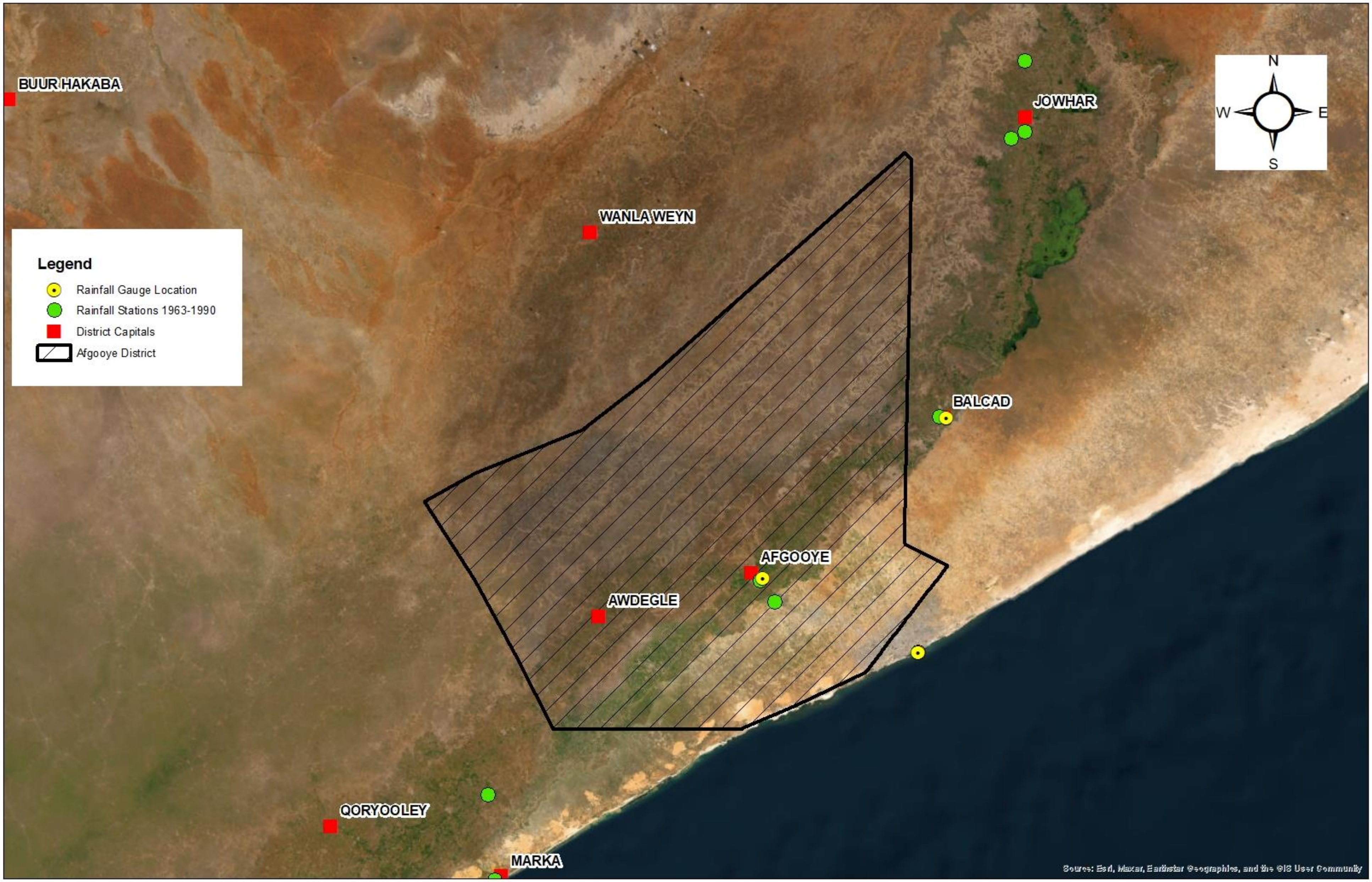


Figure 27: Afgooye District Rainfall Stations

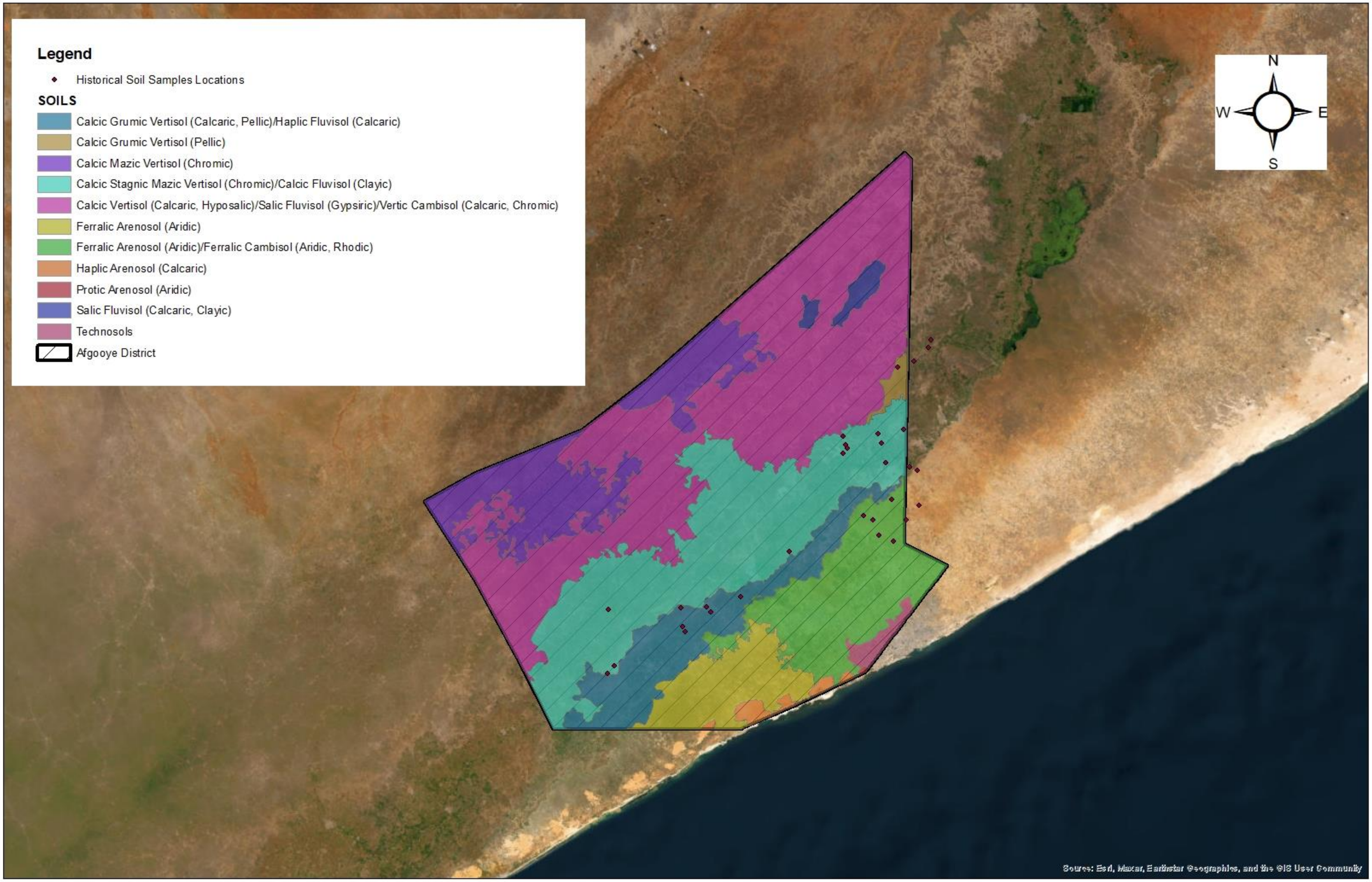


Figure 28: Afgooye District Soils Map

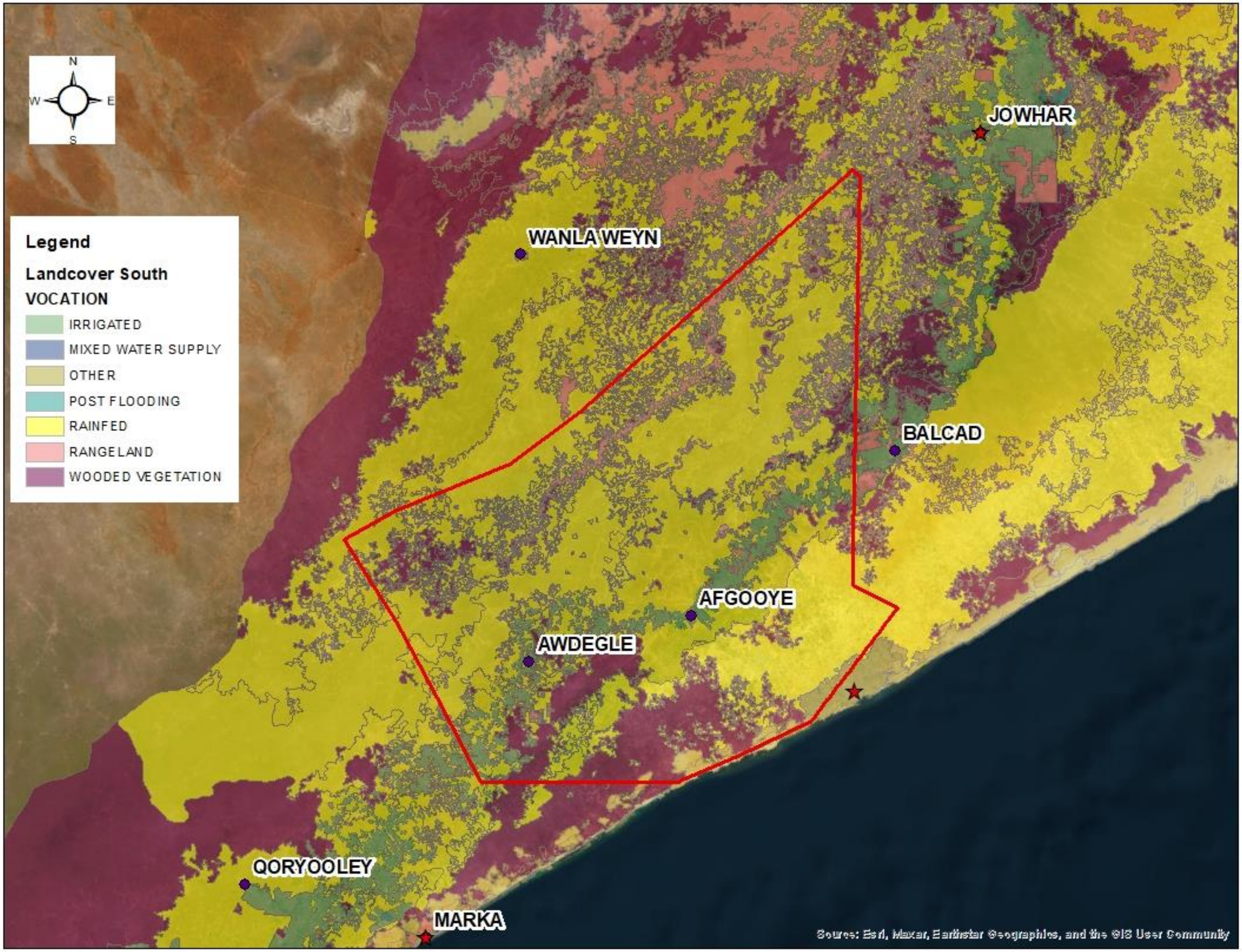


Figure 29: Afgooye District Land Cover Map

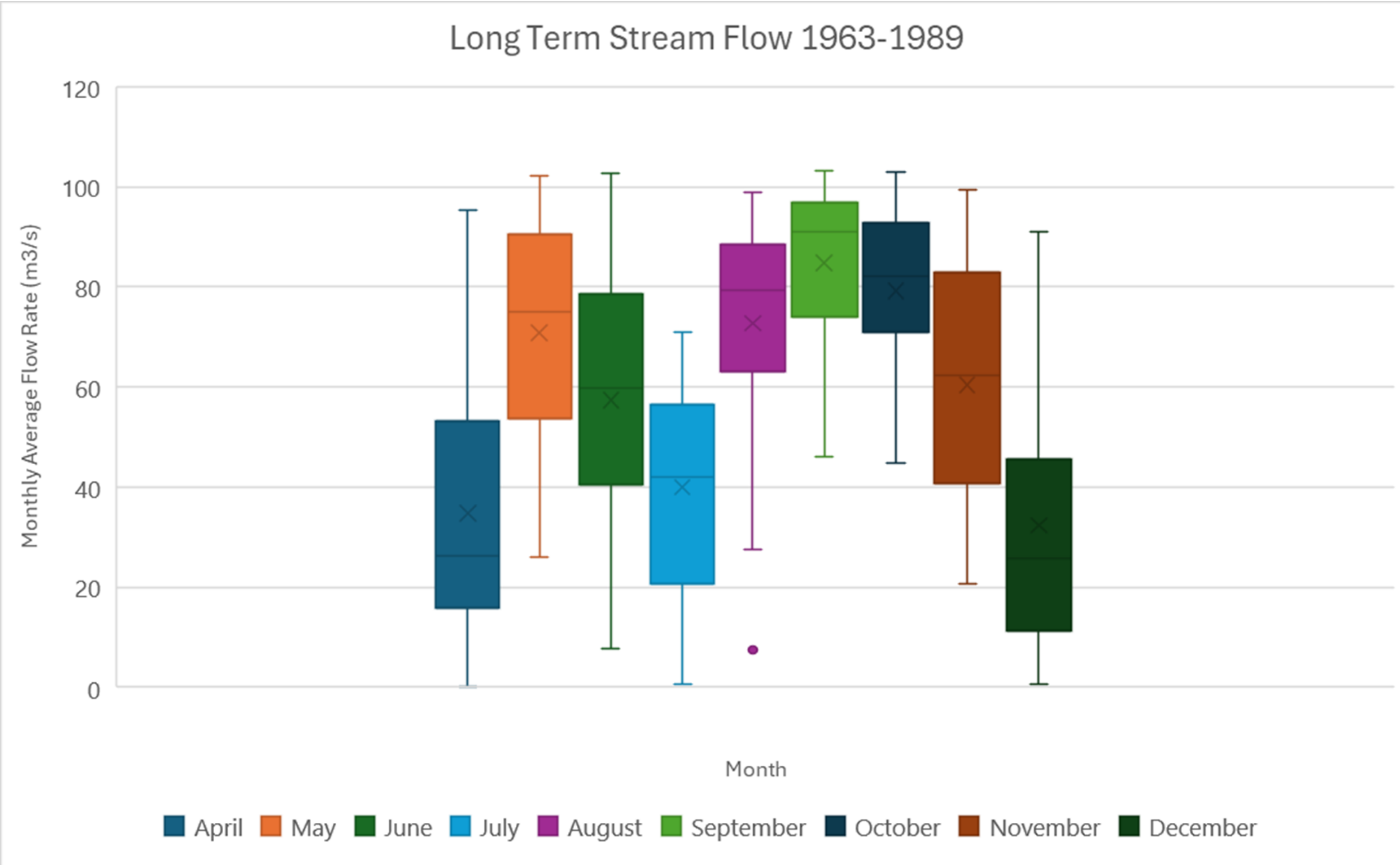


Figure 30: Stream Gauge Summary at Afgooye District

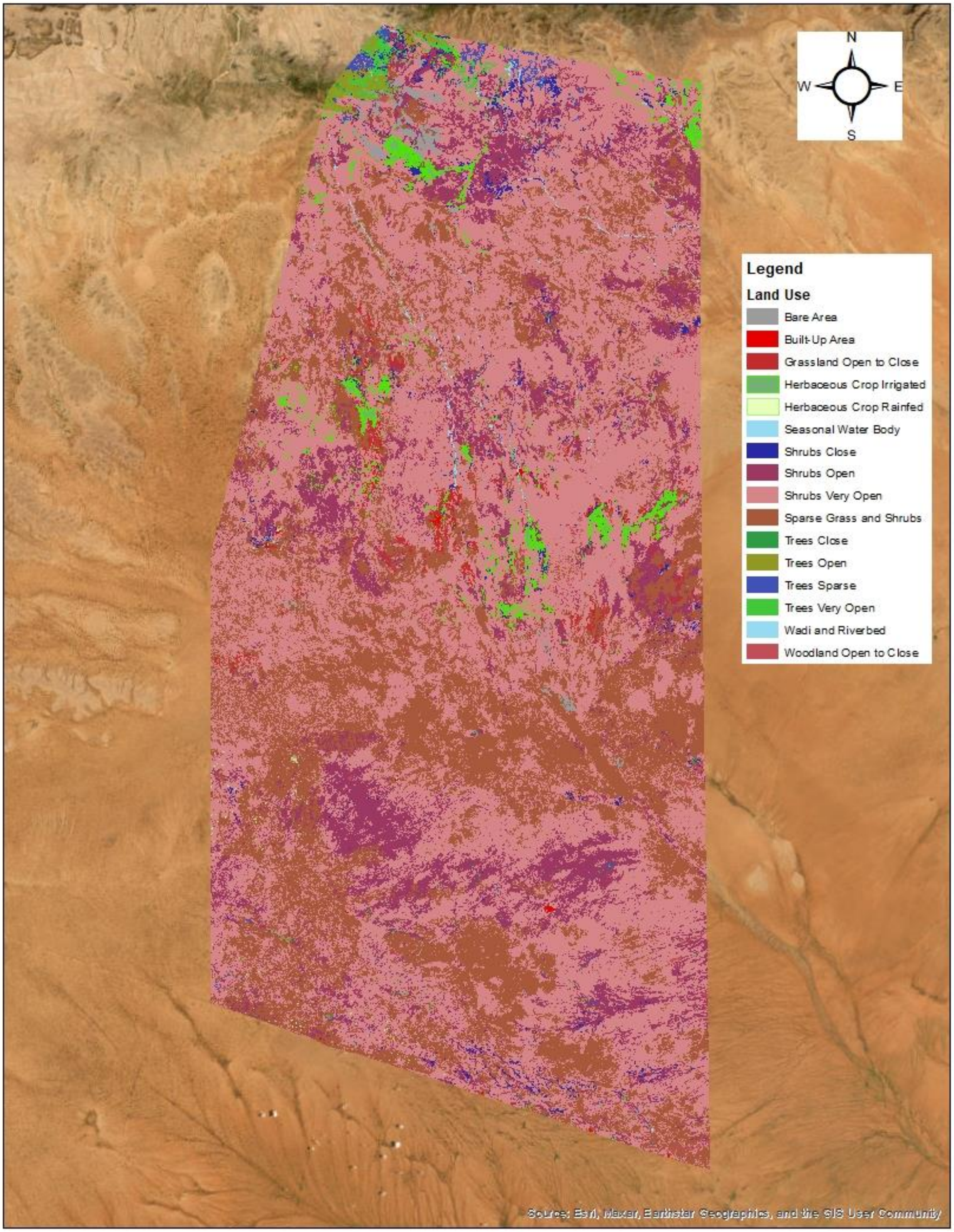


Figure 31: Odweyne District Land Cover Map

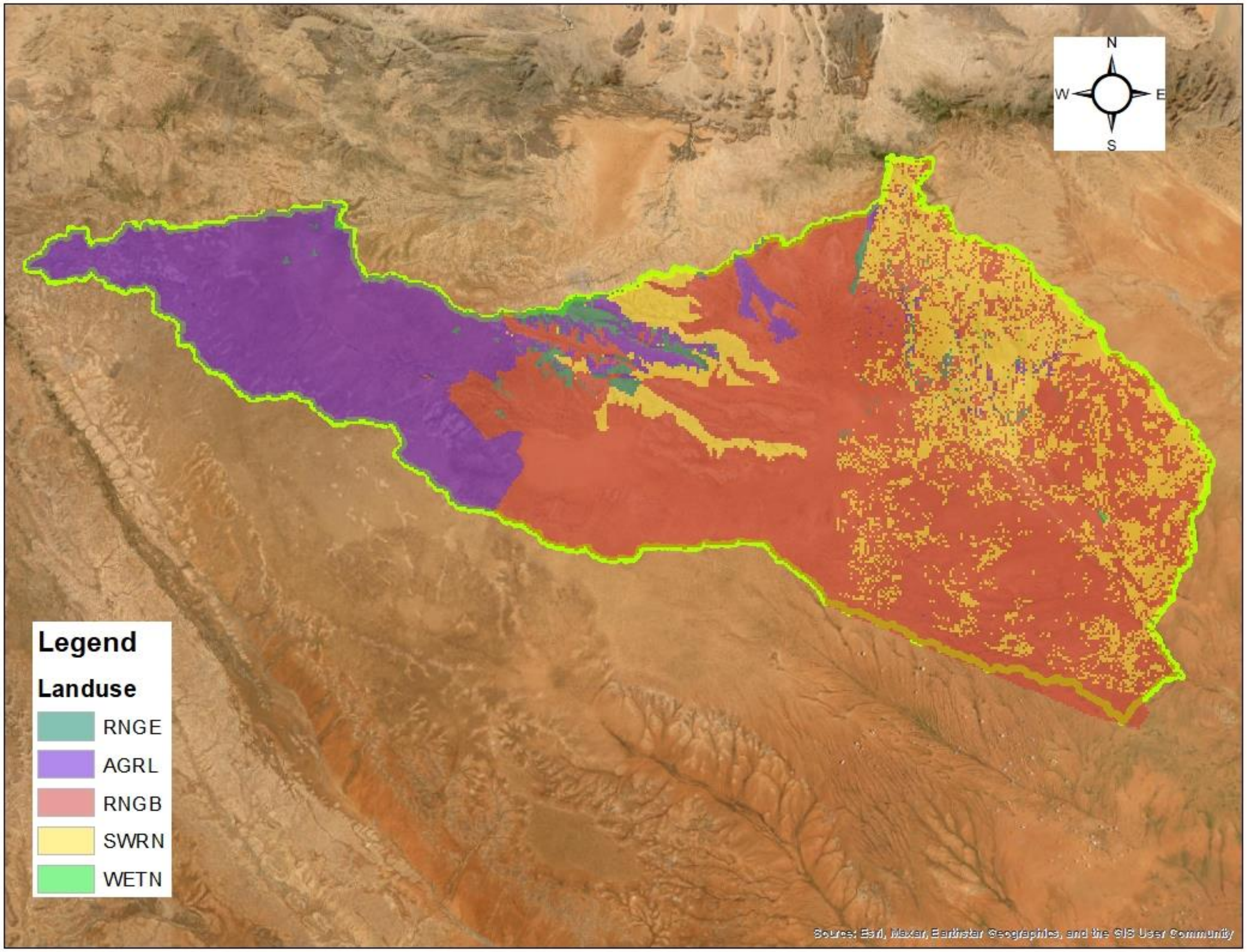


Figure 32: Odweyne District - SWAT Model Land use Classes

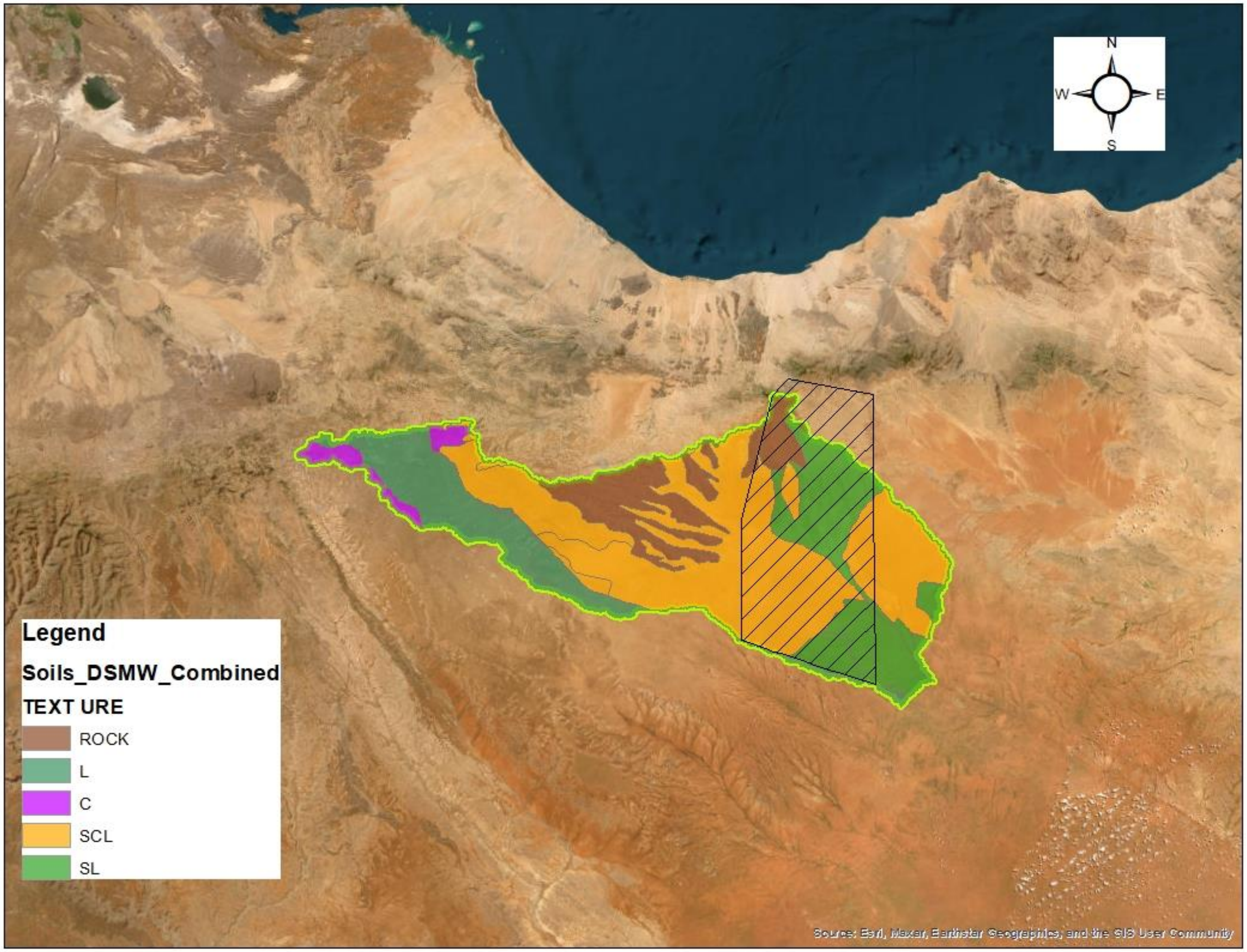


Figure 33: Odweyne District - SWAT Model Soils Data

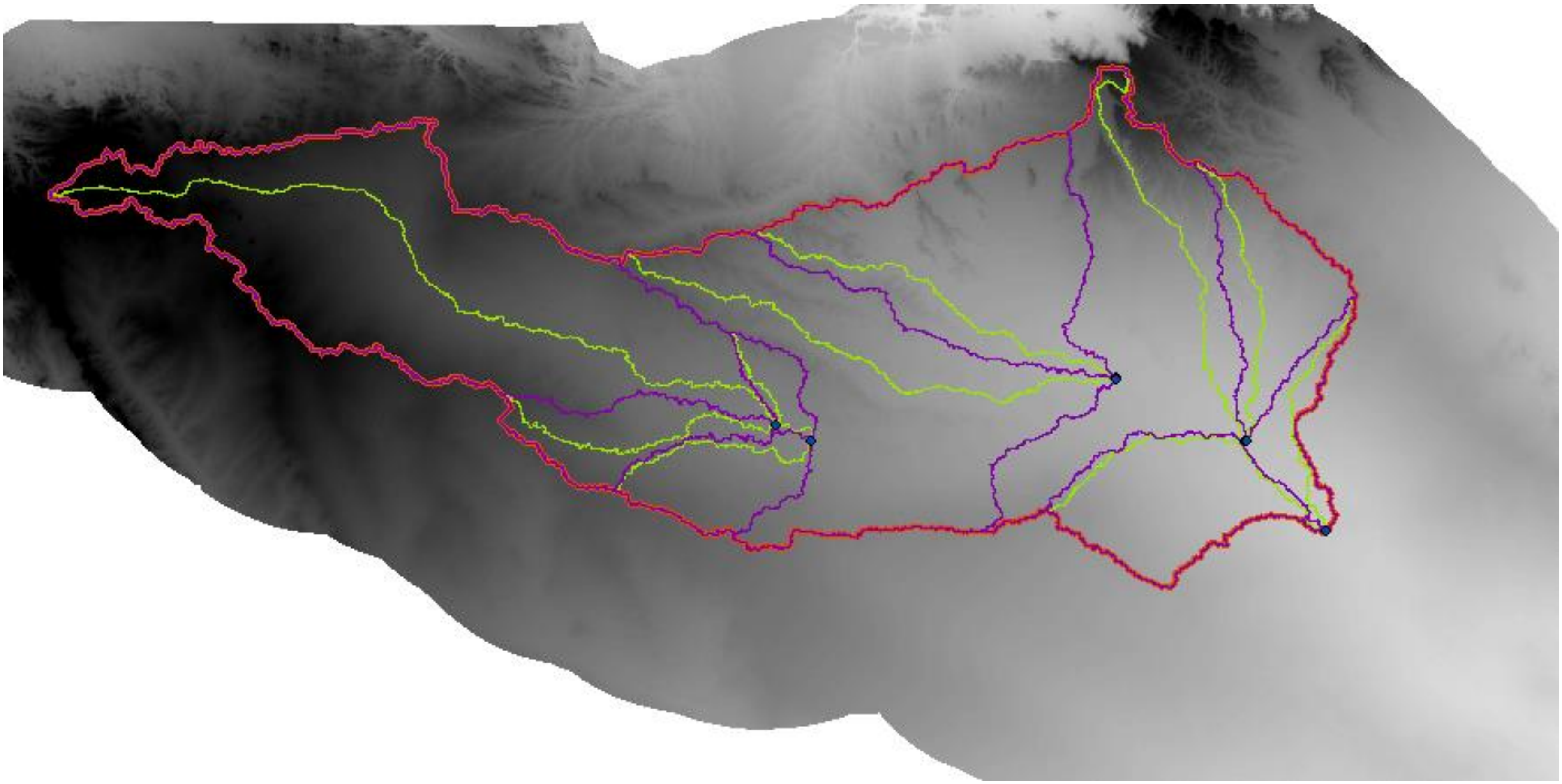


Figure 34: Odweyne District SWAT Model Sub-basins