WATER and ENERGY for FOOD

ASSIST-WE4F Deliverable #1

Water Accounting in the Zambezi River Basin for Baseline and Future Scenarios

Submitted to WE4F

International Water Management Institute

german cooperation DEUTSCHE ZUSAMMENARBEIT

Government of the Netherlands

Norad

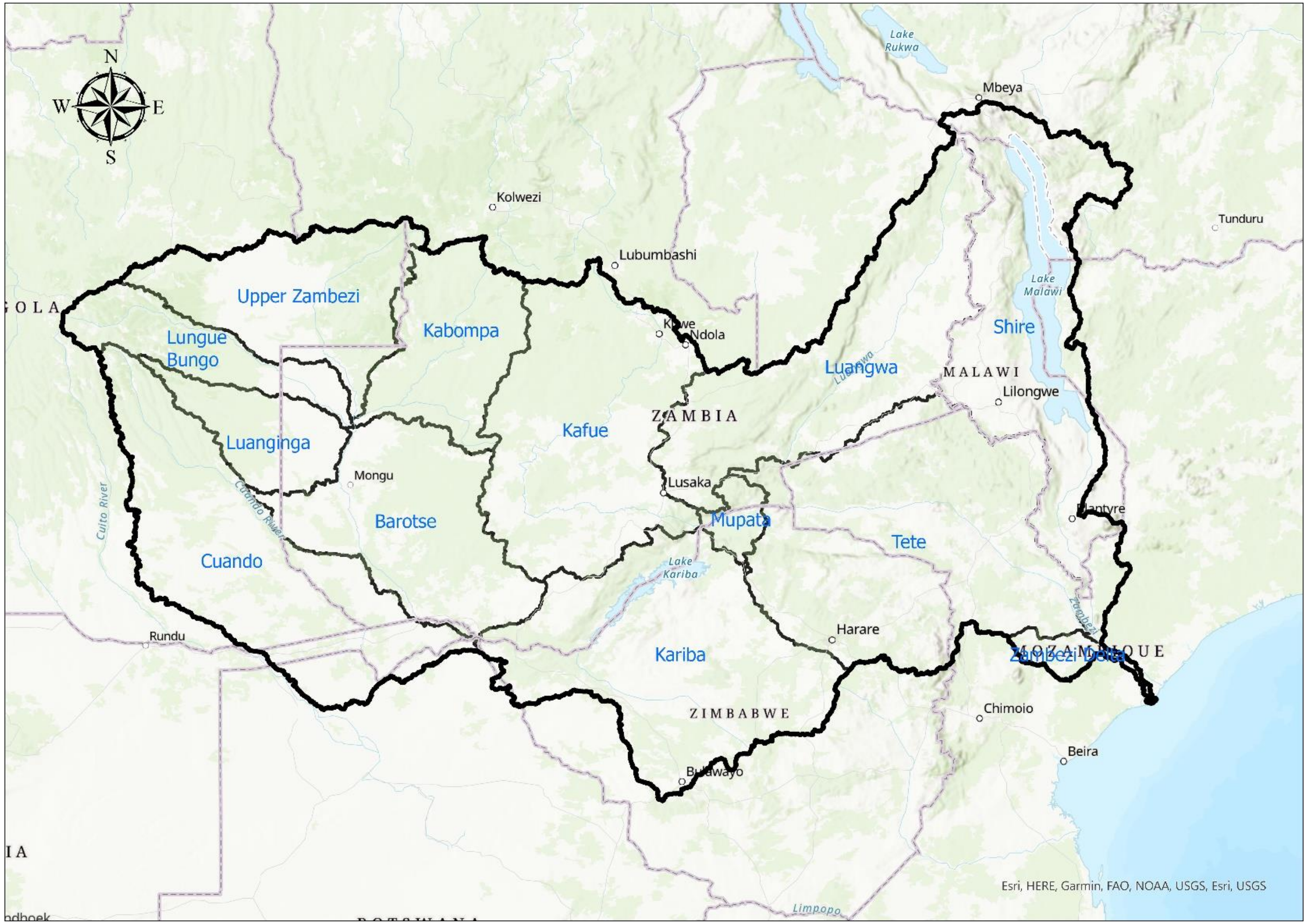
Sweden Sverige

USAID FROM THE AMERICAN PEOPLE

Introduction and Background

- The Zambezi is the fourth longest river in Africa and is the largest in Southern Africa.
- The Zambezi Basin has a total drainage area of approximately 1.4 million Sq. Km (Beilfuss, 2012).
- The main stream originates from Kalene Hills in the North-western Province of Zambia and has a total length of 2,574 km.
- The river plays a central role in the economies of eight riparian countries namely Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia, and Zimbabwe
- The basin waters meets the basic needs of app. 30 million people and sustains a rich and diverse natural environment.
- The key economic activities in the basin are agriculture, fisheries, mining, tourism, and manufacturing.
- Industry is dependent on hydroelectric power, which is the main source of energy
- Other sources of energy are primarily coal and oil.

Study Area



- Rainfall varies in the basin but is generally higher in the northern regions (500-1400mm)
- Basin is highly sensitive to climate variability
- Population is unevenly distributed

The Problem

- The Zambezi Basin is poorly gauged and is comprised of several competing water users.
- The basin is home to over 30 million people (Beilfuss, 2012) with a rapidly growing population which insures increased demand for water resources and the various ecosystem services they provide
- No clear definition of stress for sub-basins despite a number of competing water users and a fast growing population
- Few instances of water accounting based on the SEEAW and these were done at national level for Botswana (MMEWR, 2016) and Zambia (MWDSEP, 2020)
- Requirements are often unavailable or based on long term and expensive monitoring activities (Karimi, 2013; MWDSEP, 2020)
- Current water accounts have no link to LULC

Objectives

1. Quantify water available changes in Zambezi river basin and establish a baseline conditions (2003-2021) and future scenarios (2027-2045) using remote sensing observations and water accounting plus (WA+) framework.
2. Using the WA outputs, quantify indicators of water availability and change for baseline and future scenarios.
3. Generate water availability layers that will be used as inputs into ASSIST-WE4F.

Previous Water Accounting studies in the Zambezi Basin

SEE-W – Botswana (2017 to 2019)	SEE-W – Zambia (2017 to 2020)
Water Utility Corporations main abstractors; 97.1 MCM and 99.2 MCM was abstracted in 2017/18 and 2018/19, respectively. Mining water consumption increased from 26.9 MCM in 2017/18 to 27.8 MCM in 2018/19.	Households used about 1,000 MCM of water per year between 2017 and 2020. Mining used 200 MCM per year between 2017 and 2020
Agriculture remains the largest consumer despite a decrease in consumption from 81.4 MCM in 2017/18 to 76.5 MCM in 2018/19.	Rain-fed agriculture accounted for 12,000 MCM whereas irrigated agriculture accounted for 3,300 MCM
Abstraction by the Electricity industry remained constant at 0.4 MCM.	Energy sector accounted for 60,000 MCM, the largest amount of water used from 2017 to 2020

Limitation of previous studies

- Previous studies does not capture the comprehensive understanding of the water balance of the Zambezi
- None of the previous studies provide detailed information on the water availability and scarcity in the basin.
- Amount of water consumed for irrigation is not quantified.
- The impact of the future climate change on water availability is not addressed.

Required Data for WA+ and Sources

- Discharge data – WARMA, ZAMCOM and ZRA
- Weather Information – Zambia Meteorological Department
- Water Governance frameworks – WARMA
- Local land cover/land use datasets vs available global datasets

Data Comparisons and Validation

- Correlation – weather information i.e CHIRPS, Arc2, RFE
- Nash-Sutcliffe Efficiency (NSE) – discharge, flows
- Confusion matrix – LULC

Determination of Hotspots and Stressed Sub-catchments – past and future

- Use of time-series WA+ information for each sub-catchment.
- Use of blue and green ET data to understand irrigation water use.
- Use of different GCM to produce future WA+ sheets.
- Determine future stress points.

Challenges Faced in the Zambezi Basin

- Lack of data - poorly gauged
- Number of conflicts between users e.g. hydropower vs irrigation
- Low climate change resilience results in low productivity during extremes i.e. lowered power generation and low yields
- Water governance - management challenges that are related to the transboundary nature of the basin
- LULC as a result of an increasing population and economic activities

Challenges in Zambezi Basin (continued)

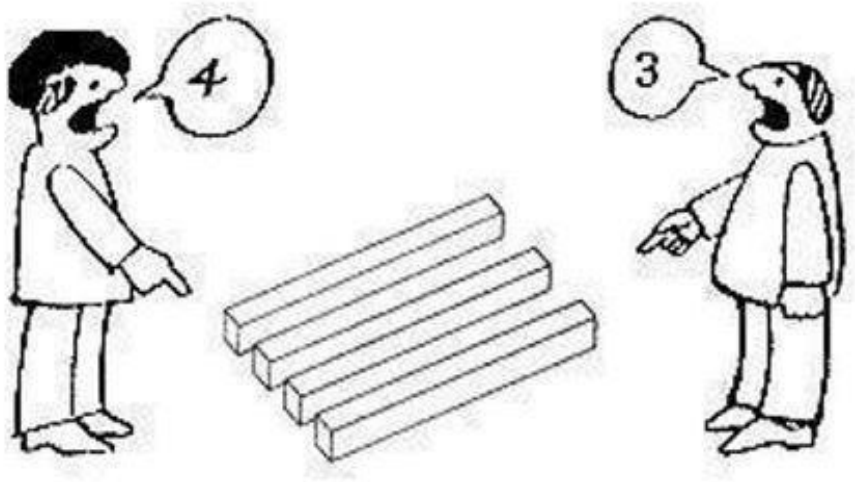
- Lack of regular and consistent data to comprehensively complete water accounting
- Lack of a central repository for water accounting data
- Water accounts so far have been experimental and not yet mainstreamed into policy and decision making, planning and water resources management
- Need for a National Water Statistics Survey programme

Possibilities and Opportunities

- Currently, SEEA-W accounts are not very comprehensive as they require a lot of data. WA+ can be used to supplement or substitute these accounts for decision making purposes
- Water accounting data could be used for conflict resolutions between different users as it may be seen as a trustworthy source of information
- Decisions are currently based on point data. WA+ can improve spatial information regarding water
- Increased prospect of inter-basin water transfer and conjunctive water use

Introduction to Water Accounting Plus (WA+) Framework

Why water accounting?



The need for an **independent, international standard and scientifically-sound** water accounting system that describes all flows and stocks, not only those that are measurable

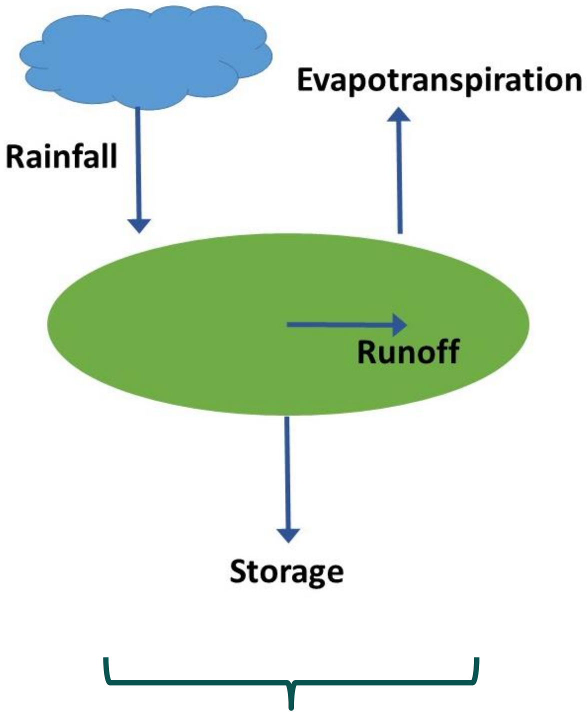
More accurate water accounting aids a stronger dialogue about water

Technical Approach: Definitions

A **water balance** describes the flow of water into and out of a system

- A water balance can be used to help manage water supply and predict where there may be water shortages

- **Water accounting** is an approach which can be used to establish baselines of water resource availability and use, and to track changes in water flows and storage in a region over time
    - A water account can be used to identify whether water is available for further allocation, and to identify the sustainability of interventions at the basin scale

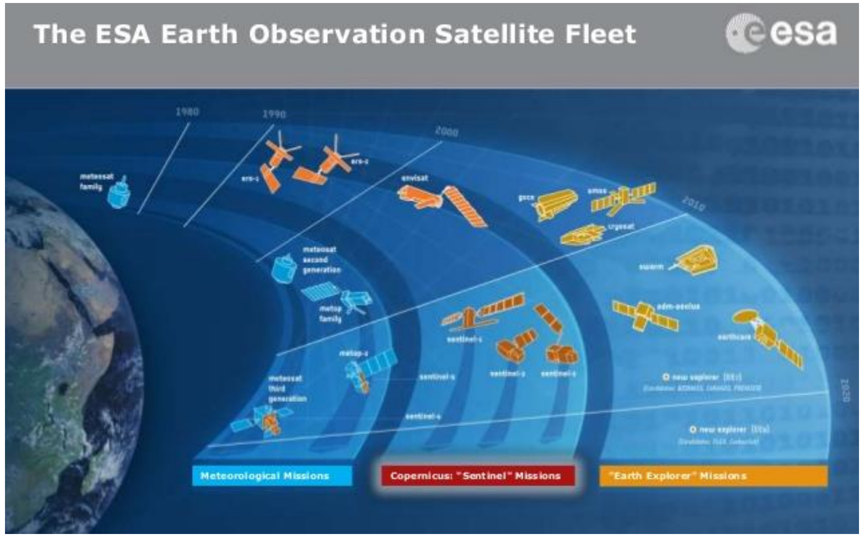


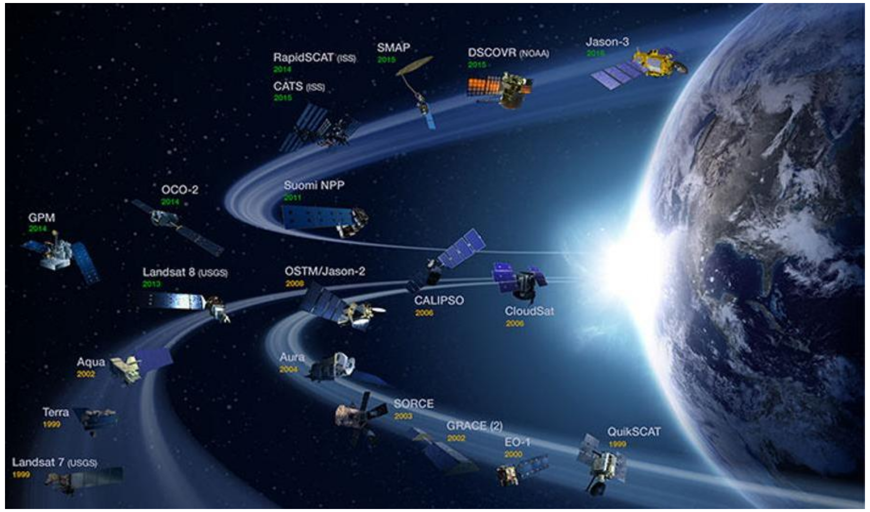
Remote sensing data is key for WA+

- Availability – in data scarce regions
- Accessibility - freely available on the web
- Coverage – global data
- Time saving – ready to use data available

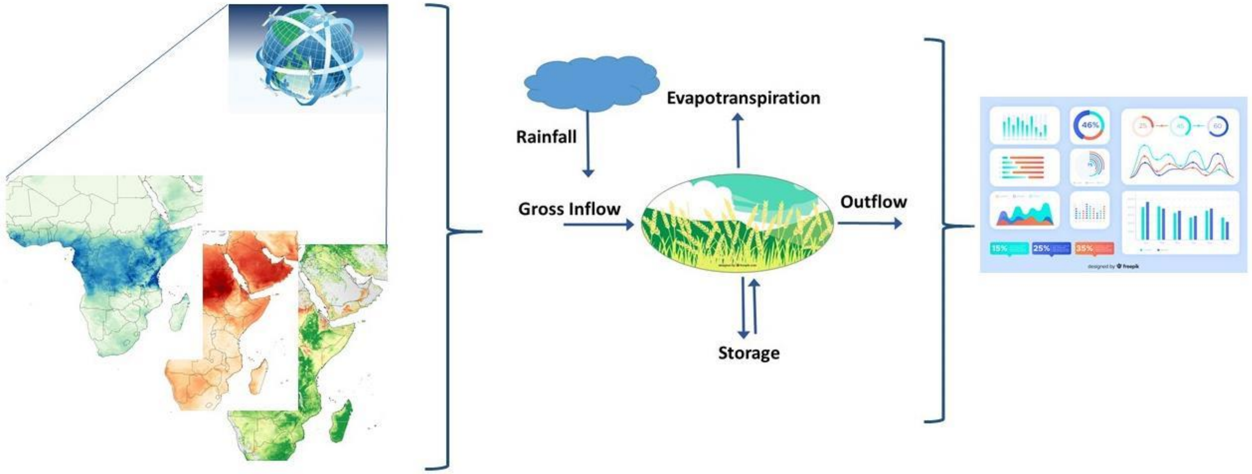
Complemented by

- Hydrologic Models
- Station data
- Auxiliary data





Water Accounting Plus (WA+) framework



Water Accounting+ can provide a basic understanding of a basin's water accounts and establish a baseline.

Limited data? No problem! WA+ relies largely on remote sensing imagery, making it a feasible tool for data scarce basins and a reliable source for transboundary waters.

Using open-source code (meaning anyone can access it!), WA+ uses pre-written code to analyze the remote sensing data.

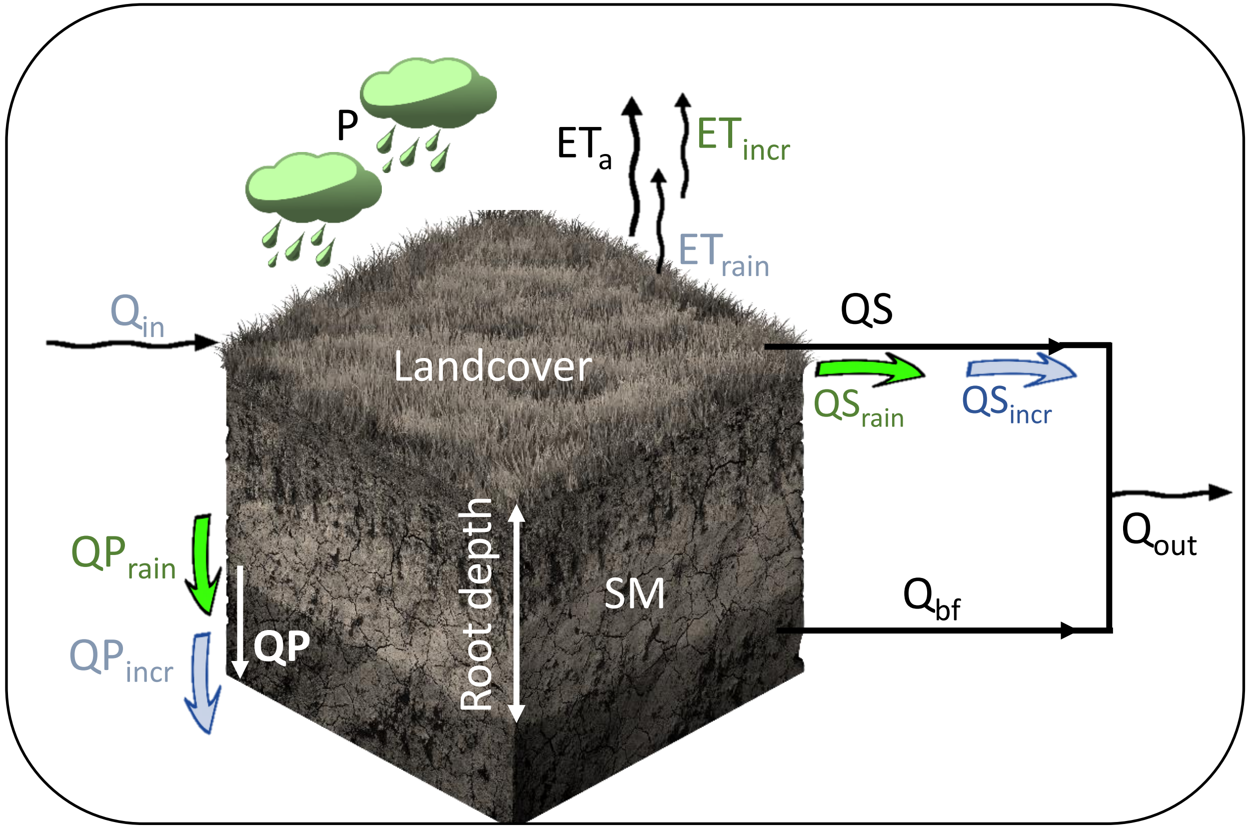
WA+ produces organized results, categorized into: Resource Base, Evapotranspiration, Agricultural Services, Utilized Flow, Surface Water, Groundwater, Ecosystem Services, & Sustainability.

WA+ outputs can be used to ignite well-informed, transparent discussions on water resource issues.

WA+ Inputs and Outputs

Inputs

- P – Precipitation
- ET_a – Evapotranspiration
- LCC – Land cover classification
- ET_{ref} – Reference ET
- I – Interception
- θ_{sat} – Soil saturation
- E – Evaporation
- T – Transpiration
- nRD – number of rainy days
- Q_{out} – Basin outflow
- Q_{bf}/Q_{out} – Baseflow ratio
- Q_{in} – Interbasin transfer



Outputs

- ET_{incr} – Incremental/Blue ET
- ET_{rain} – Rainfall/Green ET
- QS – Surface runoff
- QS_{rain} – QS from rainfall
- QS_{incr} – QS Blue water
- QP_{rain} – Percolation losses
- QP_{rain} – QP from rainfall
- QP_{incr} – QP from blue water
- Q_{bf} – Baseflow
- SM – Soil moisture

Land use and water resources

Modify
water flow
(diversion,
retention…)

Protected Land Use

Utilized Land Use

Manageable

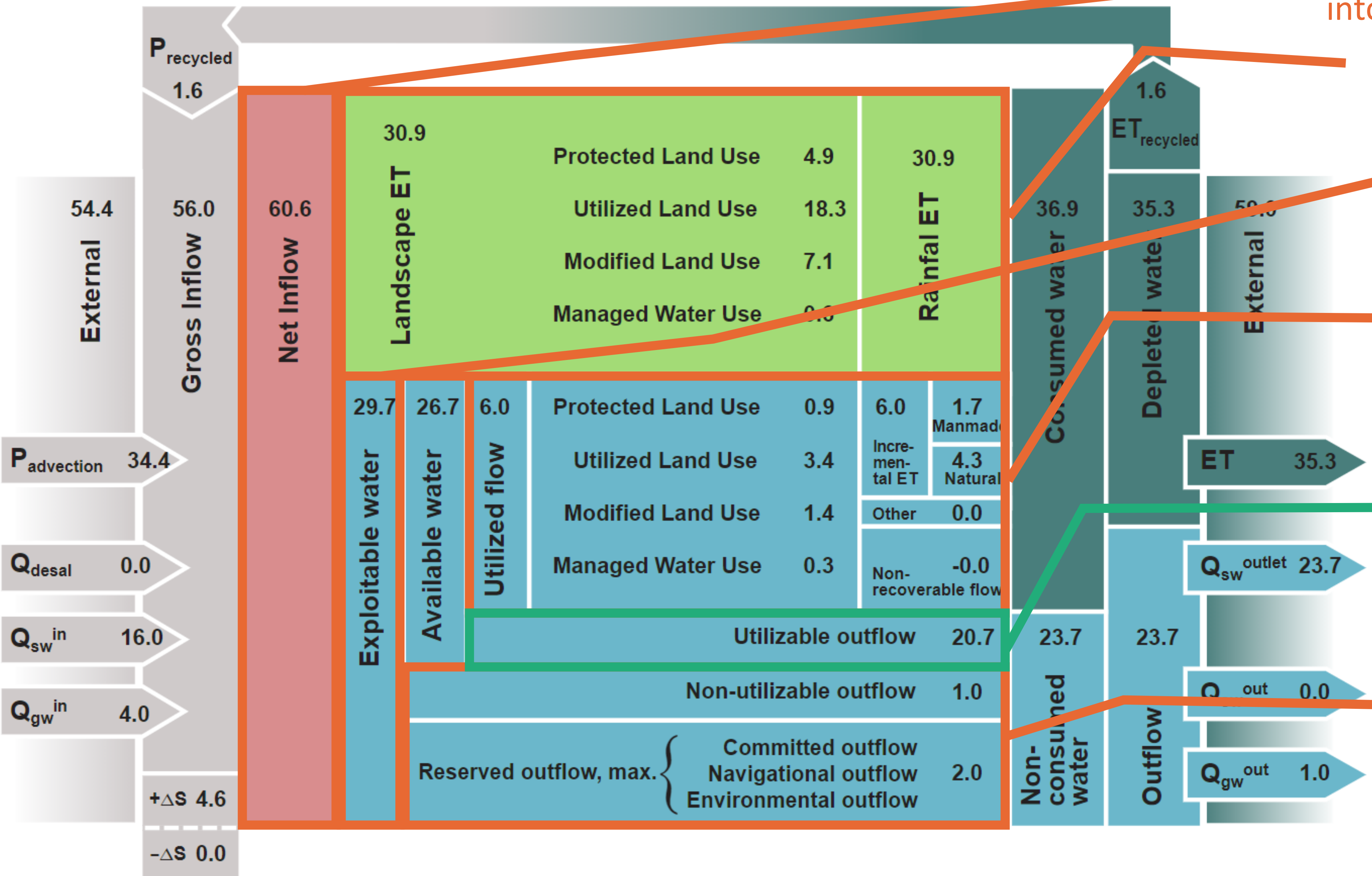
Modify
land use
practices
(cropland,
urban,
forest,…)

Modified Land Use

Managed Water Use

Managed

Water Accounts help the user to understand:



How much water is flowing into the system

How much water is lost to landscape evapotranspiration

How much water is available to be exploited…

…of which, how much is already being utilized….

…and therefore, how much water is still available for allocation.

…and how much is reserved for downstream countries, environmental flows, etc. …

Water indicators produced by WA+

Foundational Layers

- Basin Precipitation
- Basin evapotranspiration
- Basin runoff
- Blue and green water ET
- Evaporation
- Transpiration
- Soil moisture

Water Availability indicators

- Surface water yield
- Groundwater yield
- Managed (irrigation) water use
- Exploitable water (water available after meeting landscape water demand)
- Available water (exploitable water minus irrigation water use)
- Utilizable water (water available for further use)
- Reserved flows (water reserved for meeting environmental water demand)

Advantages of WA+ approach

- Can produce water accounts for data scarce basins.
- Unlike many hydrologic models, WA+ can be used to understand beneficial vs. non-beneficial water use; blue ET vs. green ET; utilizable vs non-utilizable water in the basin;
- Uses remote sensing data to produce consistent, repeatable and scalable methodology.
- Provides continuous information on the hydrology of the basin (multi-year trends, patterns, projections)
- Produces policy relevant information for IWRM

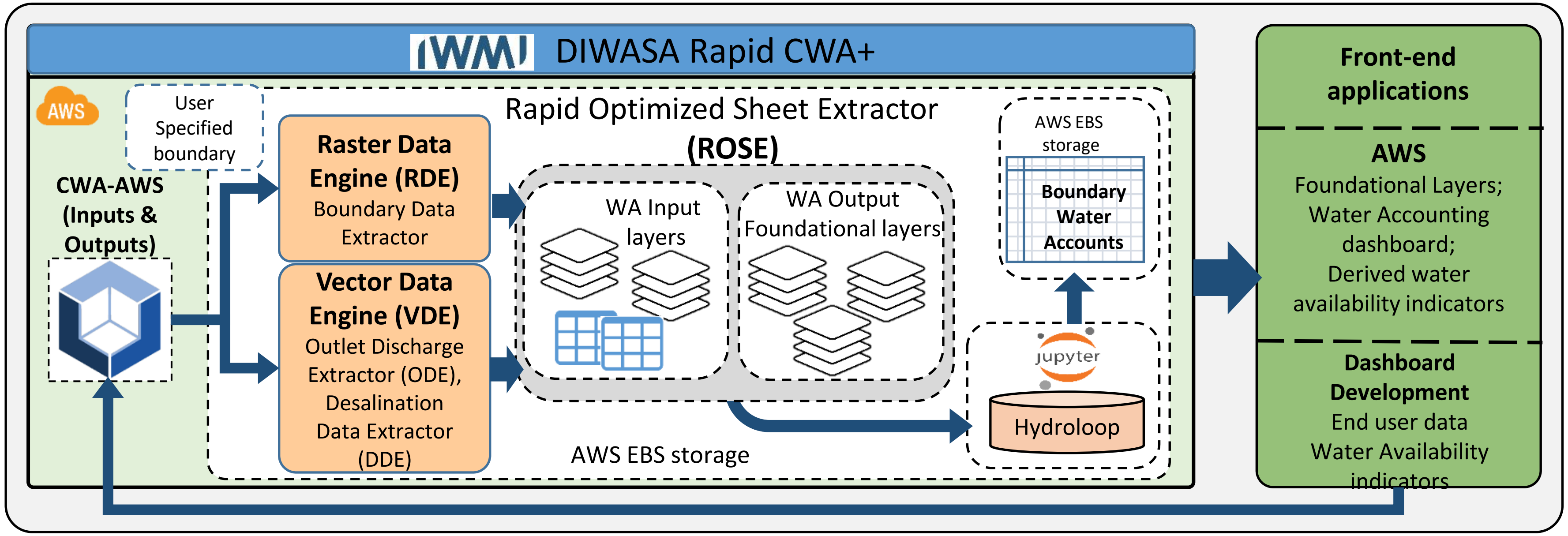
Disadvantages of WA+

- Cannot be applied to small basins (< 4000 km^2) due to coarse resolution remote sensing data used;
- Cannot be used to provide water accounts at national scales;
- Cannot be used for field-scale application such as irrigation metering;
- Cannot be used for monitoring/estimating groundwater levels;
- In situ data (discharge, rain gauge measurements, high resolution land use/land cover data is still required for calibration/validation.
- WA+ application requires basic knowledge of programming and GIS skills to run and process the WA+ outputs.

WA+ in the Zambezi Basin for baseline conditions (2003-2021)

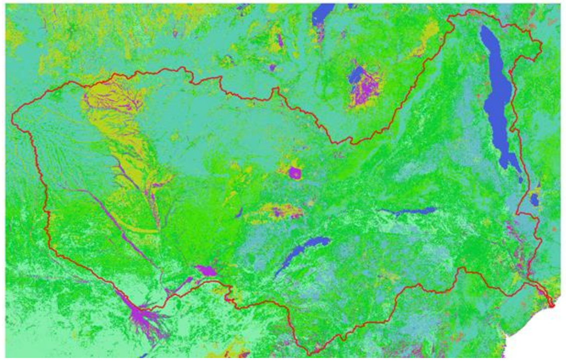
WA+ framework for Zambezi River Basin

A rapid water accounting plus framework built on continental water accounting plus (CWA+) framework was implemented for Zambezi river basin.

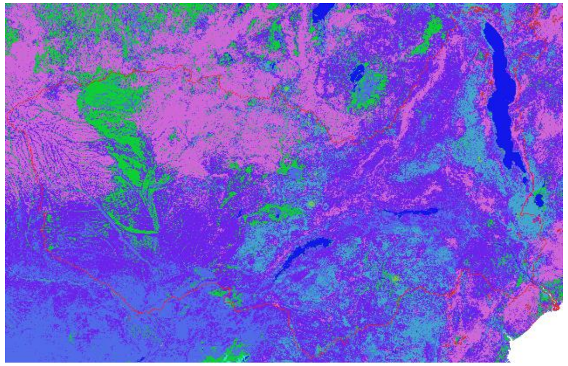


WA+ Input Datasets

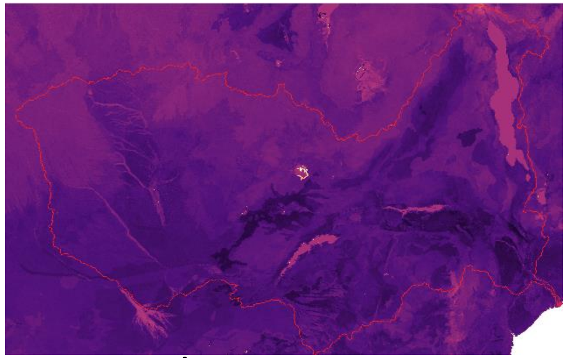
- Rainfall data – CHIRPS, MSWEP, TAMSAT, TRMM
- Number of Rainy Days
- Reference ET – WaPOR
- Evaporation – WaPOR
- Transpiration – WaPOR
- Interception – WaPOR
- In situ rainfall – ZMD, SASSCAL
- Discharge – ZAMCOM, WARMA
- LCC – WaPOR, ILUA Zambia
- Soil Water Content
- Elevation
- Leaf Area Index
- Net Primary Productivity
- Net Dry Matter



Land Cover

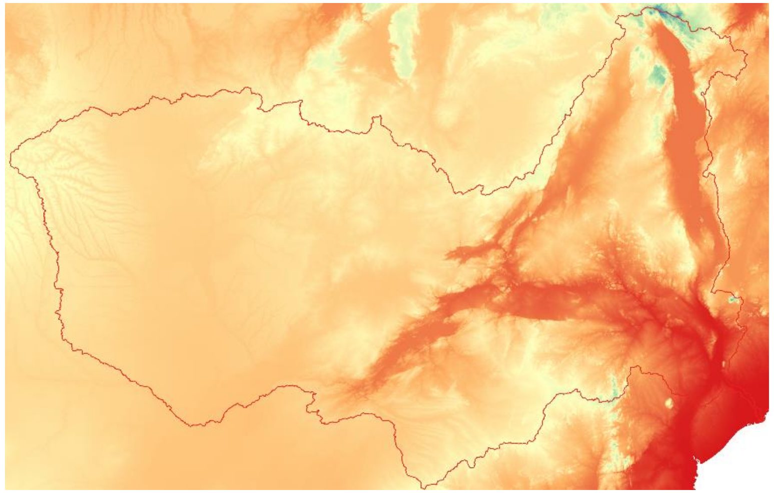


Reclassified Land Cover

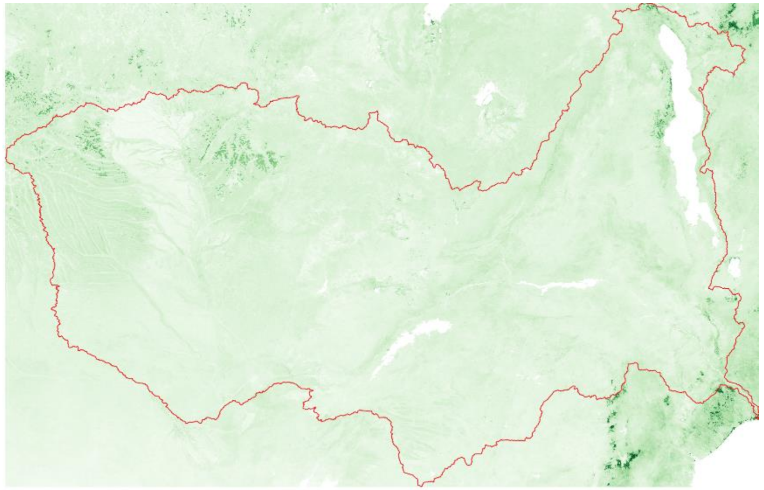


Soil Water Content

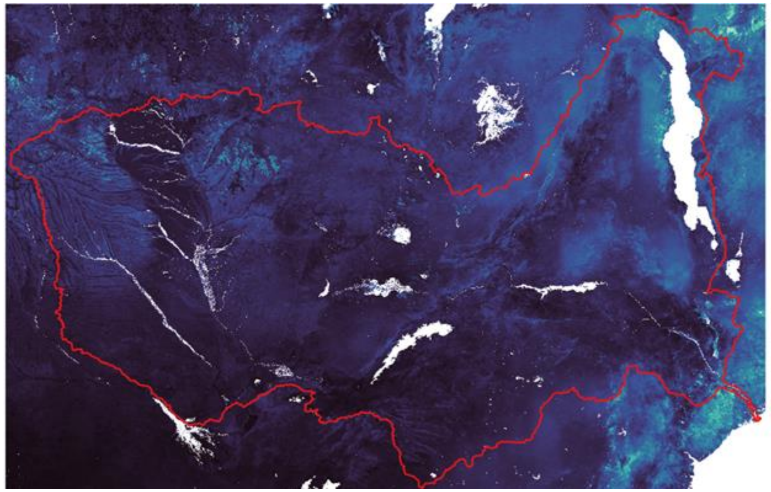
WA+ Input Datasets - Maps



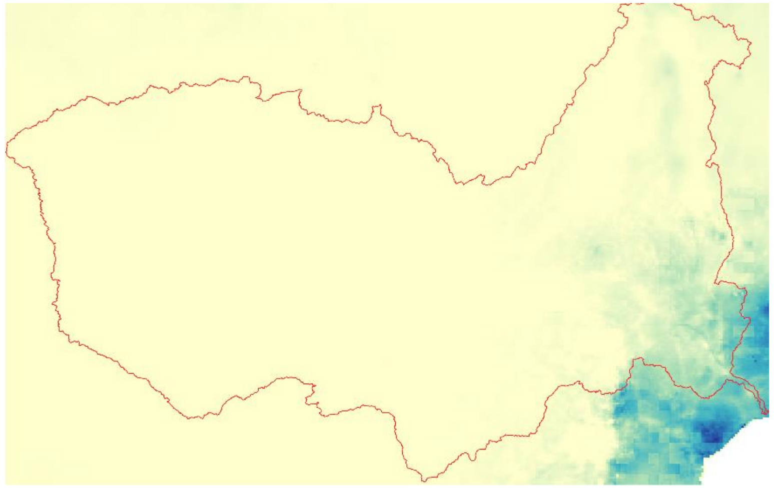
Digital Elevation Model



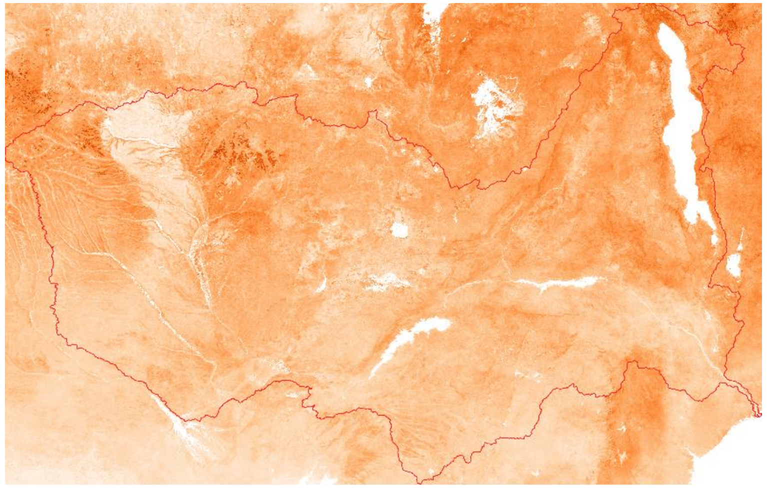
Leaf Area Index



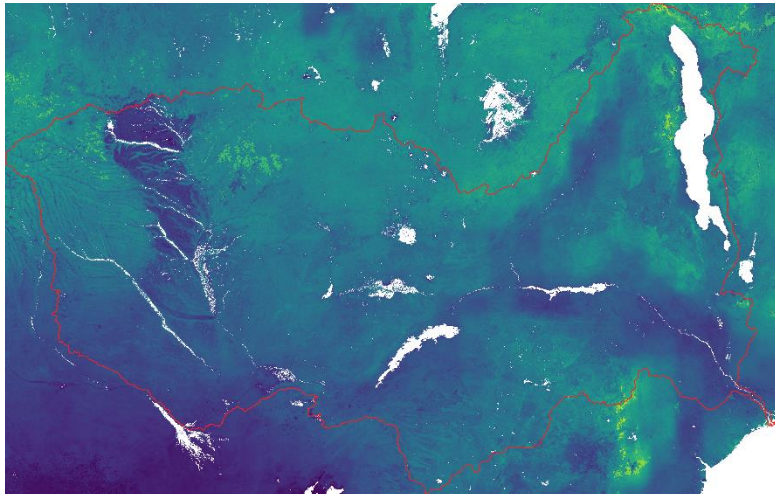
ET



Precipitation

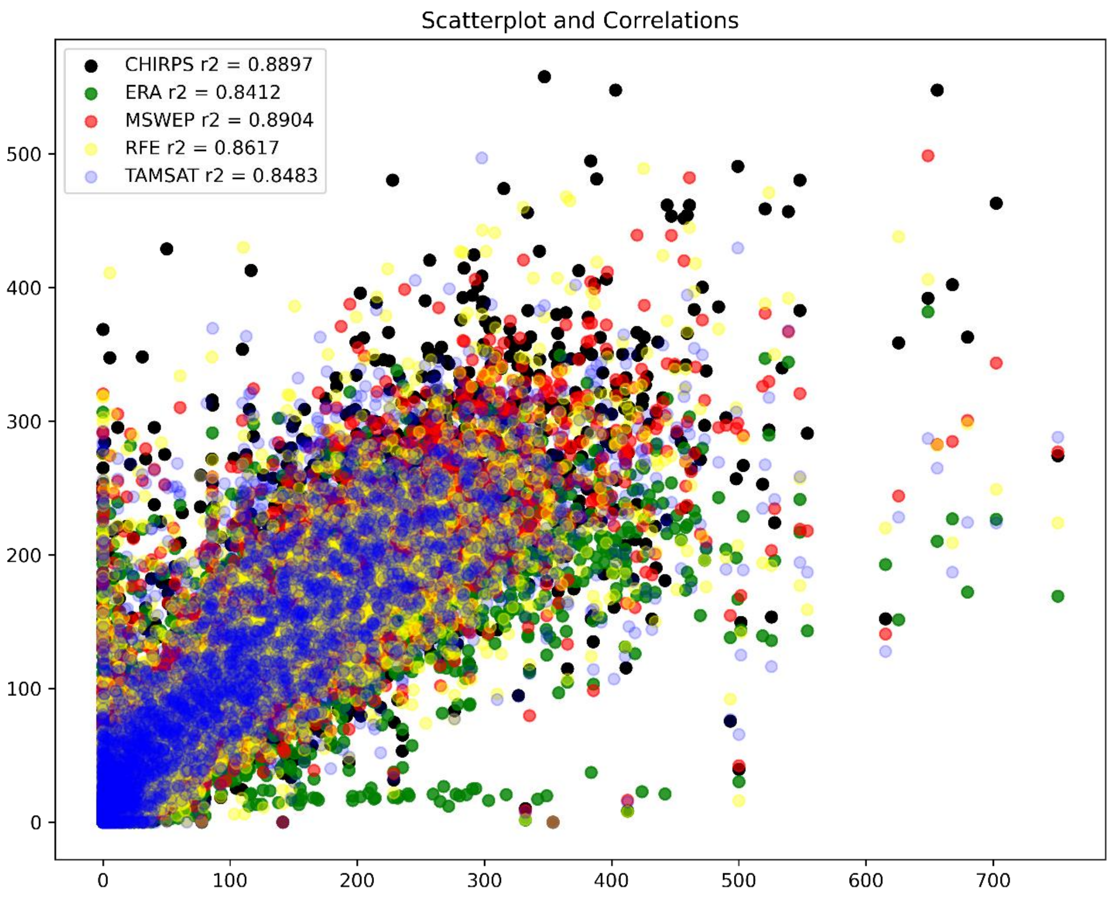


Net Dry Matter



Net Primary Productivity

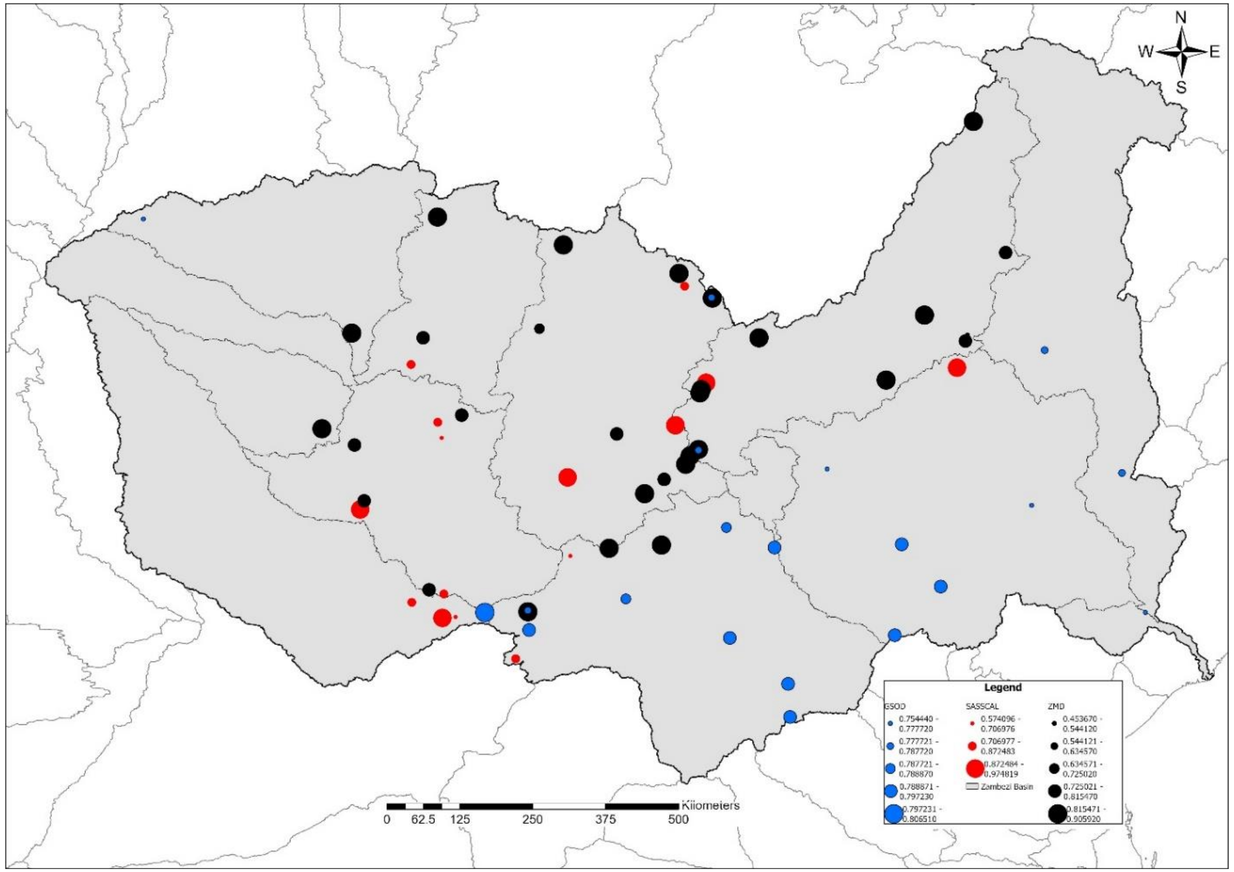
Basin-wide Validation Analysis



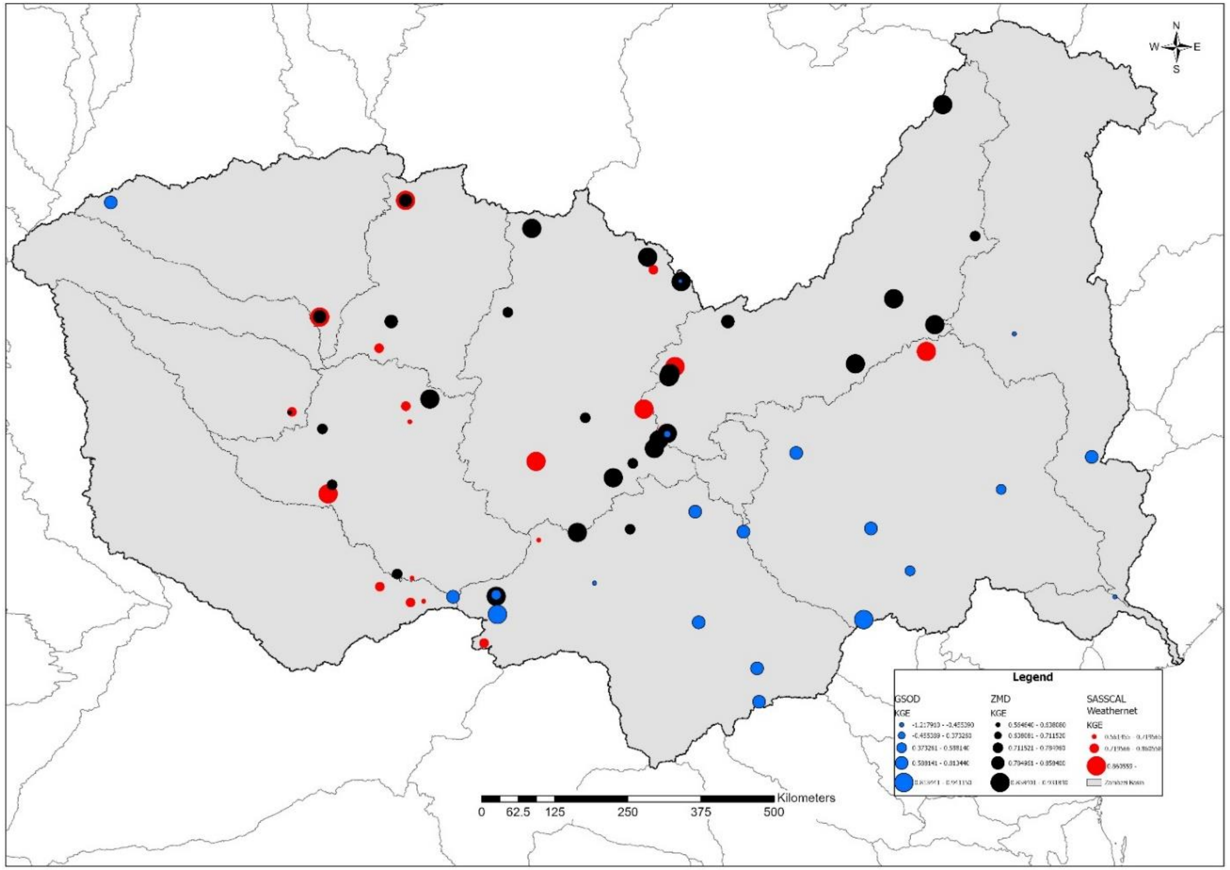
Data	R2	Tau	RMSE	MARE	P-bias	NSE	KGE	KGE	NP KGE
CHIRPS	0.89	0.81	50.10	0.32	-0.61	0.79	0.86	0.86	0.88
ERA	0.84	0.73	61.14	0.40	13.77	0.69	0.67	0.75	0.78
MSWEP	0.89	0.77	49.97	0.33	-1.54	0.79	0.83	0.82	0.85
RFE	0.86	0.79	55.75	0.36	3.67	0.74	0.79	0.81	0.87
TAMSAT	0.85	0.78	58.10	0.39	-0.86	0.72	0.88	0.79	0.88

Basin-wide Validation Analysis

Station vs MSWEP KGE



Stations vs CHIRPS KGE



Summarized Results of NSE and KGE

Nash-Sutcliff Efficiency

Data	Median	Mean
CHIRPS	0.79586	-5.50731
ERA	0.69216	-4.39119
MSWEP	0.78769	-3.70327
RFE	0.75413	-13.44030
TAMSAT	0.71665	-3.50745

Modified Kling-Gupta Efficiency

Data	Median	Mean
CHIRPS	0.84839	0.49405
ERA	0.73588	0.45695
MSWEP	0.80958	0.49615
RFE	0.80301	0.32583
TAMSAT	0.78002	0.46470

GSOD vs Satellite Rainfall KGE

median KGE	MSWEP	CHIRPS	RFE	ERA
Daily	0.30	0.28	0.22	0.20
Monthly	0.79	0.76	0.73	0.54
annual	0.78	0.76	0.77	0.56

Kling-Gupta Efficiency

Data	Median	Mean
CHIRPS	0.83656	0.34017
ERA	0.65721	0.29161
MSWEP	0.80165	0.39867
RFE	0.77455	0.11492
TAMSAT	0.75025	0.33446

Non-parametric Kling-Gupta Efficiency

Data	Median	Mean
CHIRPS	0.85833	0.50570
ERA	0.76295	0.48576
MSWEP	0.82465	0.51807
RFE	0.82552	0.34837
TAMSAT	0.82344	0.50616

Weather Station Data

- Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL) Weathernet
  - Automatic stations across Botswana, Namibia and Botswana
  - 2013 to 2023
  - 19 stations within the Zambezi basin

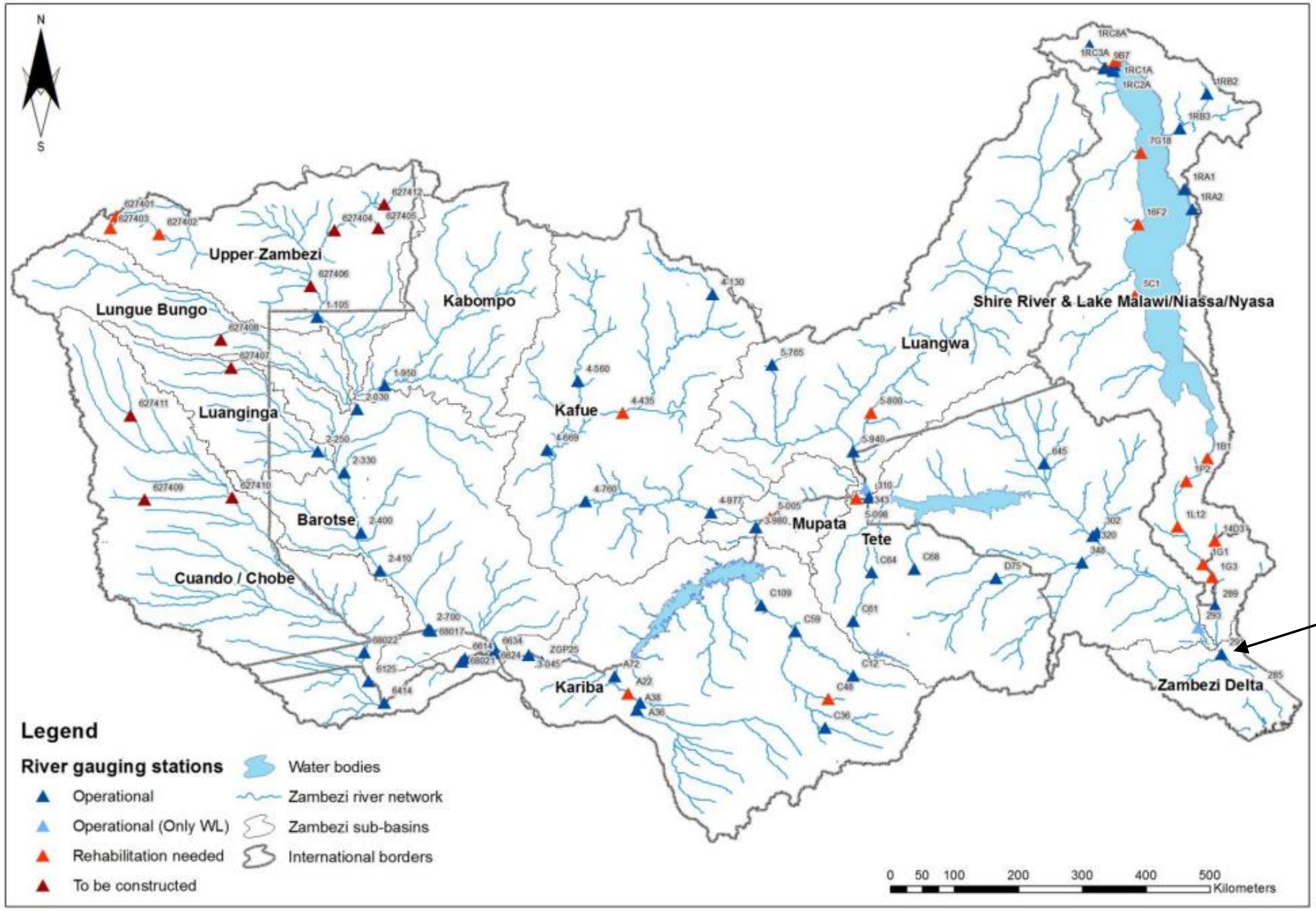
- Zambia Meteorological Department (ZMD)
  - Manual stations across Zambia
  - Data available from July 1989 to August 2020
  - 30 stations within the Zambezi Basin

- Global Surface Summary (GSOD)
  - Derived from The Integrated Surface Hourly (ISH) dataset
  - 1929 to date
  - Over 9000 stations globally
  - 20 within the Zambezi Basin

❑ Validation analysis carried out at a monthly time step

❑ Each metric was calculated at each station, and from an aggregate of all stations

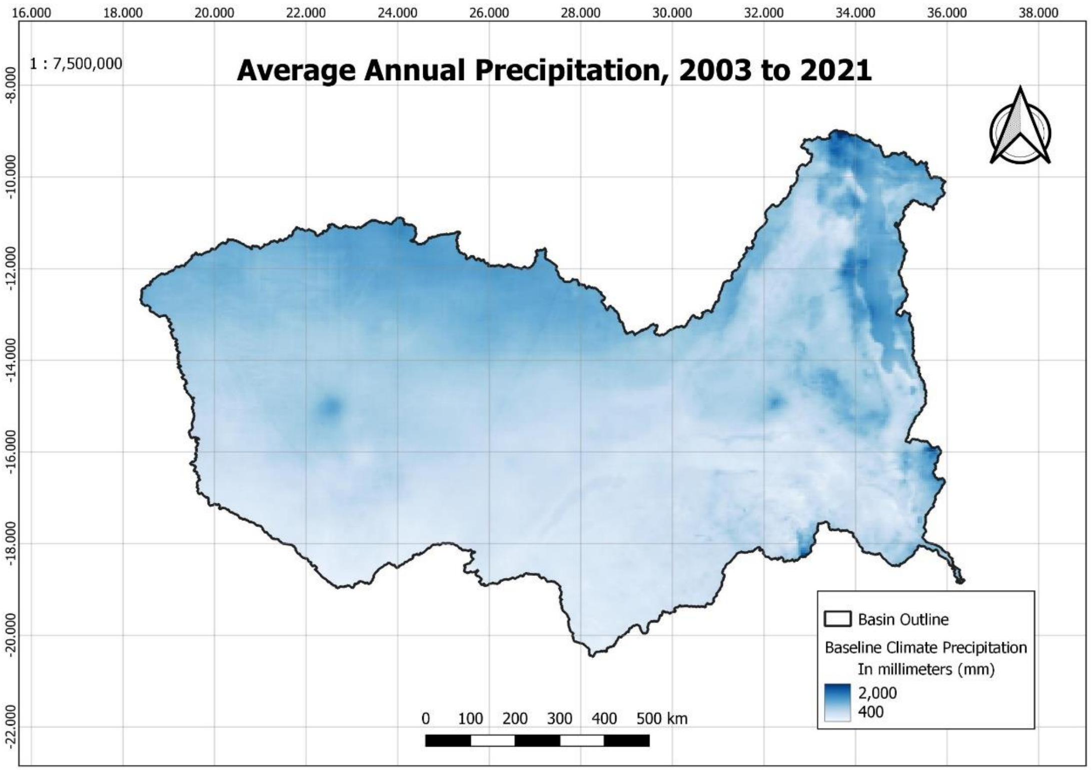
Zambia discharge data

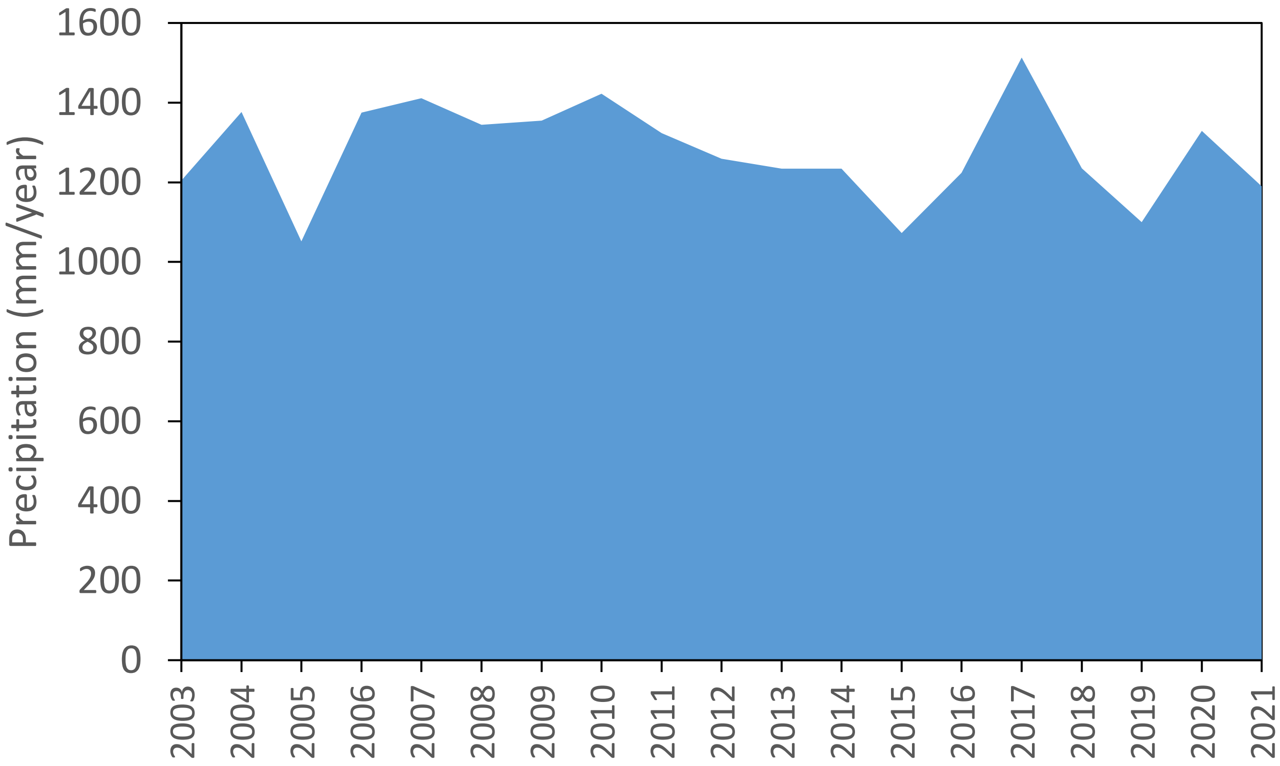


Data was gathere for about 8 discharge Station s but most of them had missing data (>50% missing).

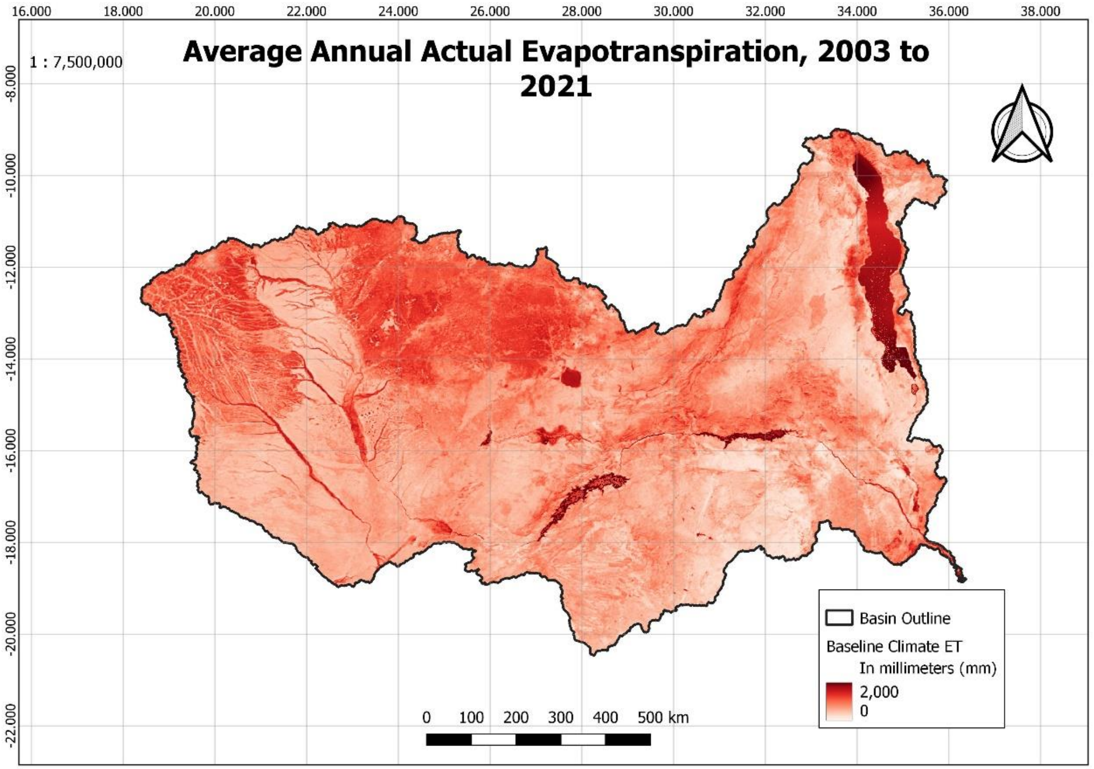
Station ID#291 was used to model River basin outlet discharge.

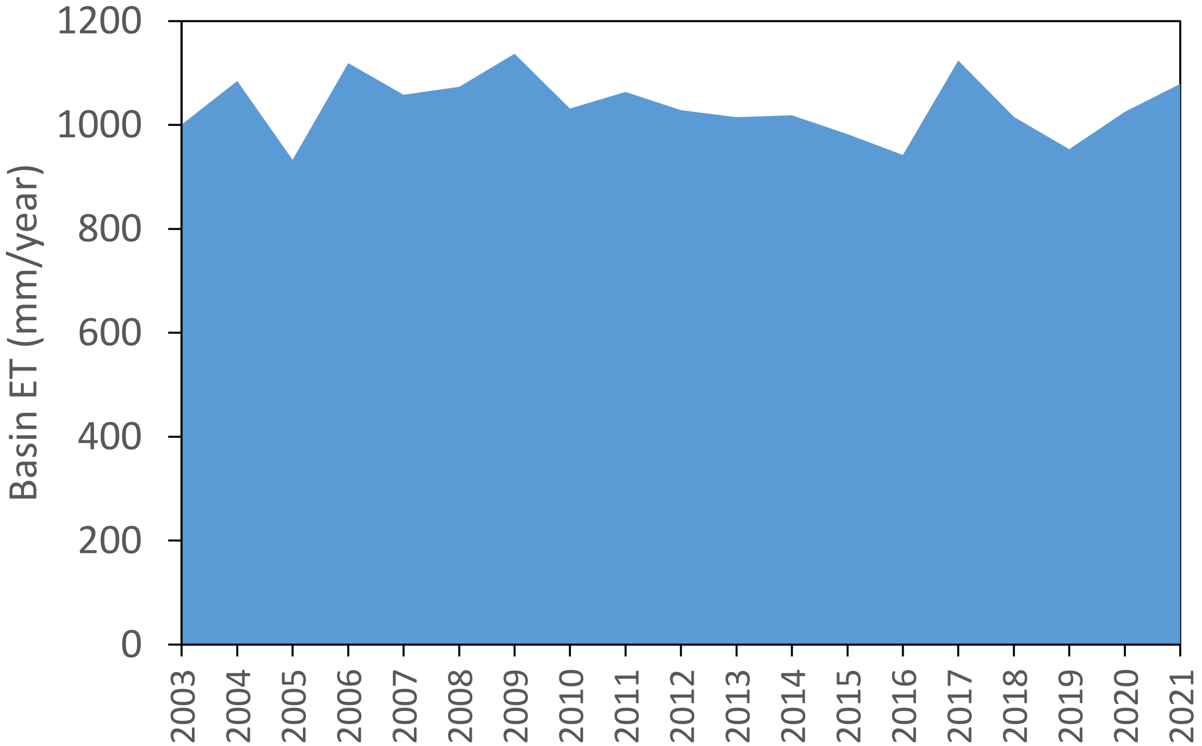
Basin Monthly/Annual Precipitation



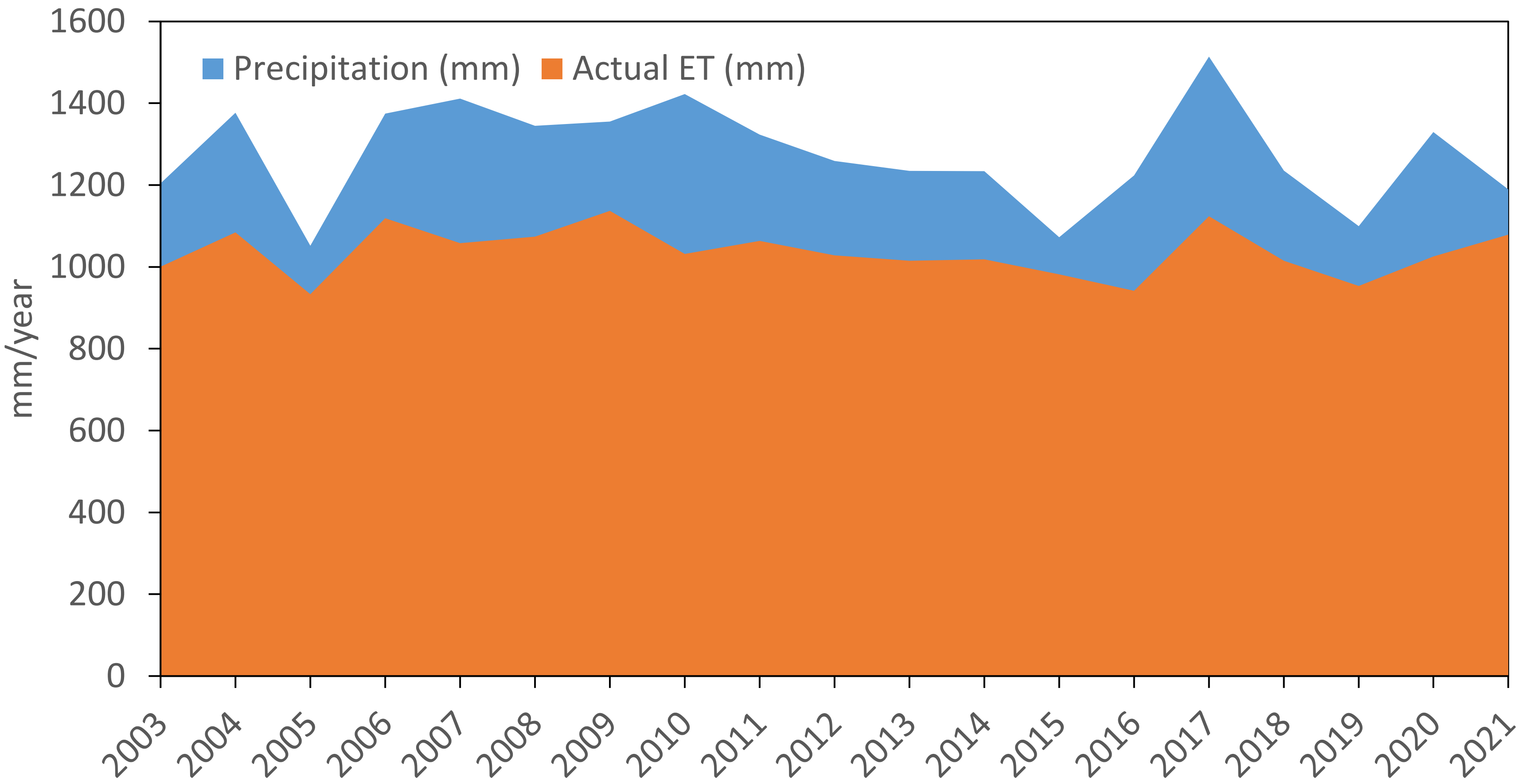


Basin Monthly/Annual Evapotranspiration





Zambezi Basin Precipitation and ET (mm/year)



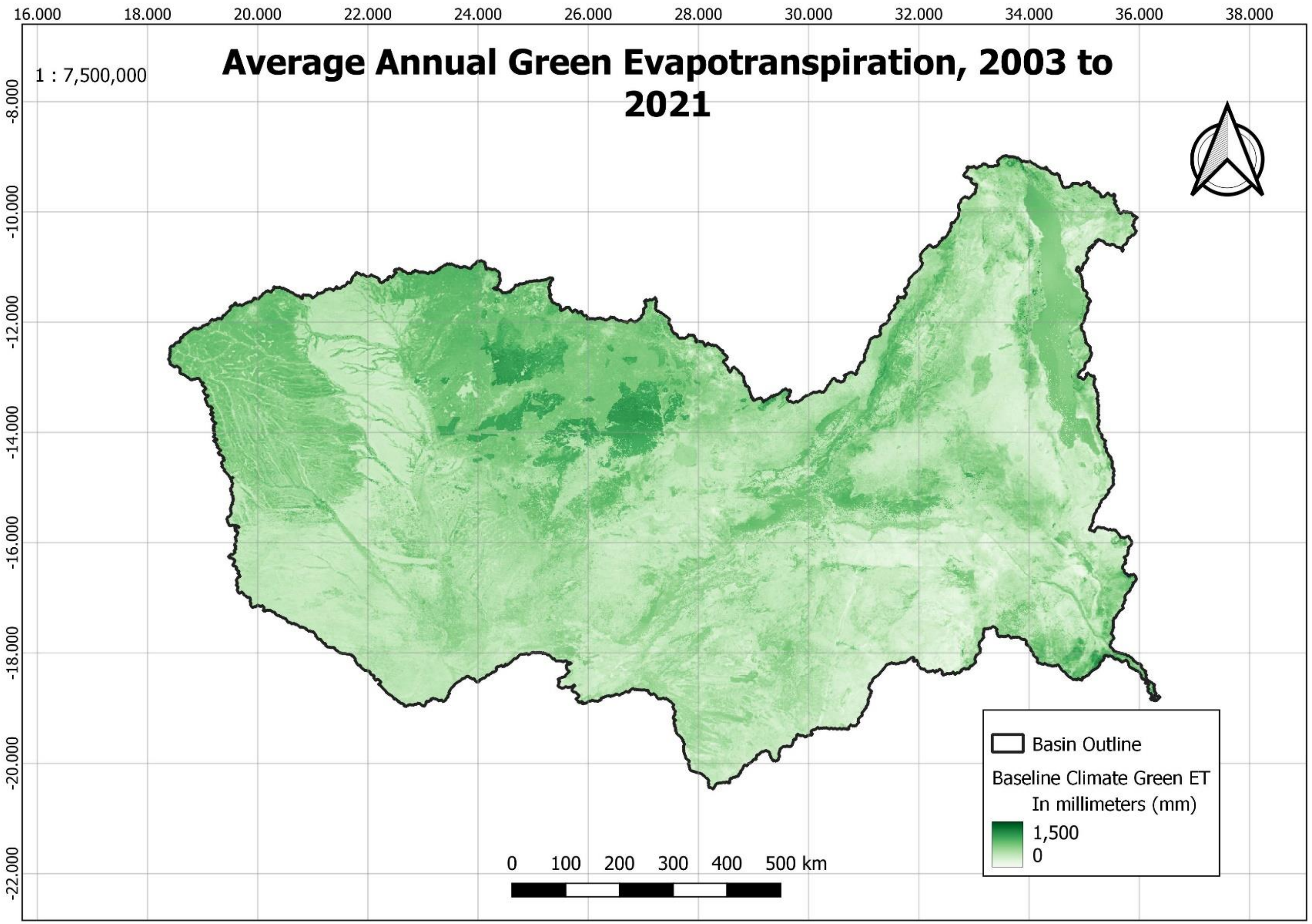
Zambezi basin rainfall shows high year-to-year variability (up to 20%).

There is no significant long-term change in the basin rainfall.

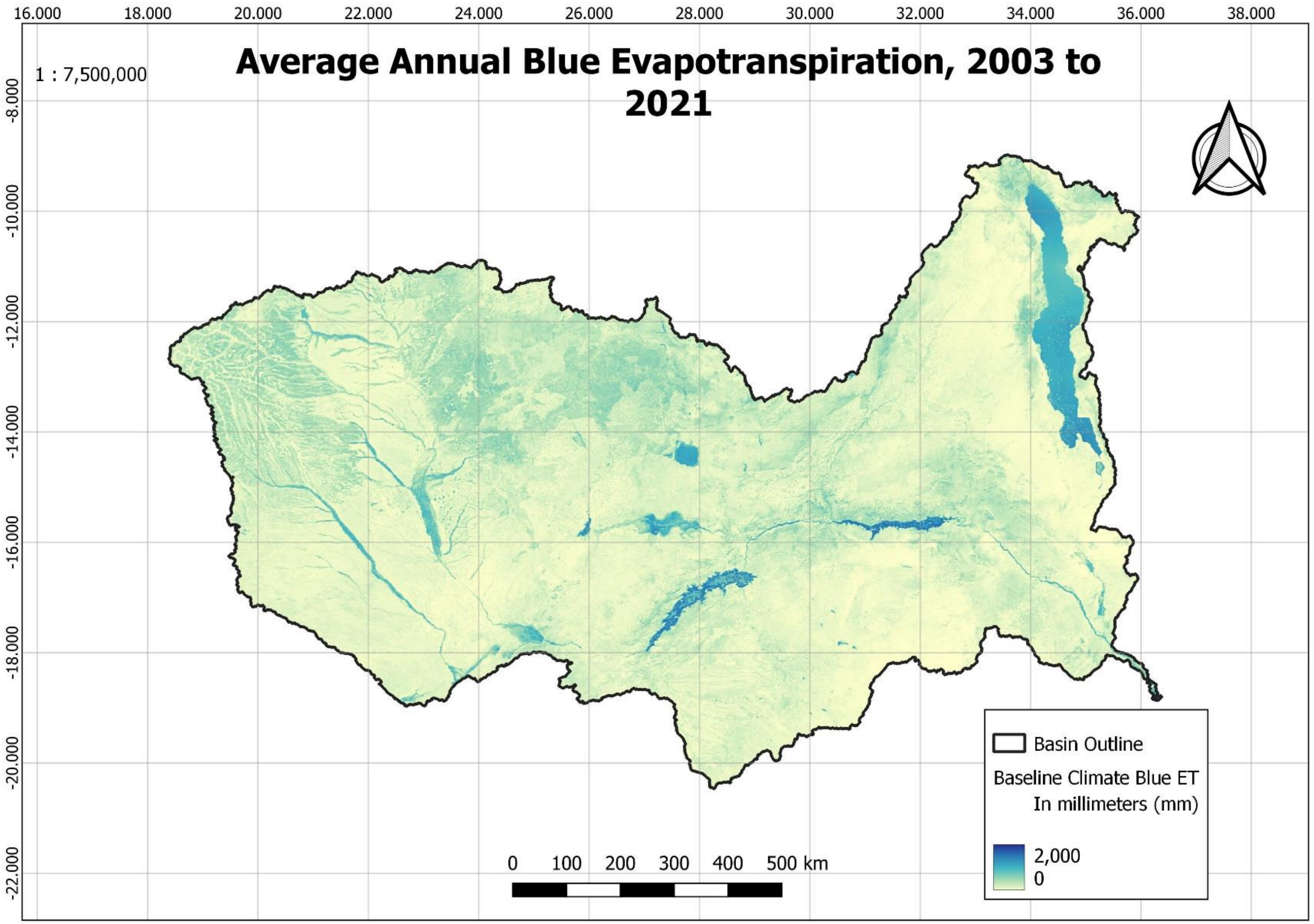
Zambezi basin ET shows low year-to-year variability.

There is no significant long-term change in the basin ET.

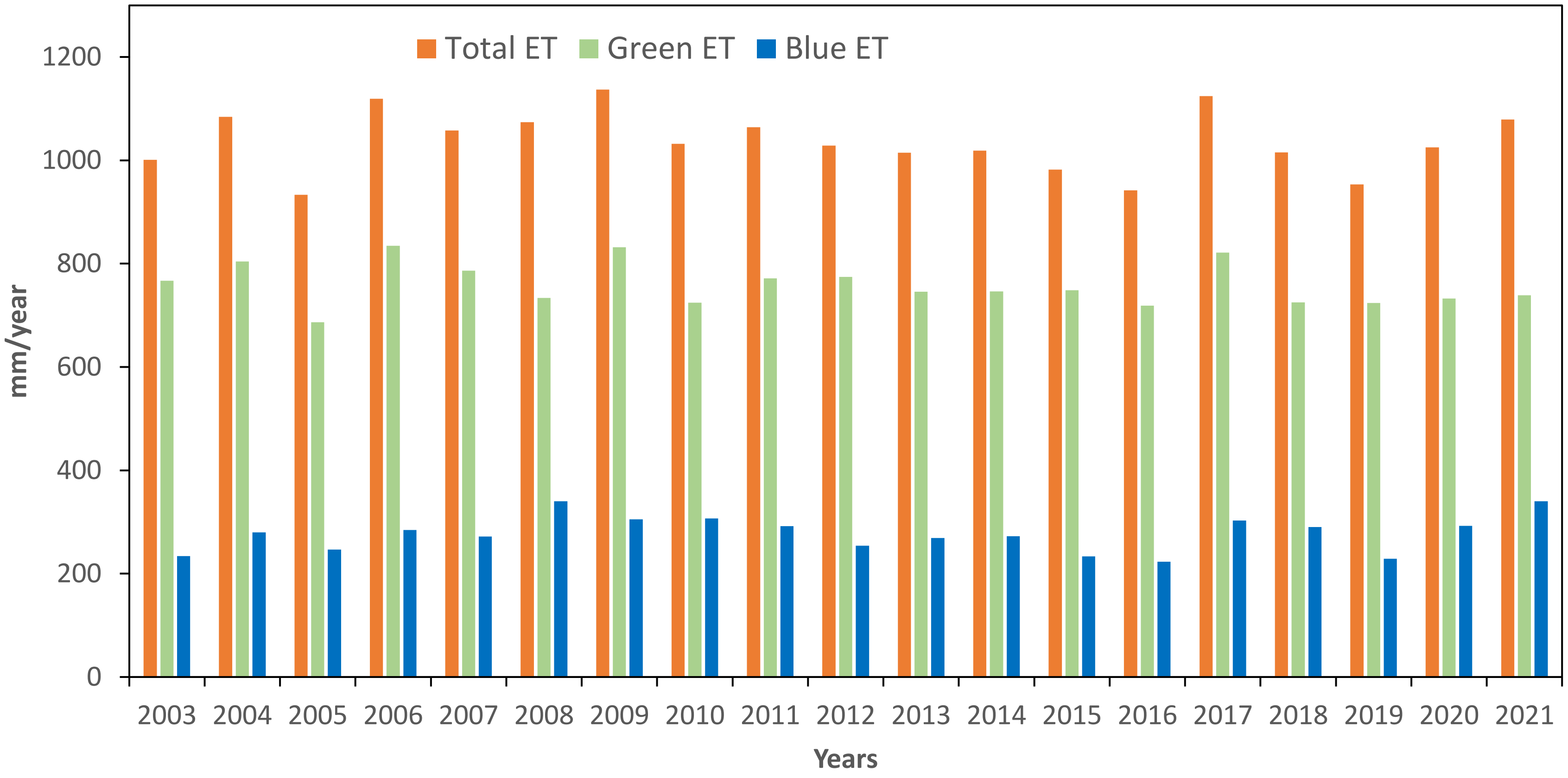
Average Basin ET green (2003-2021)



Average Basin ET-blue (2003-2021)



Zambezi Basin Actual, green and blue ET

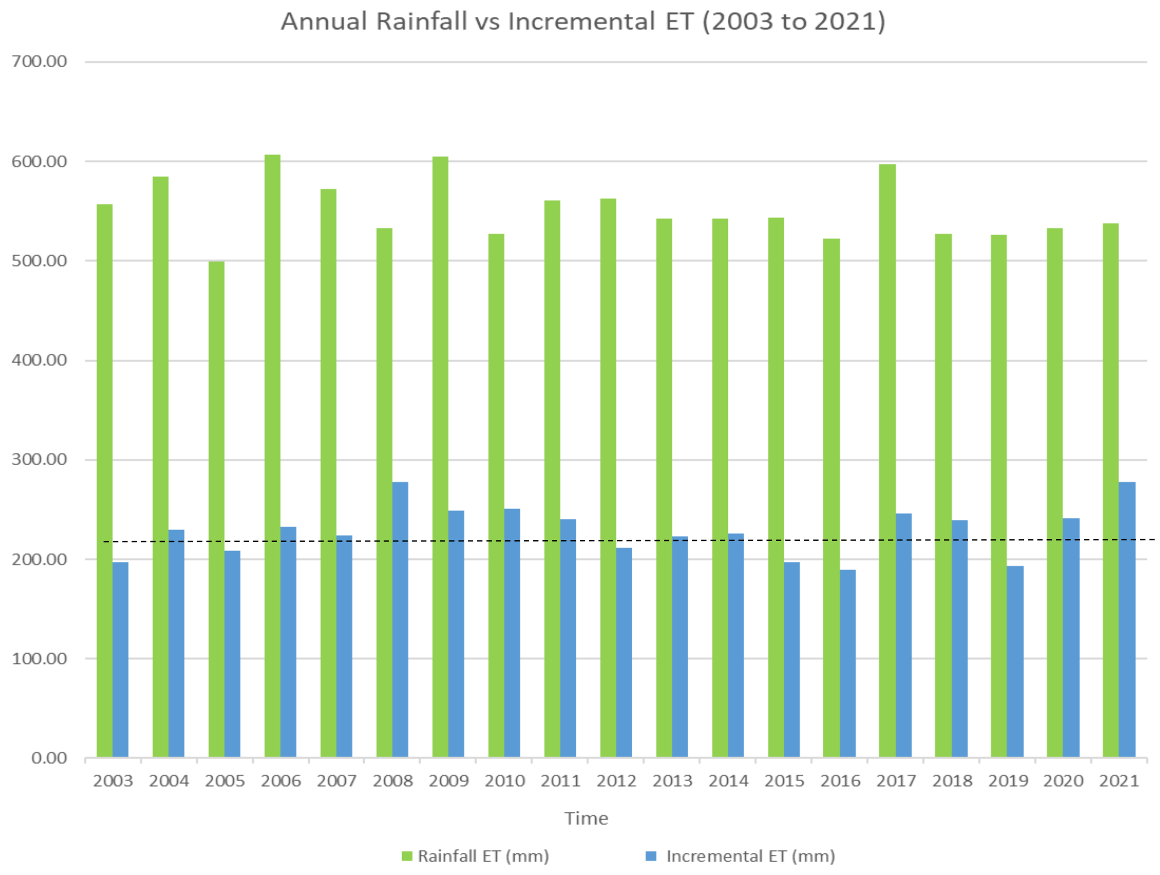


The total ET (orange-bars) is the water consumed by the landscape in the Zambezi basin.

Green ET (green-bars) is defined as water consumed from the soil moisture replenished by precipitation.

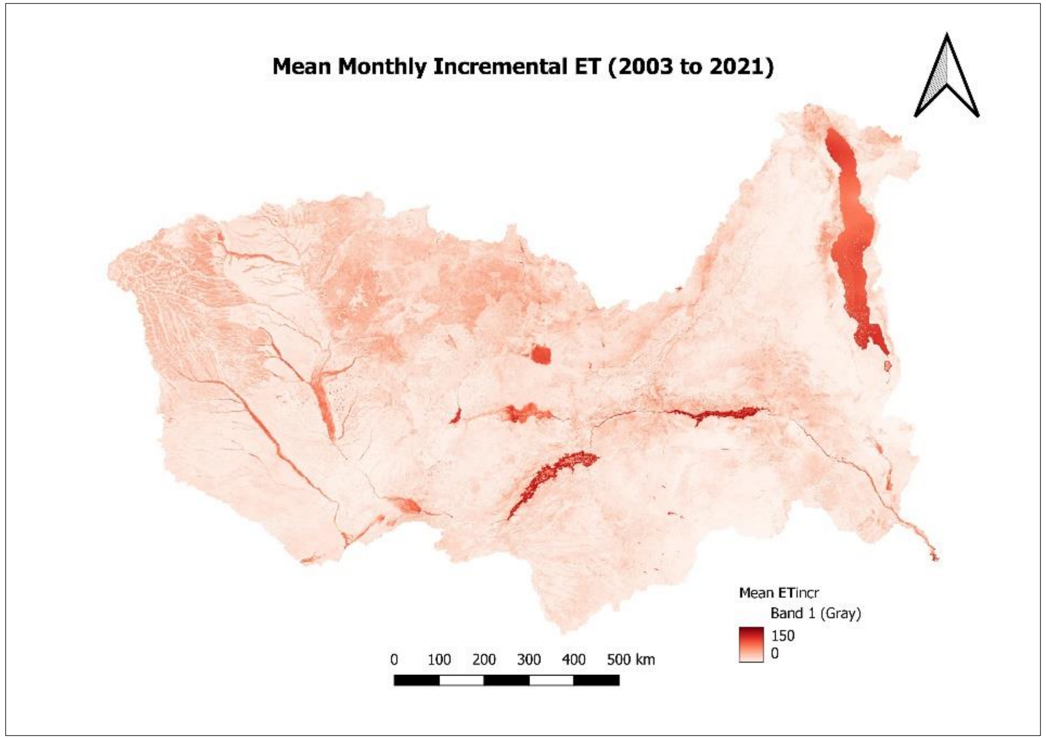
Blue ET (difference between actual minus green ET) is defined as water consumed from the blue water sources such as rivers, ponds, lakes, and irrigation from surface or groundwater sources.

Blue ET (Incremental ET)

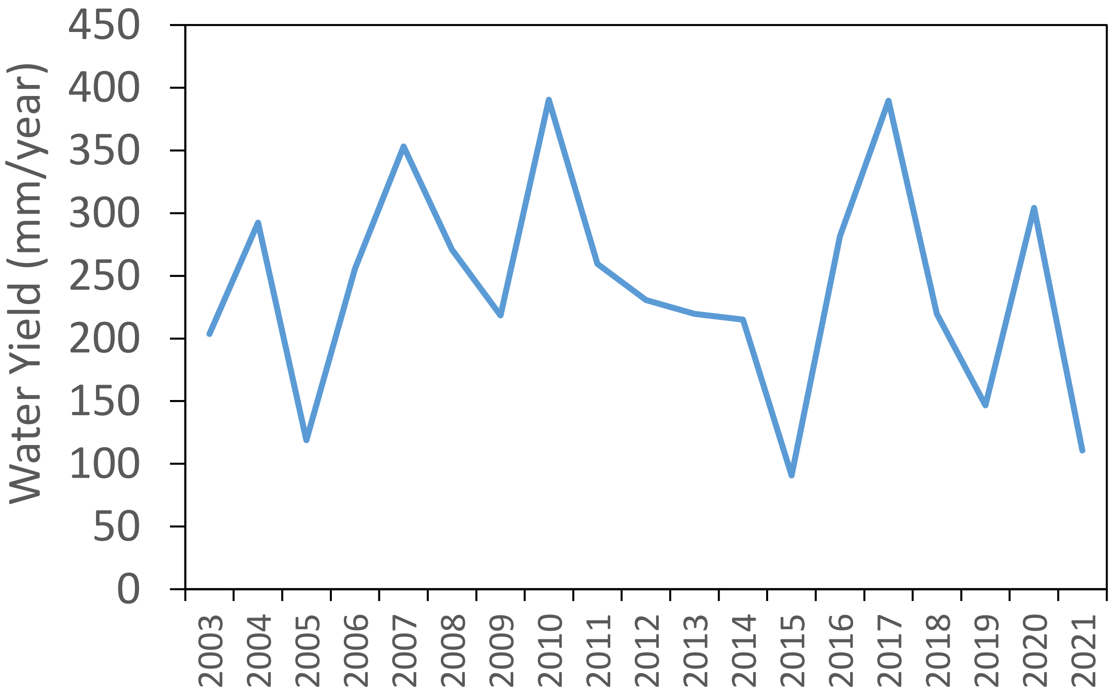


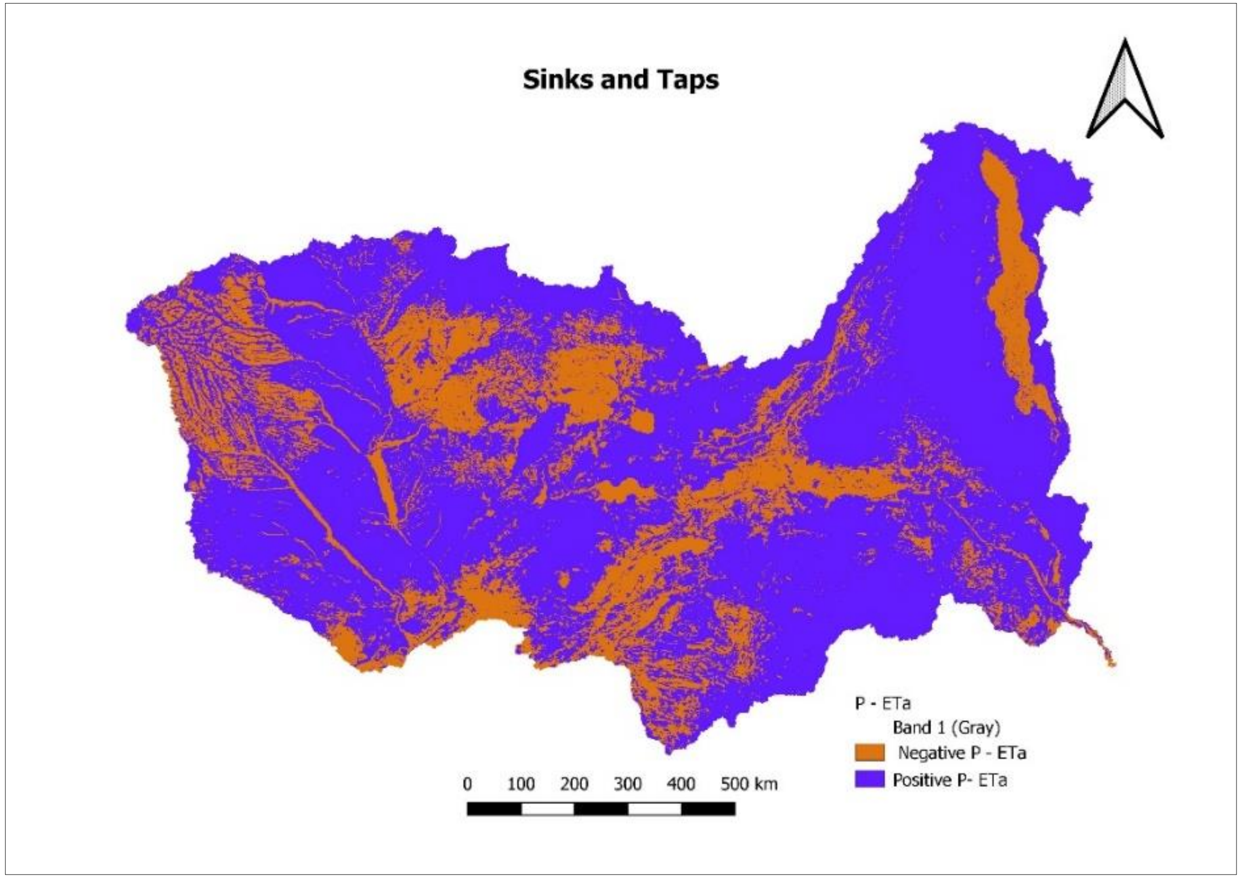
No trend in blue ET

Most blue ET is from surface water bodies and small irrigated areas scattered around the basin.



Surface water yield (P-ETa)





Zambezi basin hydrology (2003-2021)

Year	Precipitation (mm)	Actual ET (mm)	Surface water Yield (mm)	Rainfall ET (mm)	Incremental ET (mm)
2003	1204	1001	204	767	234
2004	1377	1084	292	804	280
2005	1052	933	119	687	247
2006	1375	1119	256	835	285
2007	1411	1058	353	786	272
2008	1345	1074	271	734	340
2009	1355	1137	218	832	305
2010	1422	1032	390	725	307
2011	1323	1064	259	772	292
2012	1259	1028	231	774	254
2013	1235	1015	220	746	269
2014	1234	1019	215	746	272
2015	1073	982	91	748	234
2016	1223	942	281	719	223
2017	1514	1124	389	821	303
2018	1235	1015	220	725	290
2019	1100	953	147	724	229
2020	1329	1025	304	732	293
2021	1190	1079	111	739	340

Zambezi basin hydrology (long-term average)

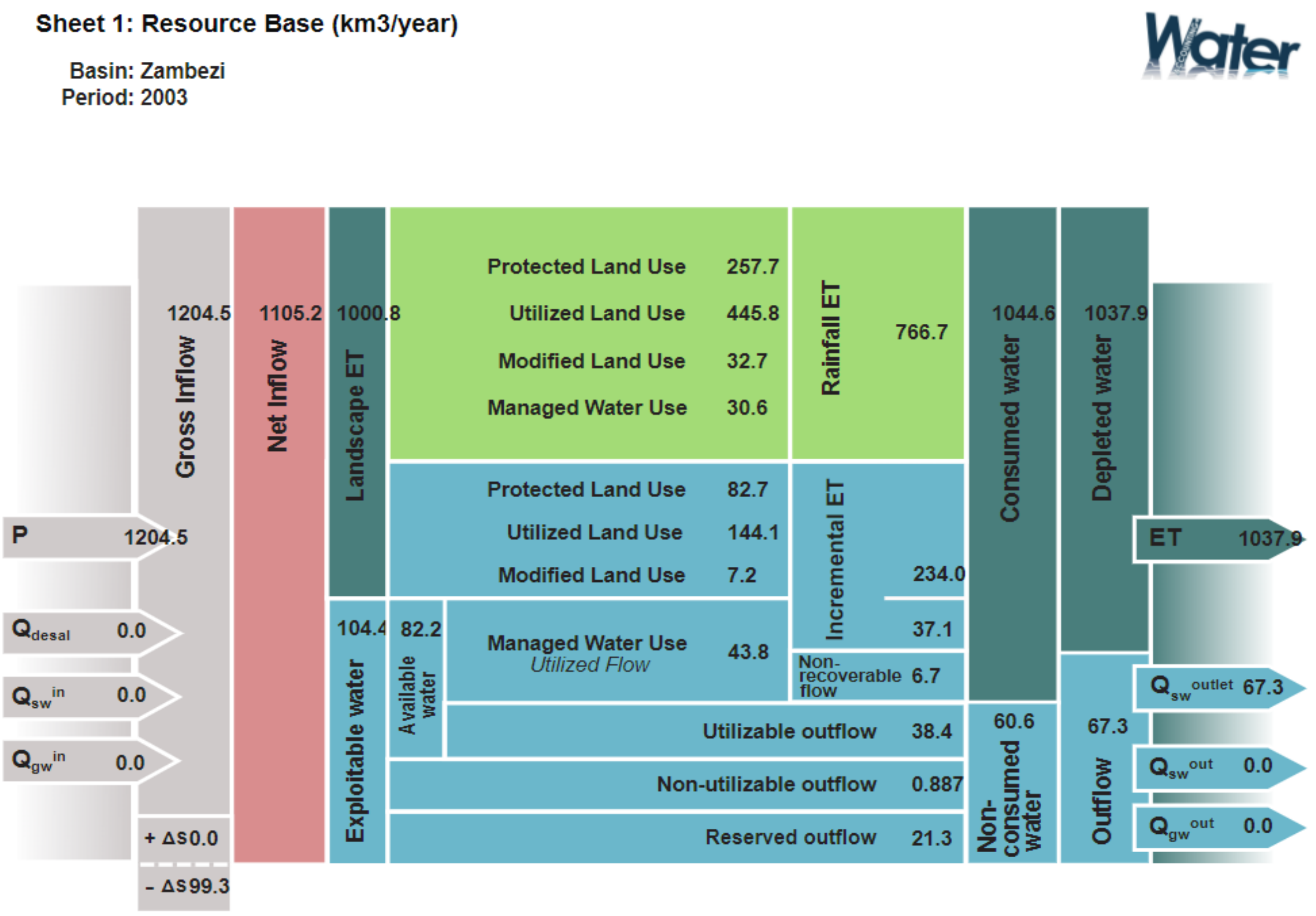
Parameter	Mean (mm)
Precipitation	1277
Actual ET	1036
Water Yield	241
Rainfall ET	759
Incremental ET	277

Precipitation exceeds the annual ET, indicating that water is available in excess at annual time scales.
The per-capita water availability is about 3.33 m^3.

About 70% of the annual ET is consumed from the green water (mostly soil moisture)

About 30% of the total ET is consumed from the blue water sources

Water Accounts for 2003



WA+ in the Zambezi Basin for future scenarios (2027-2045)

Projected climate scenarios

- NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP-CMIP6)
- Global downscaled climate scenarios derived from the General Circulation Model (GCM) runs conducted under the Coupled Model Intercomparison Project Phase 6 (CMIP6)
- The Bias-Correction Spatial Disaggregation (BCSD) method used to generate the **NEX-GDDP-CMIP6** dataset is a statistical downscaling algorithm specifically developed to address these limitations of global GCM outputs [Wood et al. 2002; Wood et al. 2004; Maurer et al. 2008; Thrasher et al. 2012]
- Available on AWS : s3://nex-gddp-cmip6/

Projected climate scenarios

- Output from 35 CMIP6 GCM models
- Ensemble of 4 common climate projections
  - ASSESS-CM2
  - CNRM-CM6-1
  - MPI-ESM1-2LR
  - MIROC6
- SSP4.5 for 3 epochs
  - 2030s (2027-2032)
  - 2035s (2033-2037)
  - 2040s (2038-2045)
- P, Tmax, Tmin

Table 1. CMIP6 models included in downscaled archive

Model	Variant	hurs	huss	pr	rlds	rsds	sfcWind	tas	tasmax	tasmin
ACCESS-CM2	r1i1p1f1									
ACCESS-ESM1-5	r1i1p1f1									
BCC-CSM2-MR	r1i1p1f1									
CanESM5	r1i1p1f1									
CESM2	r4i1p1f1									
CESM2-WACCM	r3i1p1f1									
CMCC-CM2-SR5	r1i1p1f1							*	*	*
CMCC-ESM2	r1i1p1f1									
CNRM-CM6-1	r1i1p1f2									
CNRM-ESM2-1	r1i1p1f2									
EC-Earth3	r1i1p1f1									
EC-Earth3-Veg-LR	r1i1p1f1									
FGOALS-g3	r3i1p1f1									
GFDL-CM4 (gr1)	r1i1p1f1									
GFDL-CM4 (gr2)	r1i1p1f1									
GFDL-ESM4	r1i1p1f1									
GISS-E2-1-G	r1i1p1f2									
HadGEM3-GC31-LL	r1i1p1f3									
HadGEM3-GC31-MM	r1i1p1f3									
IITM-ESM**	r1i1p1f1									
INM-CM4-8	r1i1p1f1									
INM-CM5-0	r1i1p1f1									
IPSL-CM6A-LR	r1i1p1f1									
KACE-1-0-G	r1i1p1f1									
KIOST-ESM	r1i1p1f1	***								
MIROC-ES2L	r1i1p1f2									
MIROC6	r1i1p1f1									
MPI-ESM1-2-HR	r1i1p1f1									
MPI-ESM1-2-LR	r1i1p1f1									
MRI-ESM2-0	r1i1p1f1									
NESM3	r1i1p1f1									
NorESM2-LM	r1i1p1f1									
NorESM2-MM	r1i1p1f1									
TaiESM1	r1i1p1f1									
UKESM1-0-LL	r1i1p1f2									

Key: Green = historical & all SSPs available; yellow = historical & some SSPs available; red = no data available

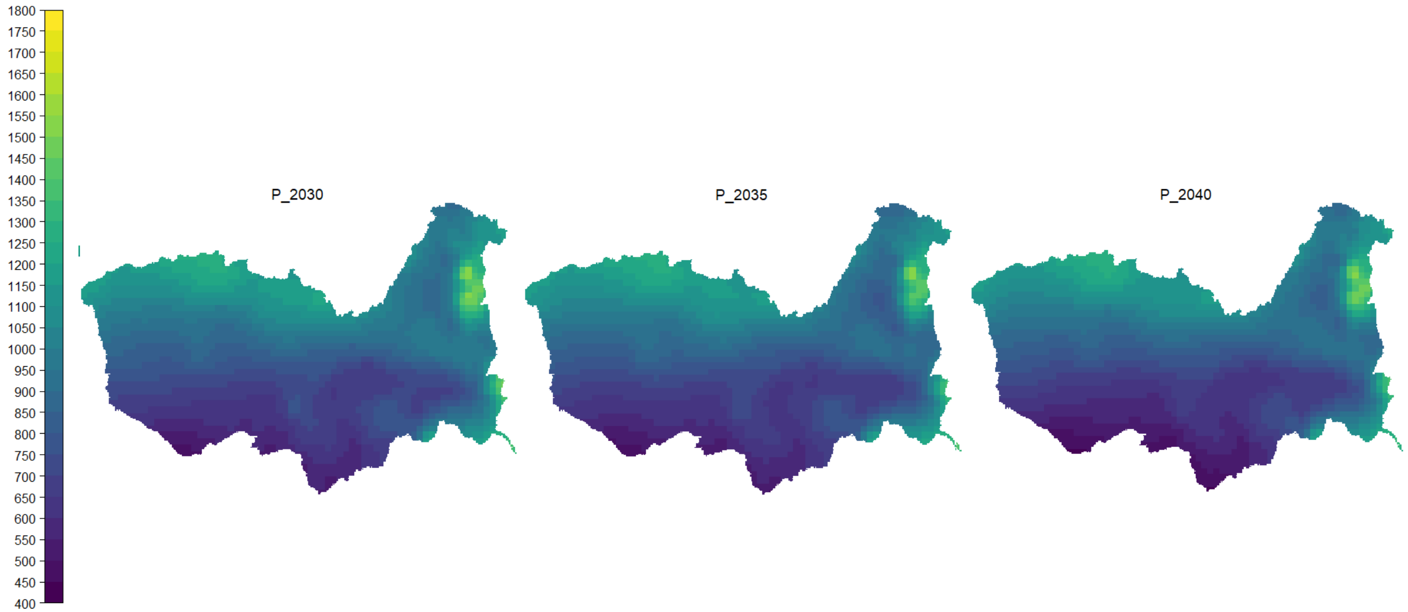
Projected climate scenarios

- Relate P, AET and PET under current conditions
- Assume same relationship holds in future
- Use projected P, Tmin and Tmax to estimate future AET

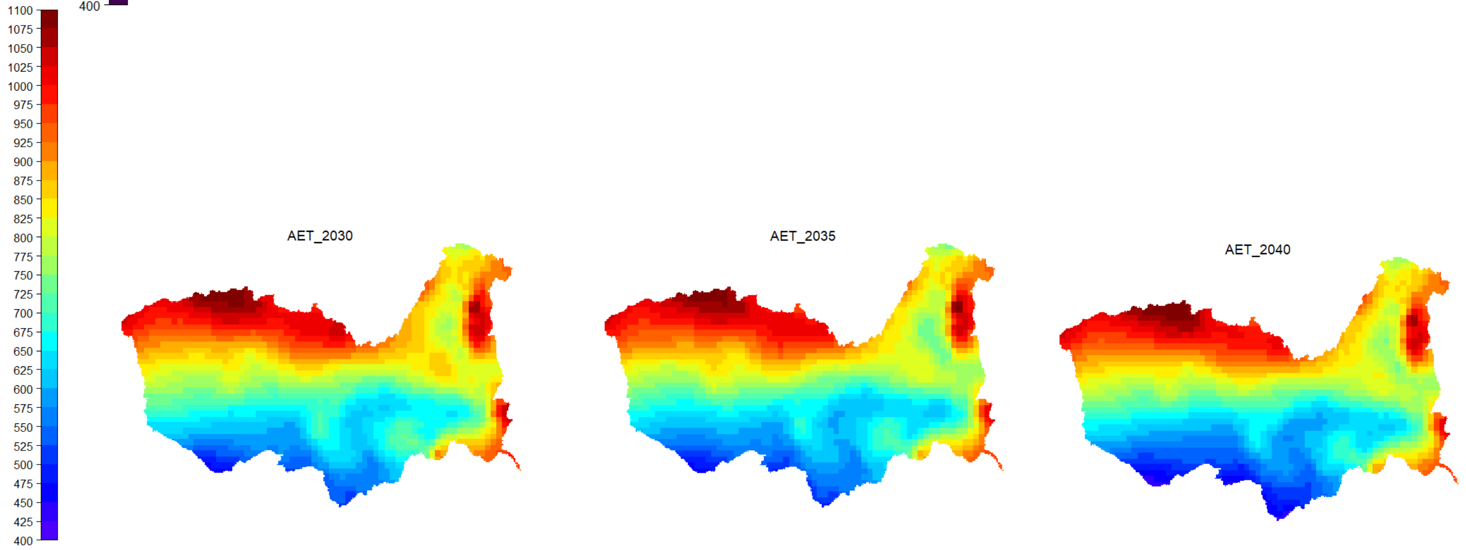
$$\frac{AET}{P} = 1 + \frac{PET}{P} - \left[1 + \left(\frac{PET}{P}\right)^{\omega}\right]^{\frac{1}{\omega}}$$

Projected climate scenarios

- P ranges 400-2000 mm/year
- Historic 770-1077 mm/year



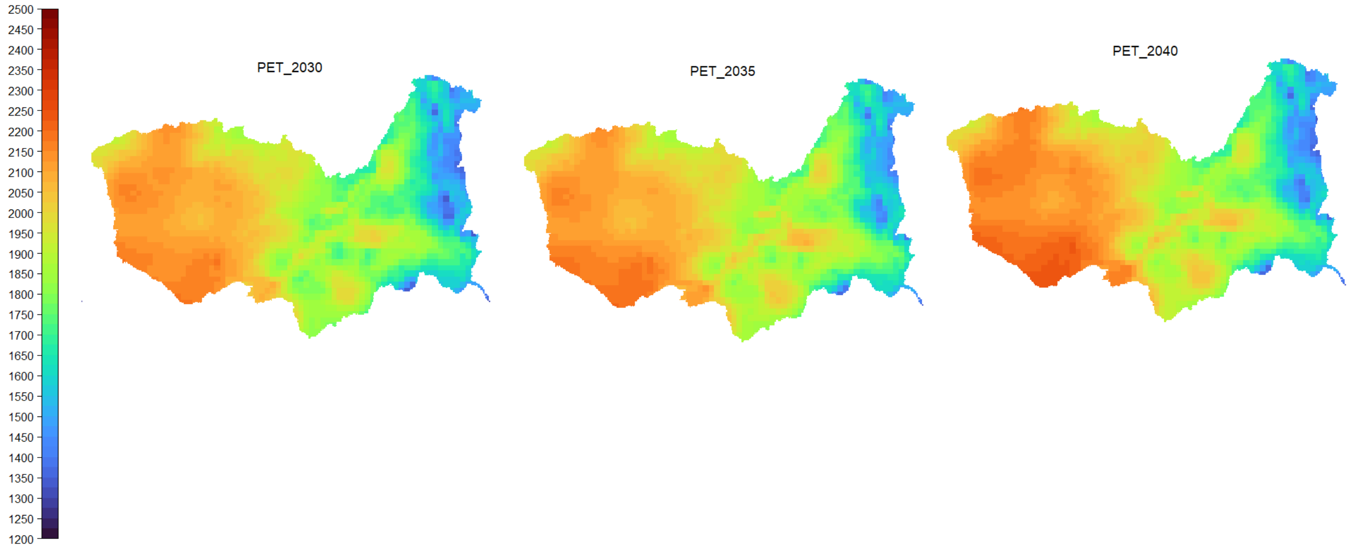
- AET ranging 400-1100 mm/year
- Historic 680-830 mm/year



Projected climate scenarios

- PET ranging 1820- 2020 mm/year

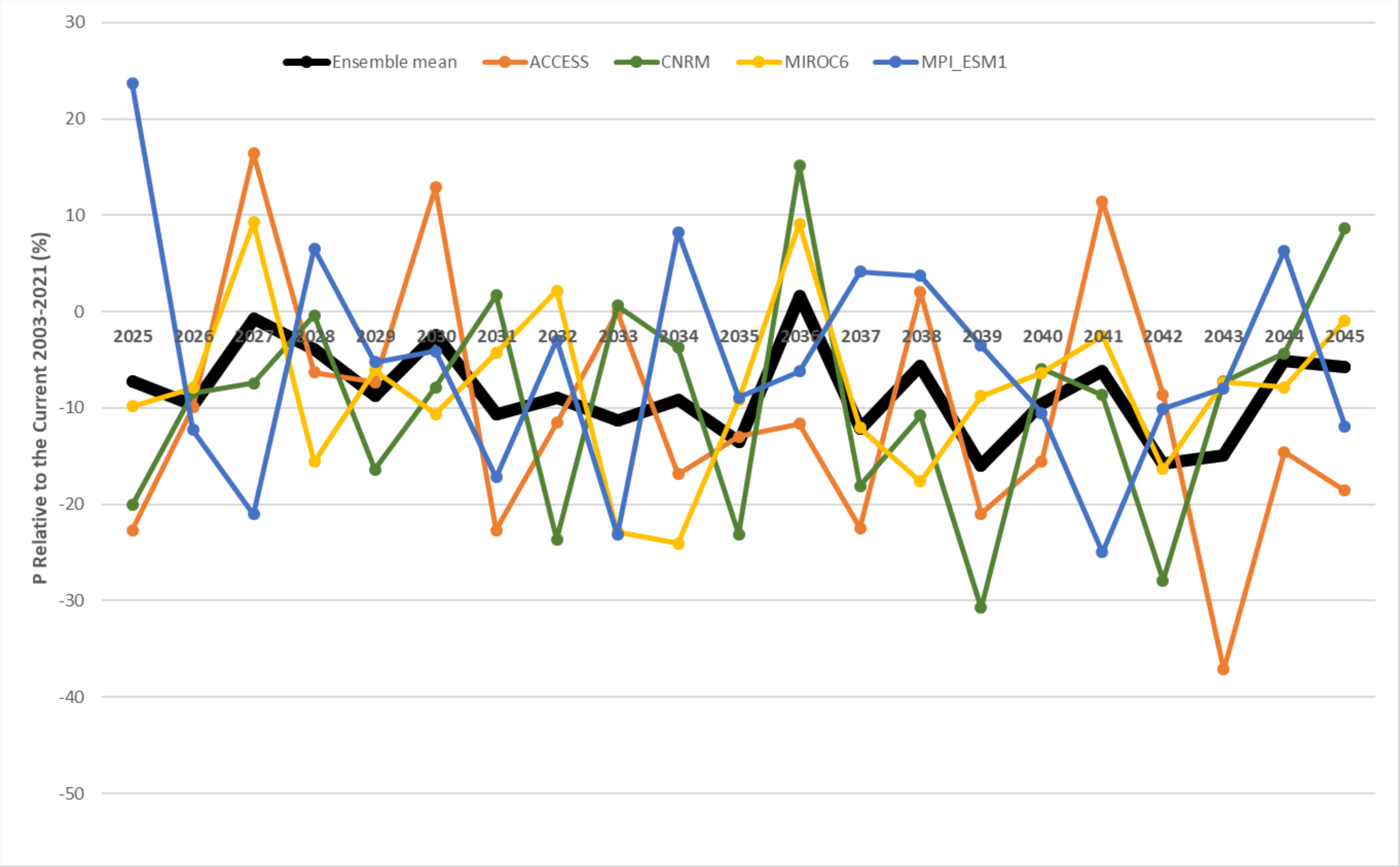
- Historic 820-1550 mm/year



Projected climate scenarios

- P decreases by 10-15%

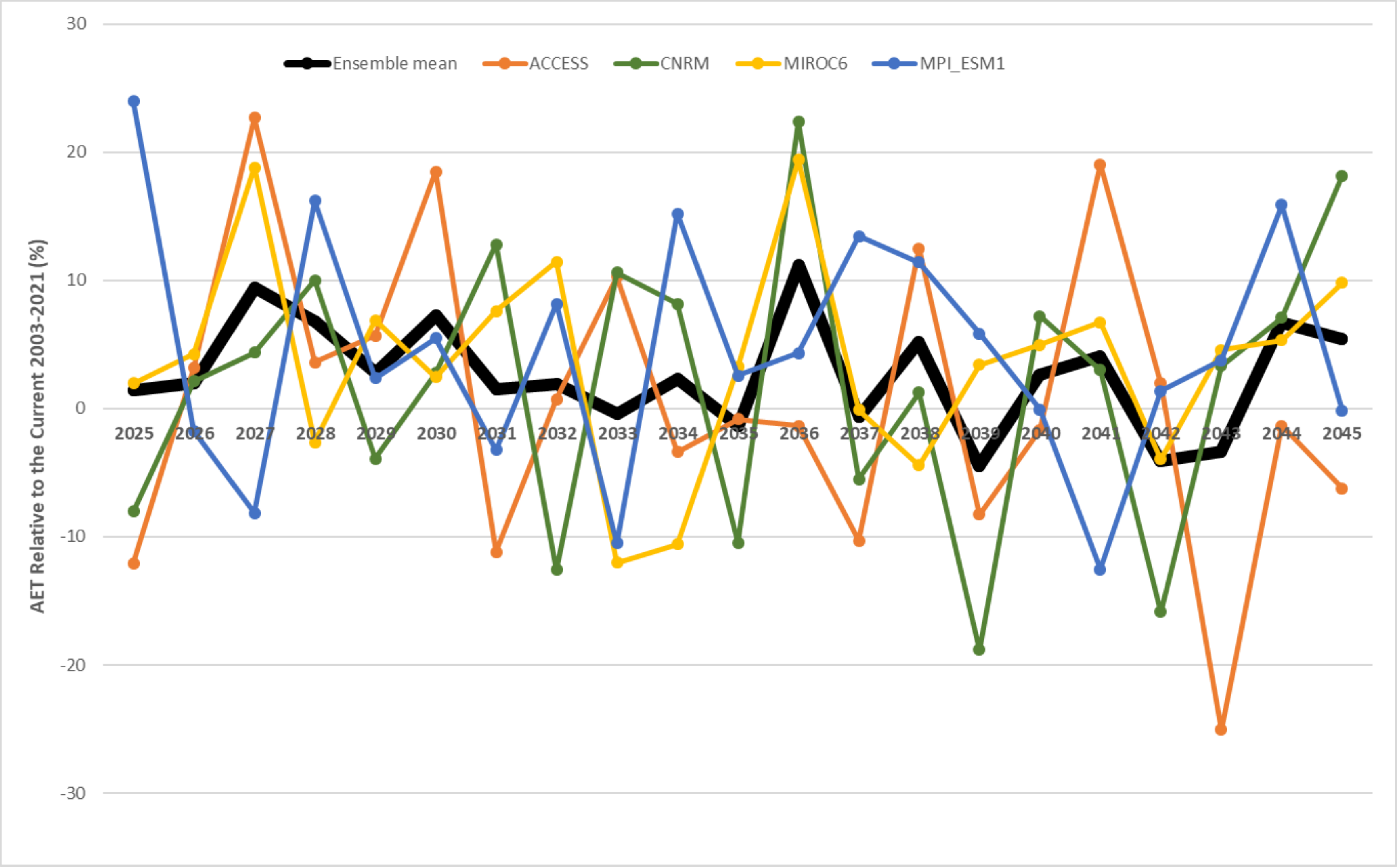
Epoch	Ensemble	ACCESS	CNRM	MIROC6	MPI_ESM1
	mm/year				
2030	876	875	853	876	898
2035	857	821	886	830	892
2040	841	881	783	844	855
Baseline	940	940	940	940	940



Projected climate scenarios - ET

- ET increases by 10%

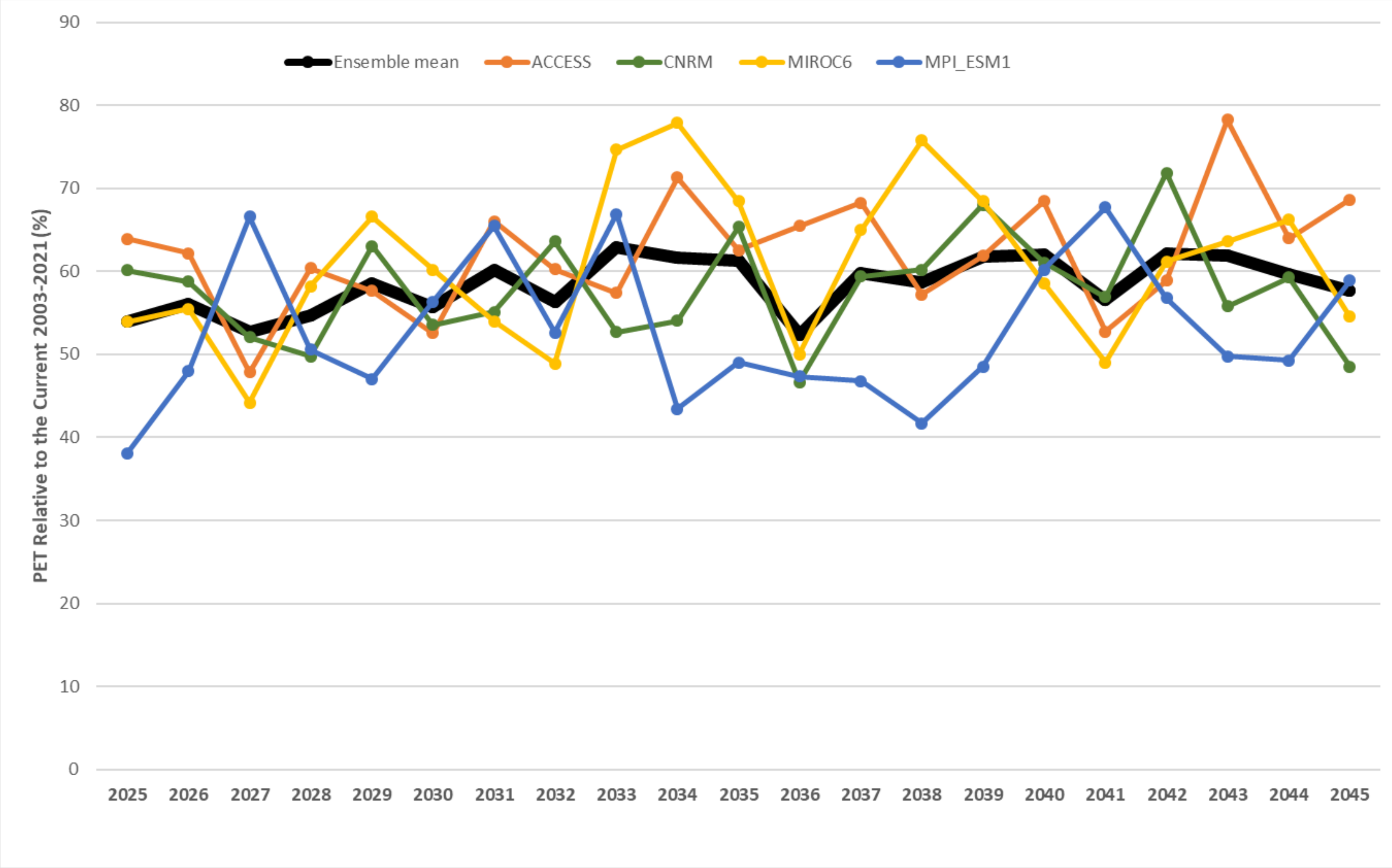
Epoch	Ensemble	ACCESS	CNRM	MIROC6	MPI_ESM1
	mm/year				
2030	787	782	770	795	800
2035	773	748	794	756	794
2040	761	792	721	766	765
Baseline	756	756	756	756	756



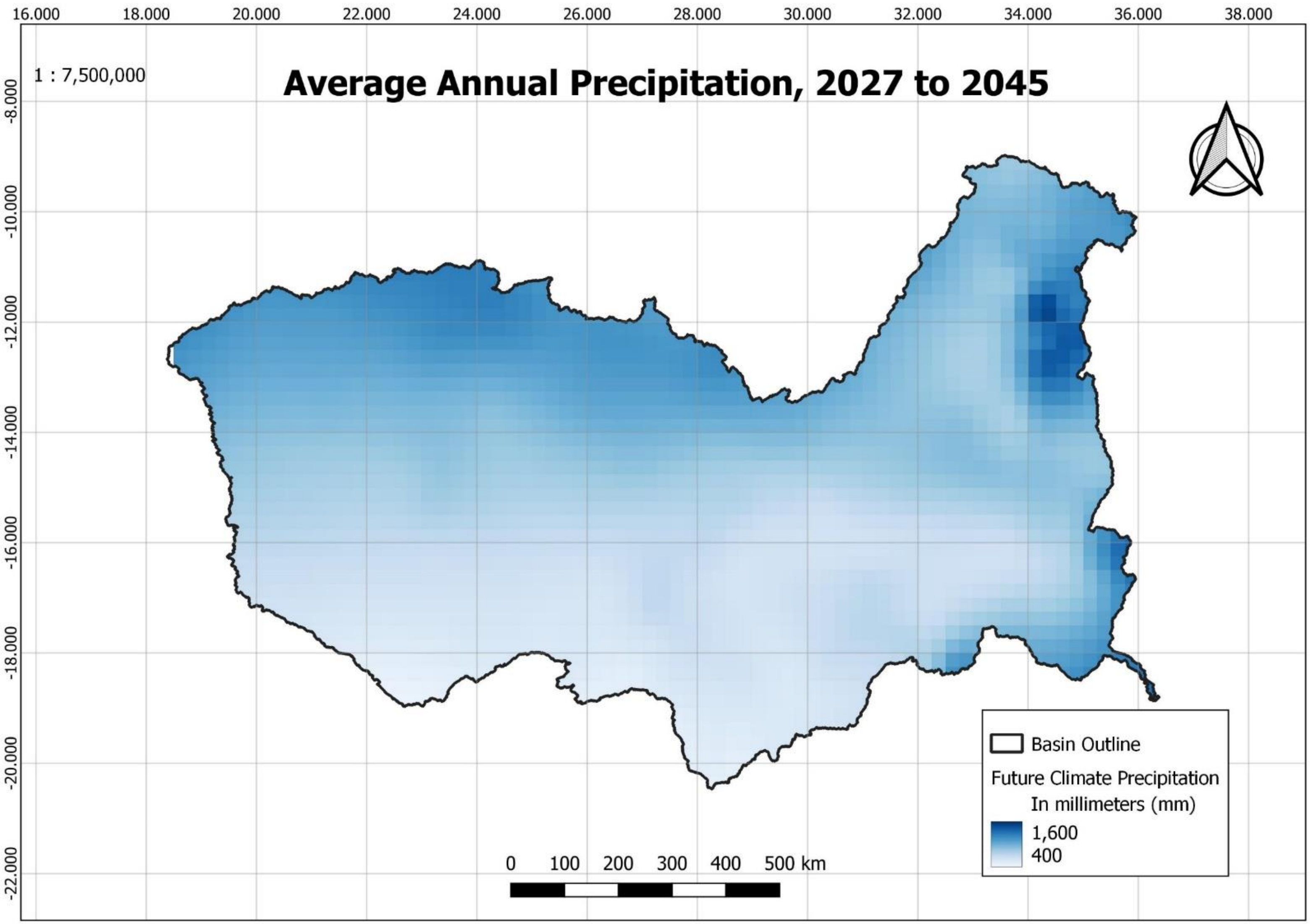
Projected climate scenarios - PET

- PET increases by 50-60%

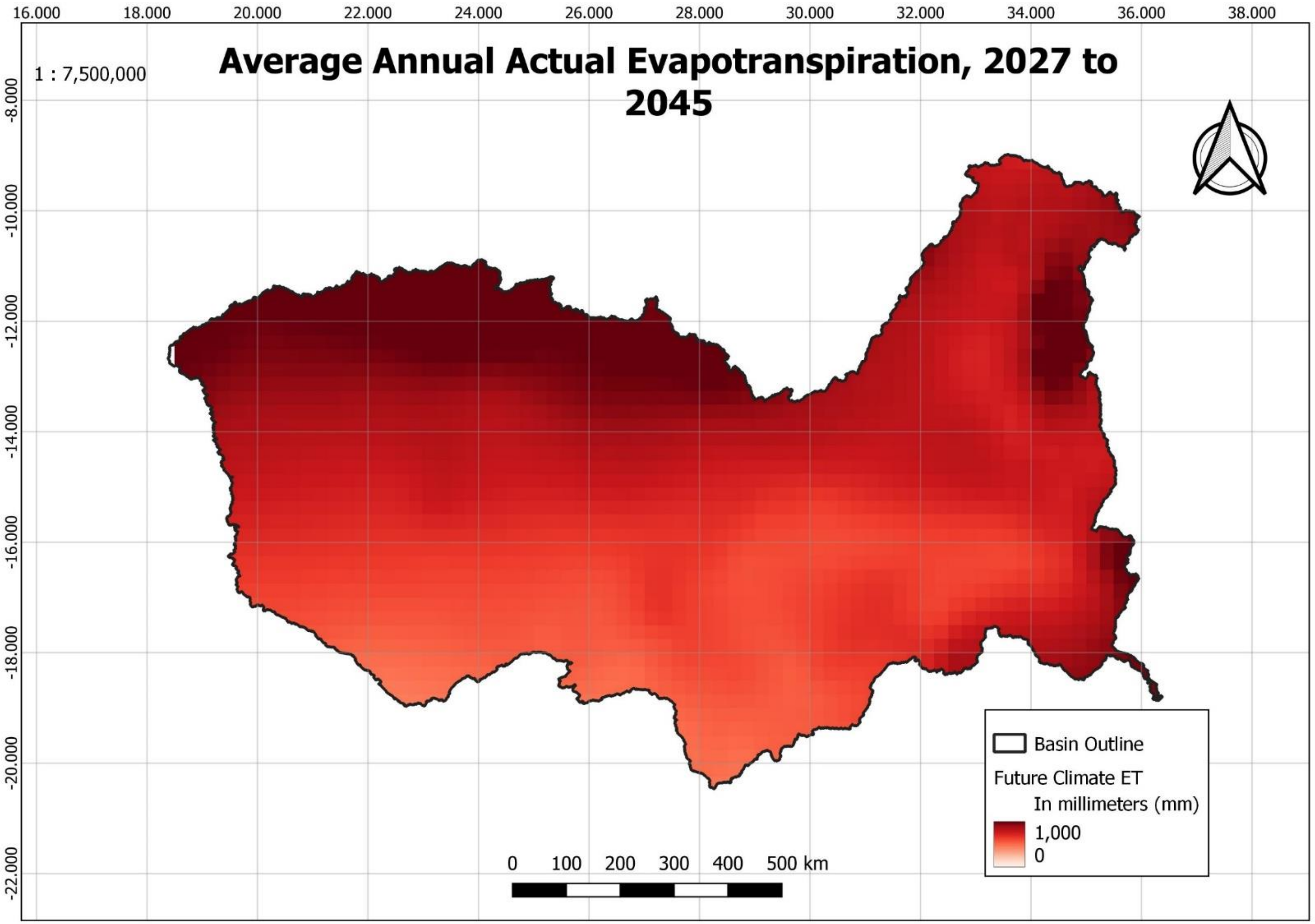
Epoch	Ensemble	ACCESS	CNRM	MIROC6	MPI_ESM1
	mm/year				
2030	1897	1925	1897	1903	1865
2035	1928	1993	1880	2020	1820
2040	1936	1930	1976	1964	1872
Baseline	1208	1208	1208	1208	1208



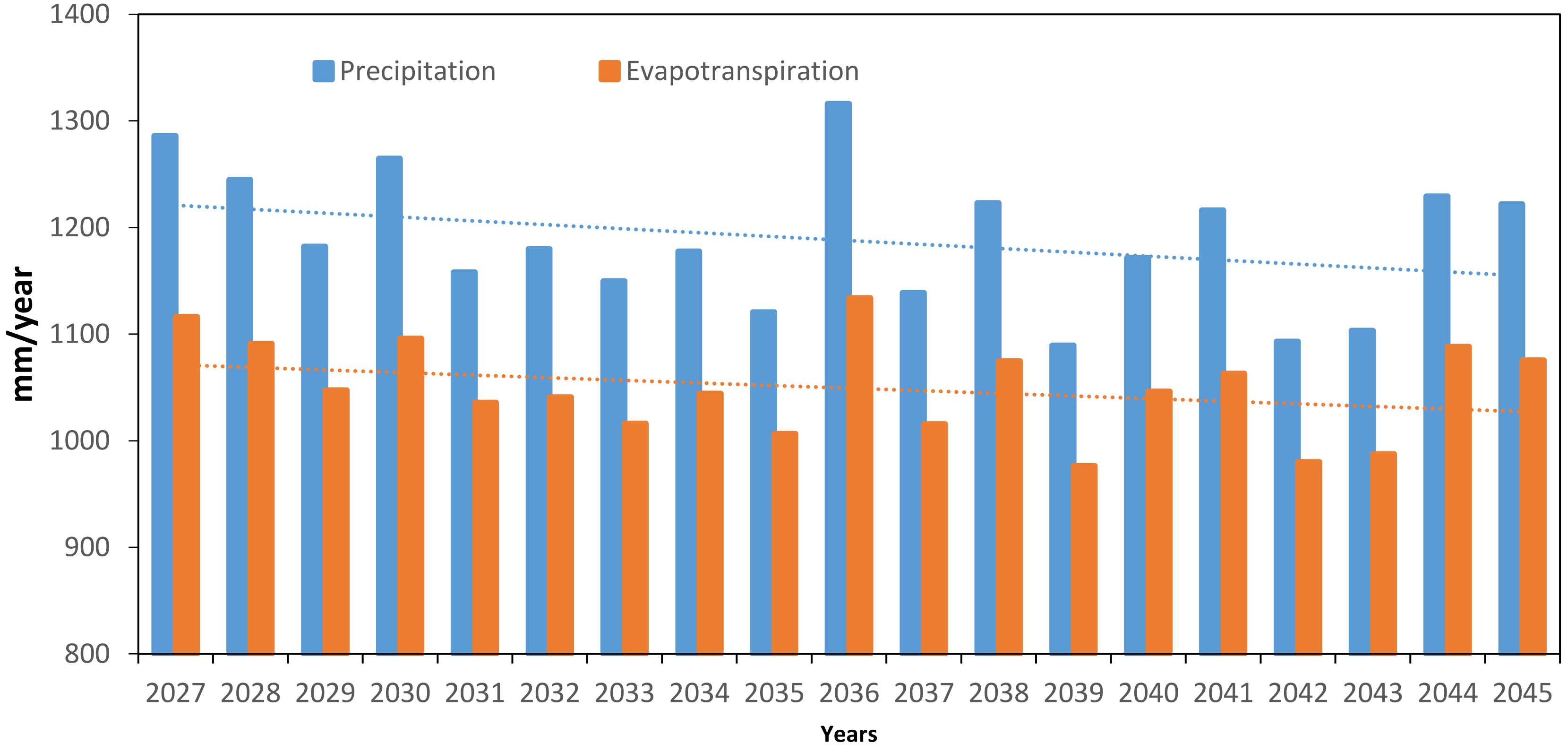
Mean Annual Precipitation (2027-2045)



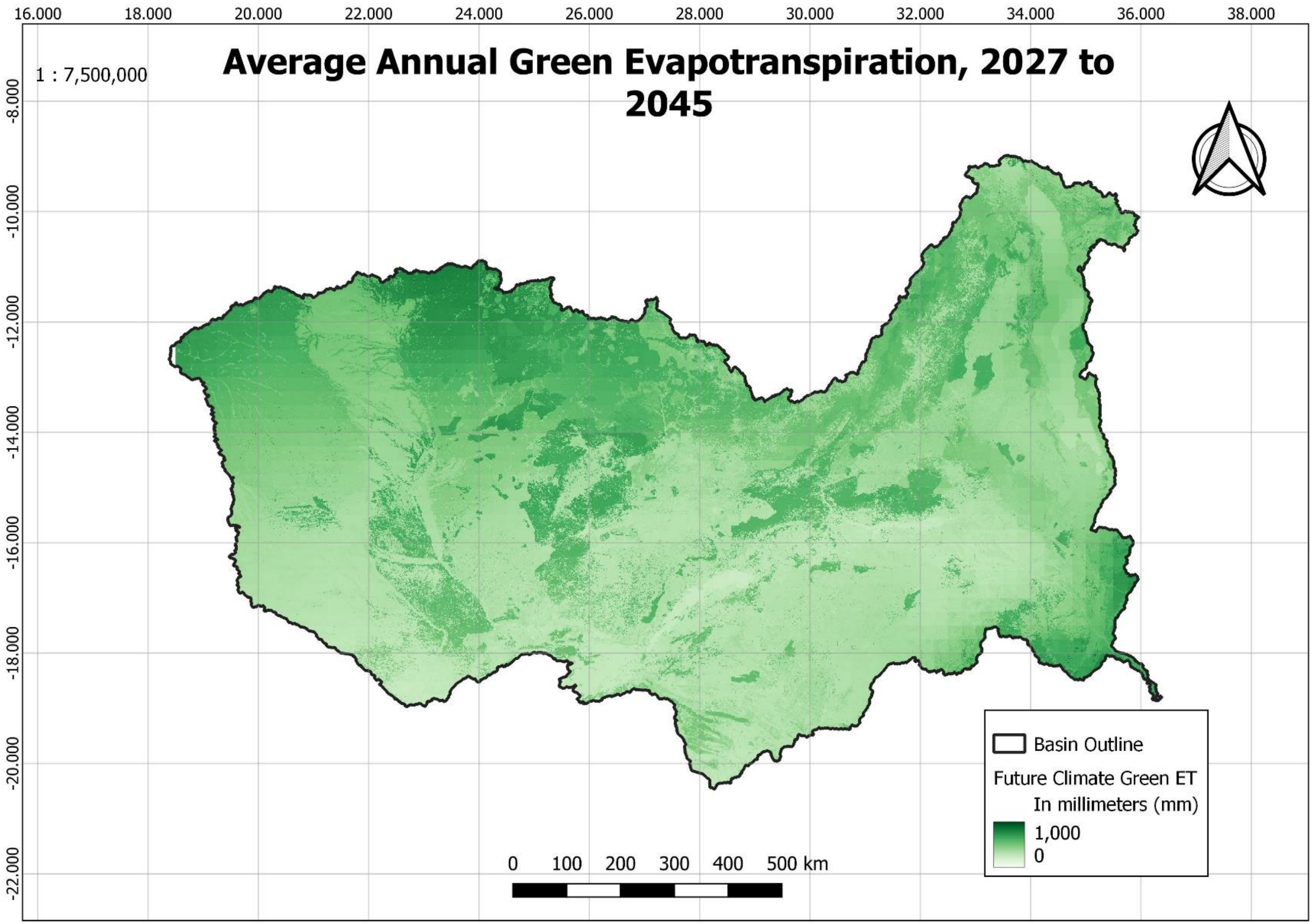
Mean Annual ET (2027-2045)



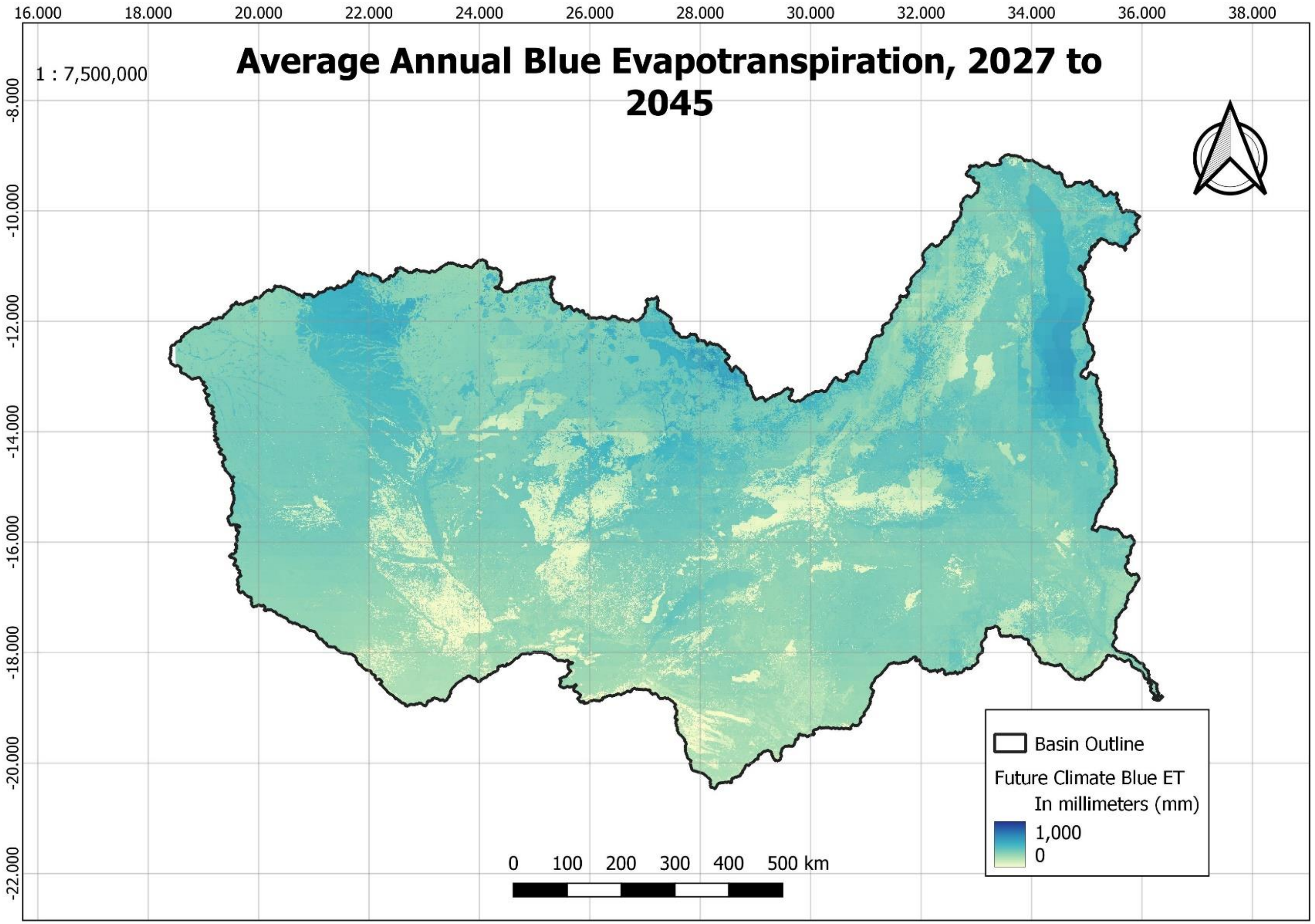
Basin P and ET (Future Scenario)



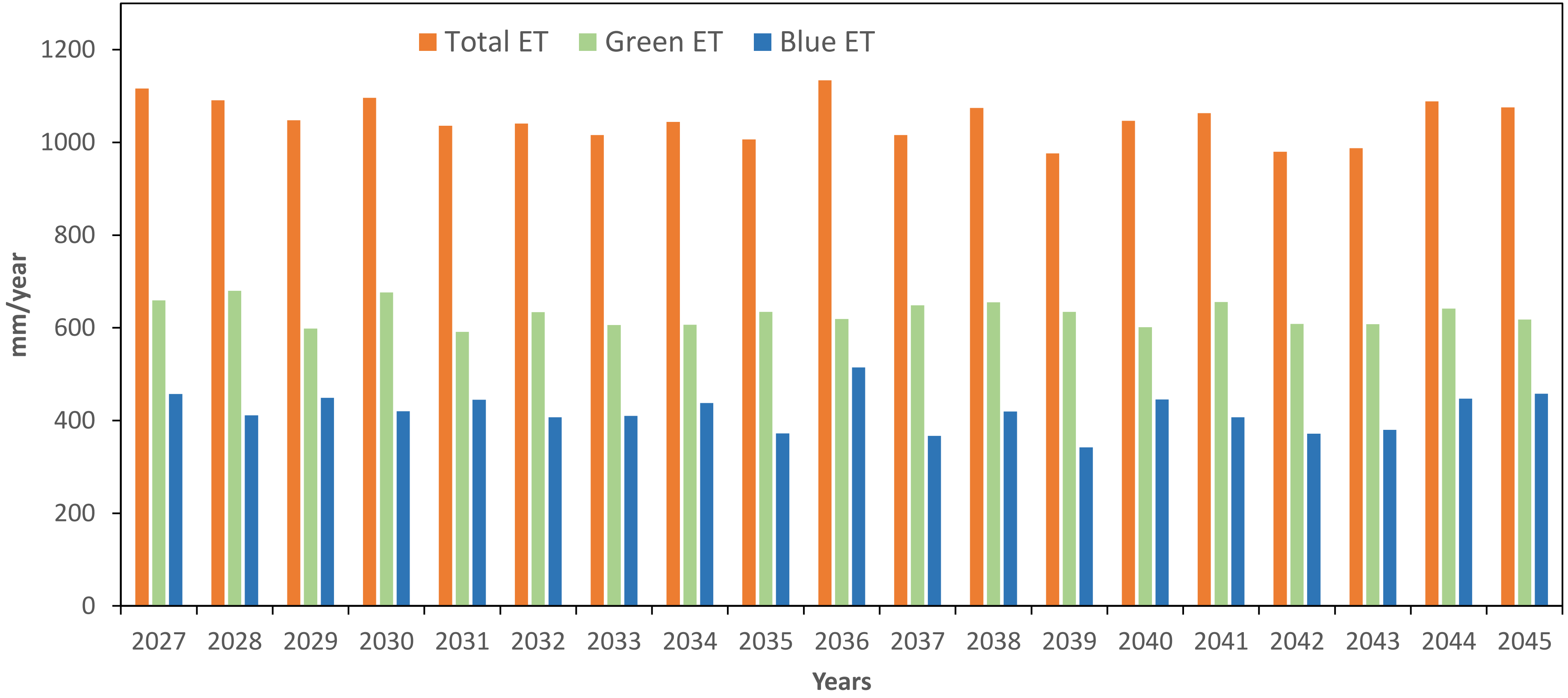
Average Basin ET-green (2027-2045)



Average Basin ET-blue (2027-2045)



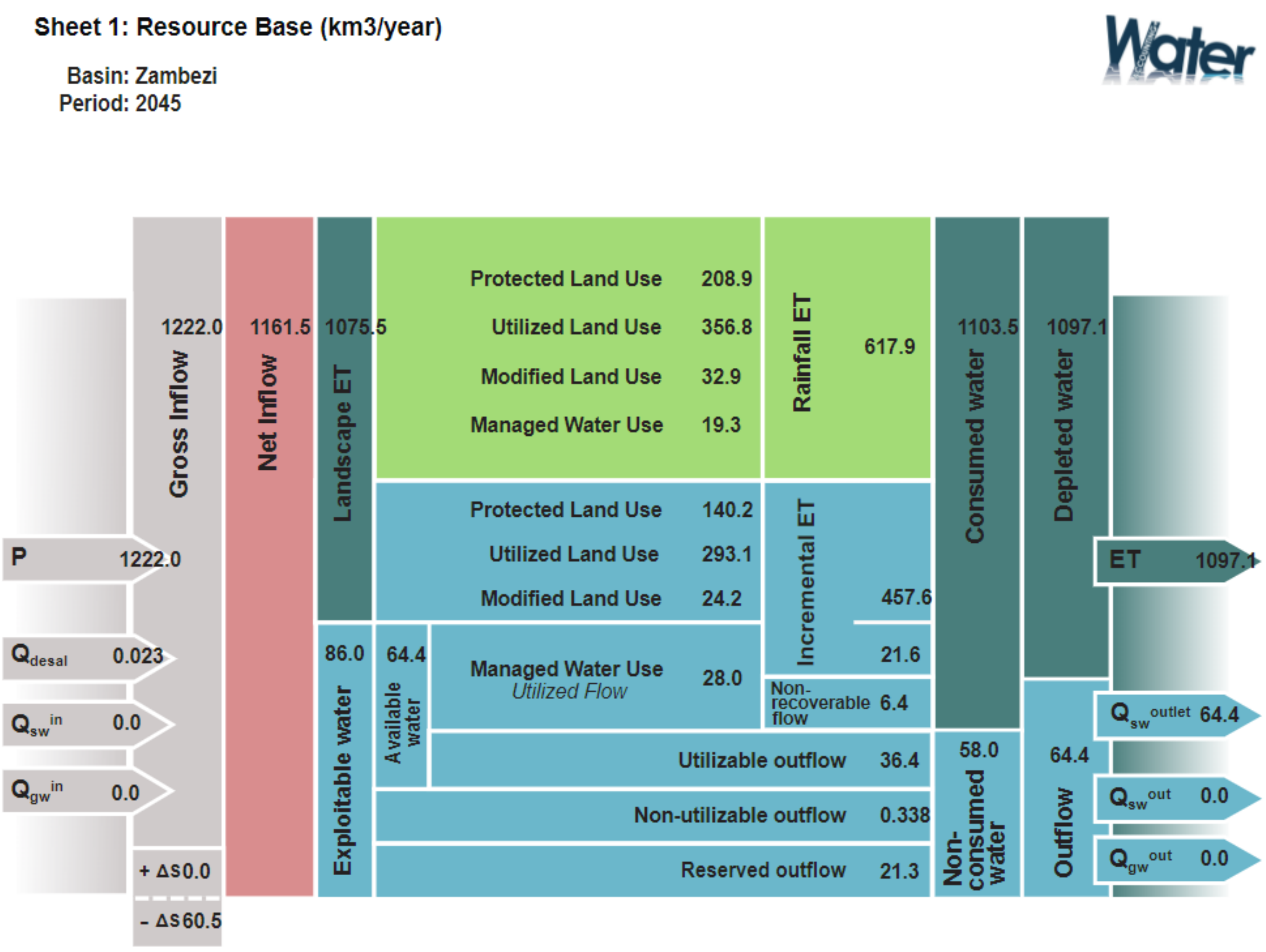
Basin Total ET, Green and Blue ET



Zambezi basin hydrology (2027-2045)

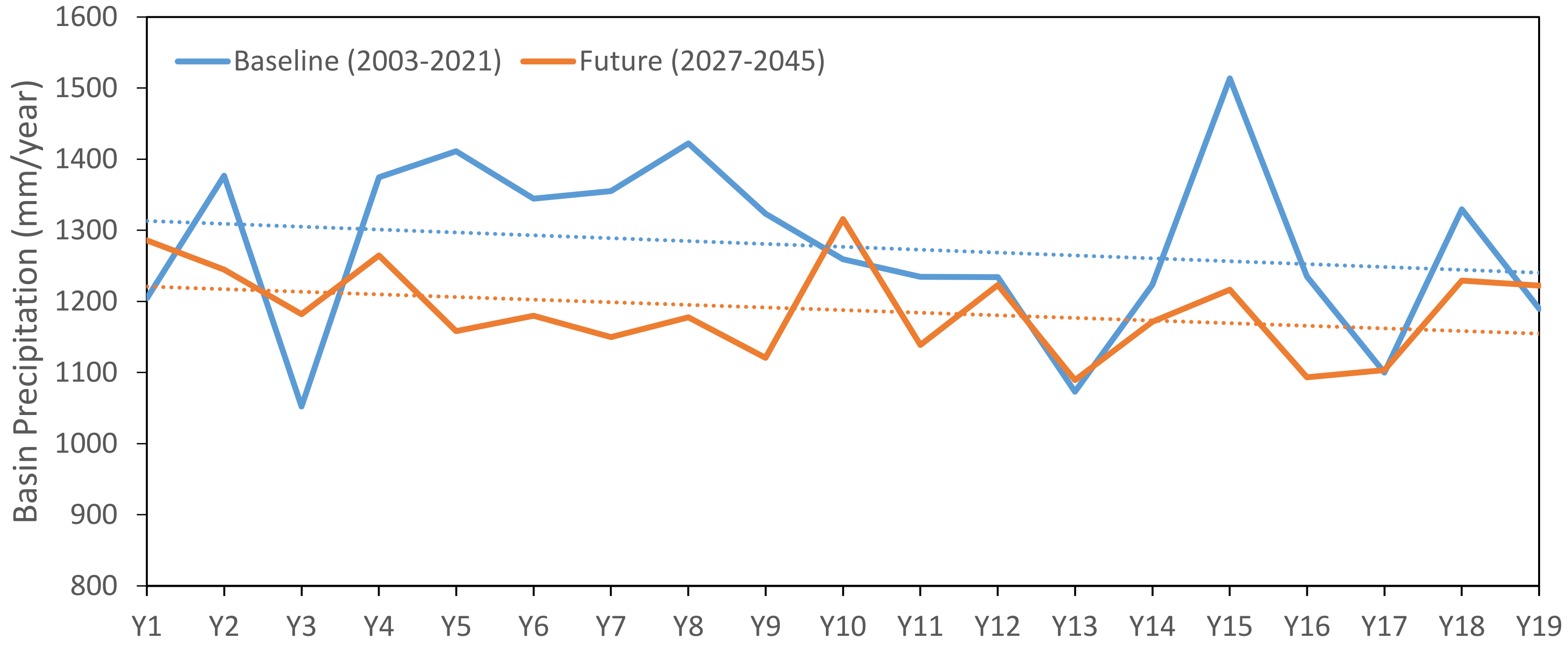
Year	Precipitation (mm)	Actual ET (mm)	Surface water Yield (mm)	Rainfall ET (mm)	Incremental ET (mm)
2027	1286	1116	170	659	457
2028	1245	1091	154	680	411
2029	1182	1047	135	598	449
2030	1265	1096	169	676	420
2031	1158	1036	122	591	445
2032	1180	1041	139	634	407
2033	1150	1016	134	606	410
2034	1178	1044	134	607	438
2035	1121	1007	114	634	372
2036	1316	1134	182	619	515
2037	1139	1016	123	648	367
2038	1223	1075	148	655	419
2039	1089	976	113	634	342
2040	1172	1046	125	601	445
2041	1216	1063	153	656	407
2042	1093	980	113	608	372
2043	1103	988	116	608	380
2044	1229	1088	141	641	447
2045	1222	1075	147	618	458

WA Resource Base sheet (2045)



Comparison of Baseline with Future Water Availability

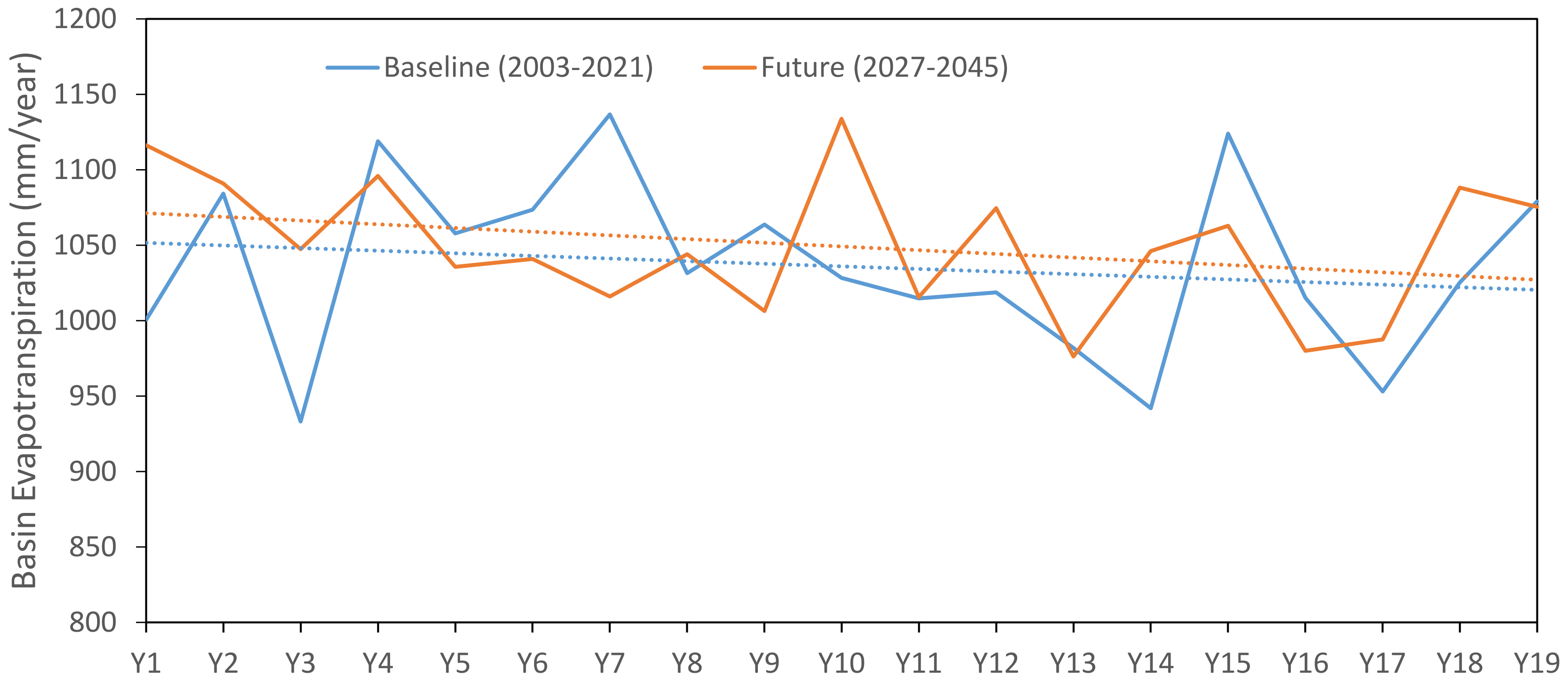
Comparison of Rainfall (Baseline vs. Future)



Precipitation in the Zambezi is declining in the baseline scenario and it continues to decline at a similar rate until 2045.

By the end of 2045, there will be about 10% decline in total precipitation since 2003.

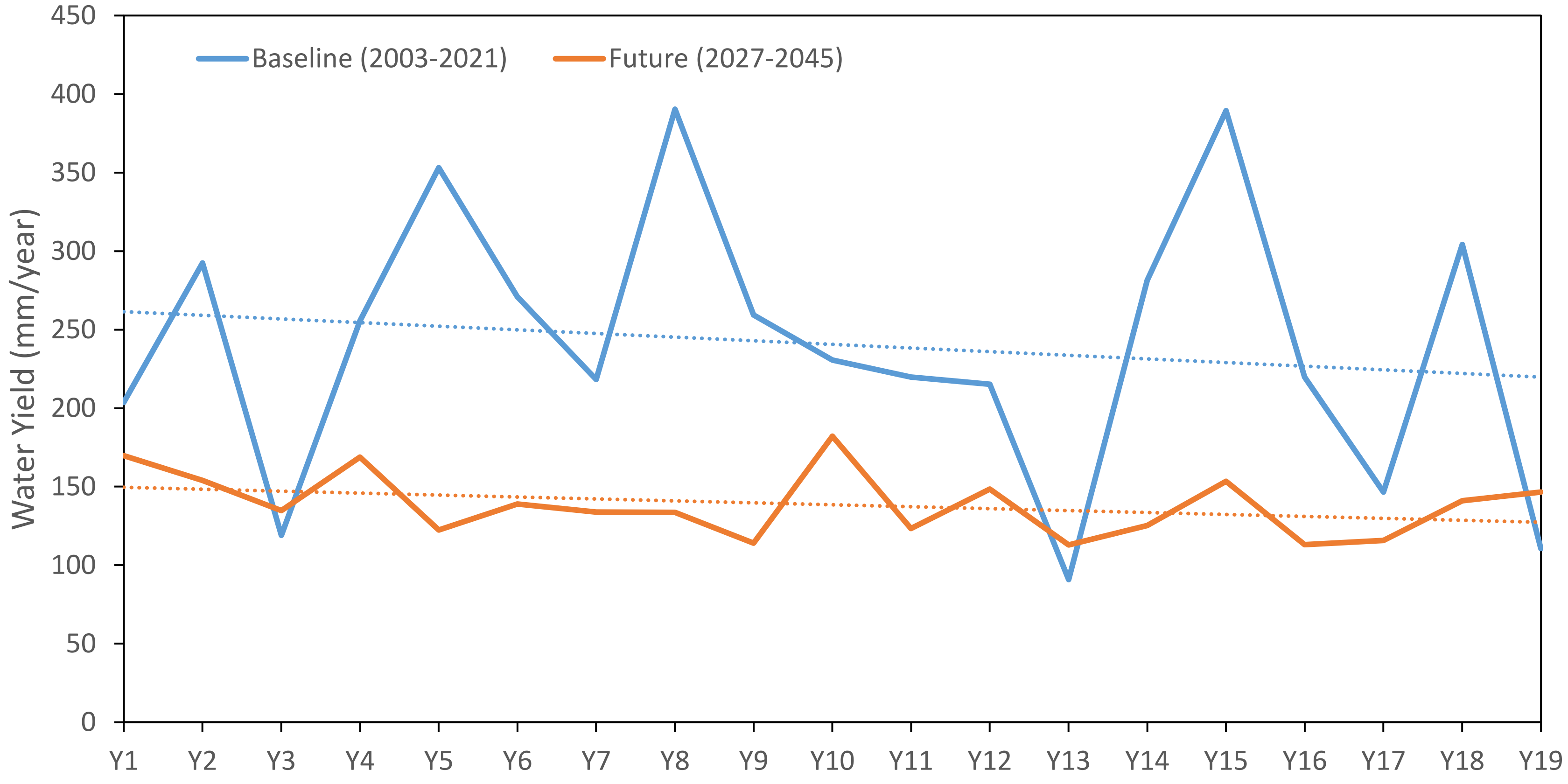
Comparison of ET (Baseline vs. Future)



The total ET in the Zambezi is declining in the baseline scenario and it continues to decline at a slightly higher rate until 2045.

By the end of 2045, there will be about 10% increase in total ET since 2003.

Comparison of Water Yield (Baseline vs. Future)

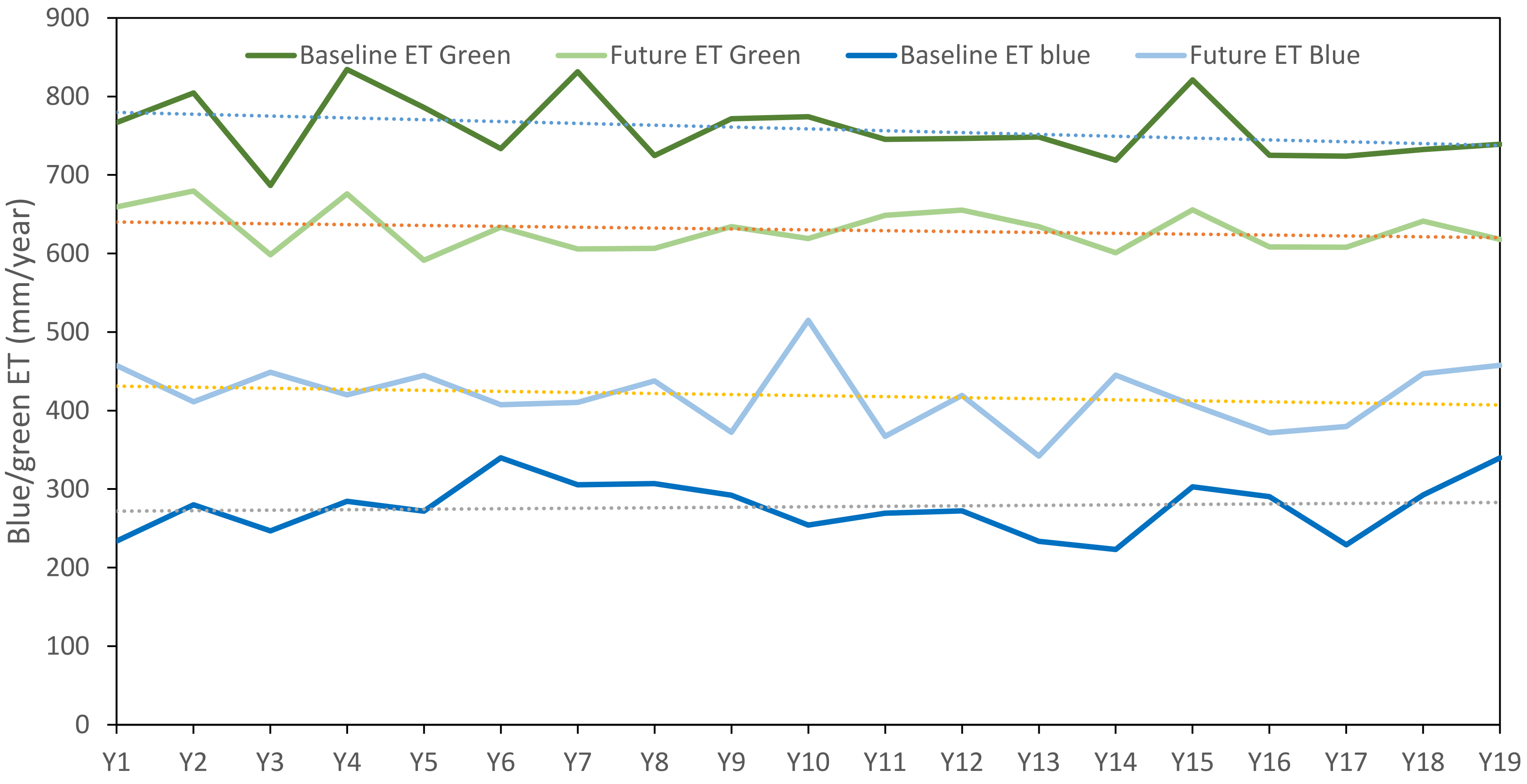


The total water yield in the Zambezi is declining in the baseline scenario and it continues to decline at a slightly lower rate until 2045.

By the end of 2045, there will be about 50% decline in total water yield since 2003.

This will have serious implications for water security in the basin.

Comparison of Green/Blue ET (Baseline vs. Future)



The total green ET in the Zambezi is declining in the baseline scenario, and it continues to decline at a slightly lower rate until 2045.

By the end of 2045, there will be about 10% decline in total green ET since 2003.

In the future, blue ET is increasing, indicating increase in evaporative water demand in the dry season or increase in the irrigation.

Zambezi basin hydrology (long-term average)

Parameter	Baseline Mean (mm)	Future Mean (mm)
Precipitation	1277	1188 ↓
Actual ET	1036	1049 ↑
Water Yield	241	138 ↓
Rainfall ET	759	630 ↓
Incremental ET	277	419 ↑

Precipitation exceeds the annual ET, indicating that water is available in excess at annual time scales.
But, compared to baseline, there will be much less water in the future.

The actual ET is increasing slightly due to increase in the PET (increase in temperature)

More Blue ET is consumed in the future.

Conclusion

- The WA+ framework was implemented for Zambezi river basin region over 2003-2021 and baseline information on water availability and change were generated.
- The WA+ framework was extended into 2027 to 2045 to understand the impact of future climate change scenarios on water availability and change.
- Results indicate that Baseline conditions indicate that Zambezi basin is a water surplus basin where annual P exceeds annual ET. However, the water availability in the basin is on decline.
- The decline in baseline condition of water availability is found to continue into the future with almost up to 50% decline in water availability by 2045 resulting acute water shortages in the future.

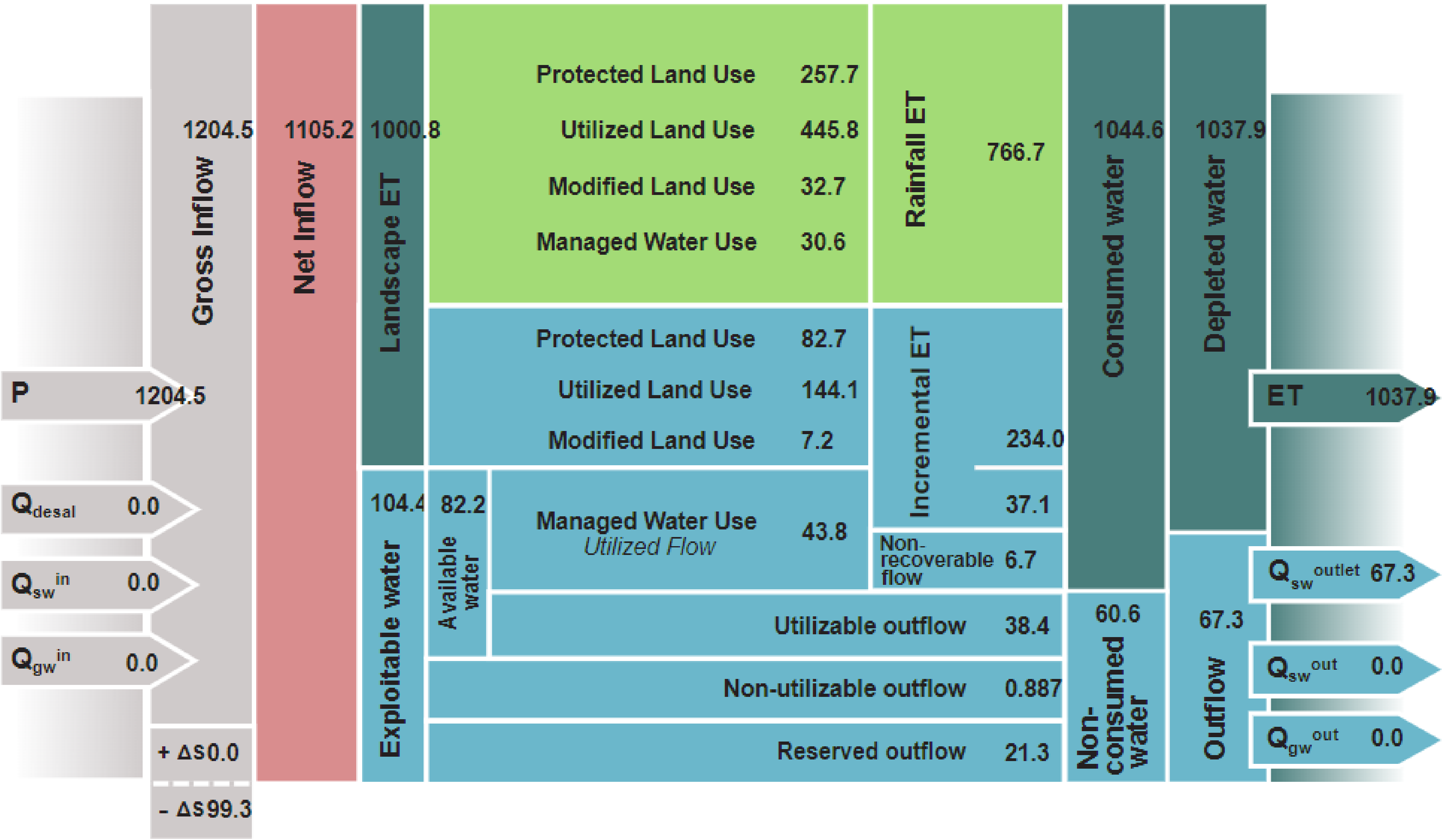
Next Steps

1. Generation of water accounting indicators (baseline and future scenarios) for dashboard inputs
2. Sustainability analysis
3. Dashboard Development
4. Capacity building workshop

Annex 1: Baseline Scenario Water Accounts (2003-2021)

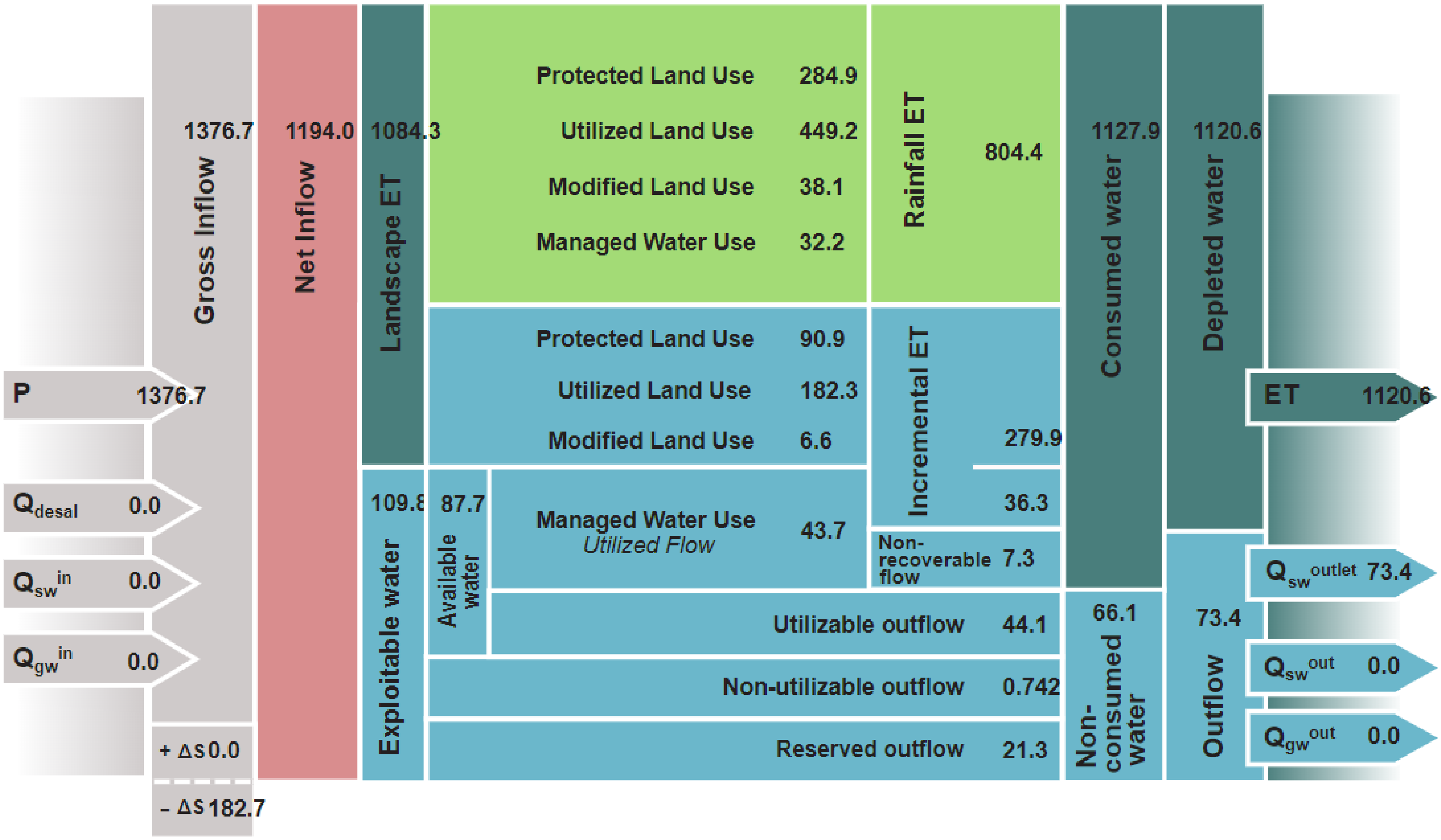
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2003



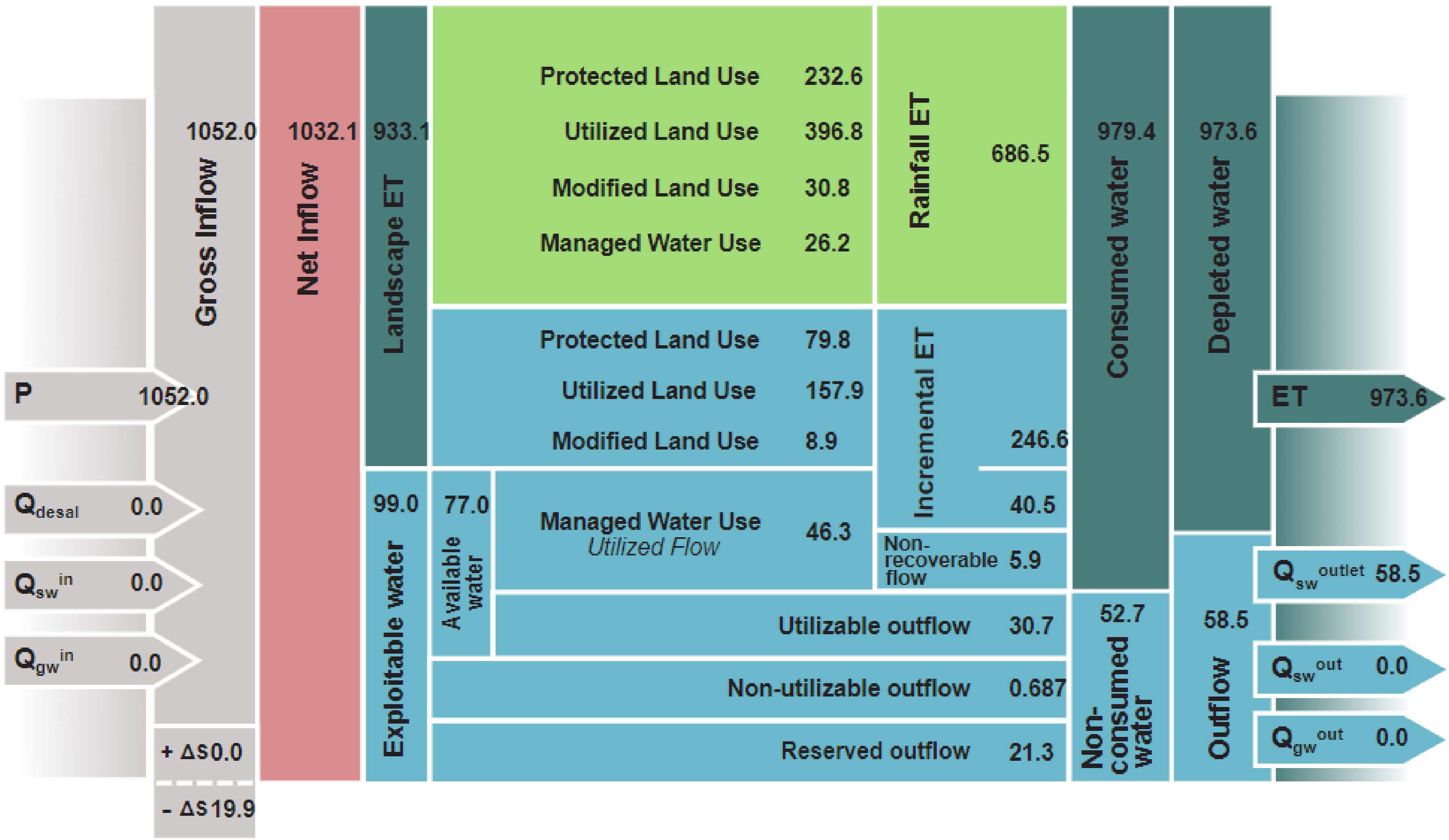
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2004



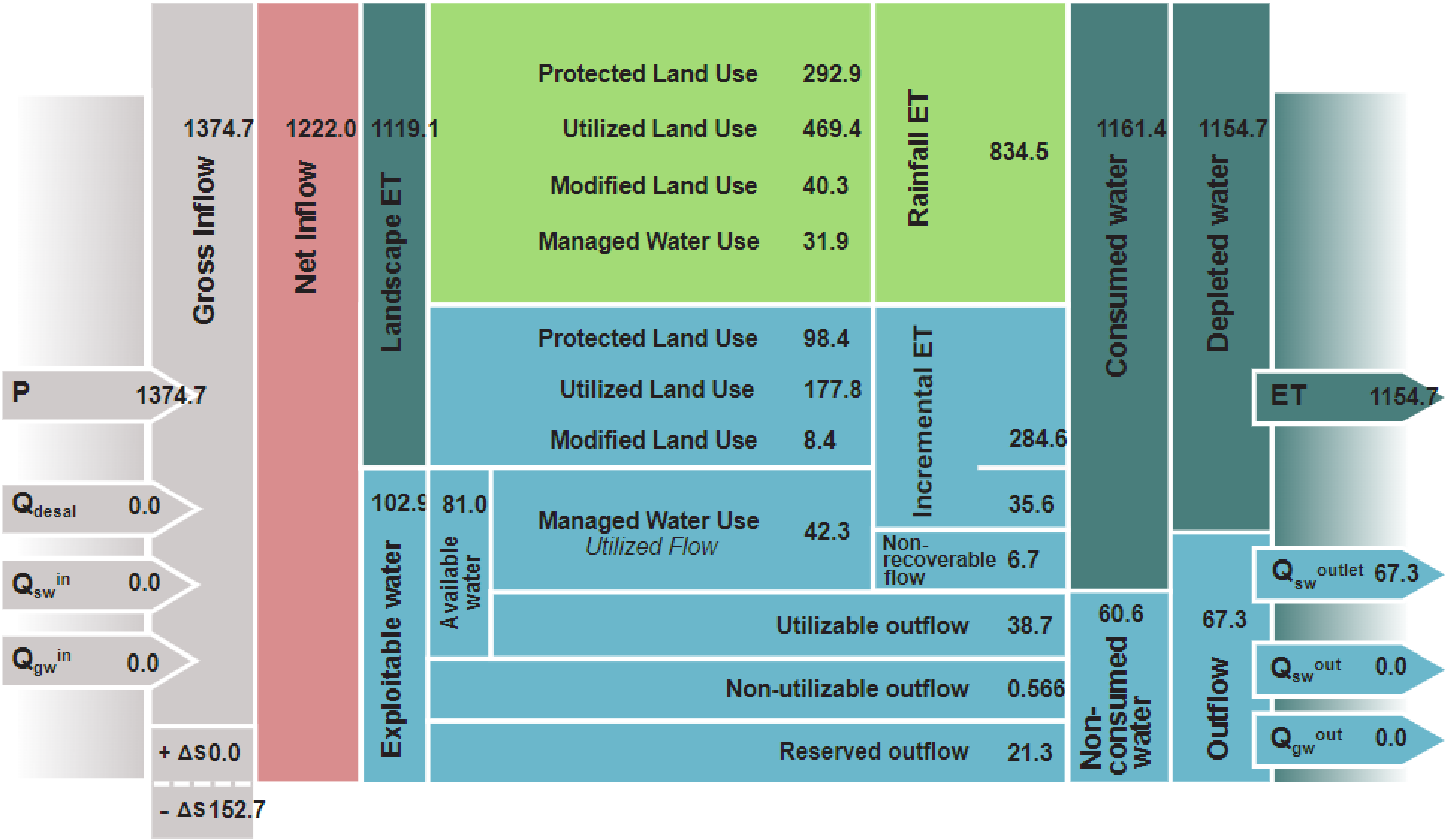
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2005



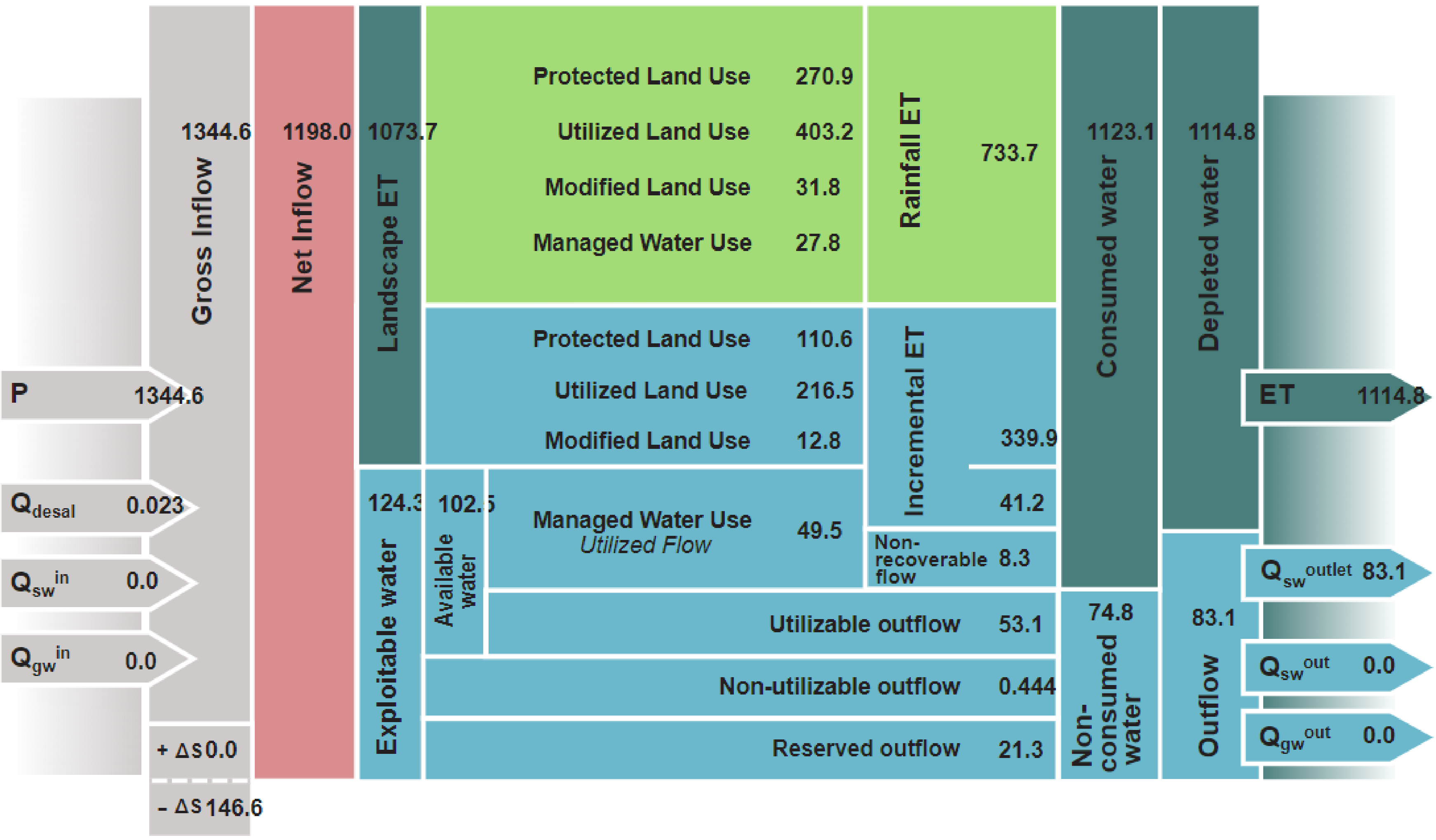
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2006



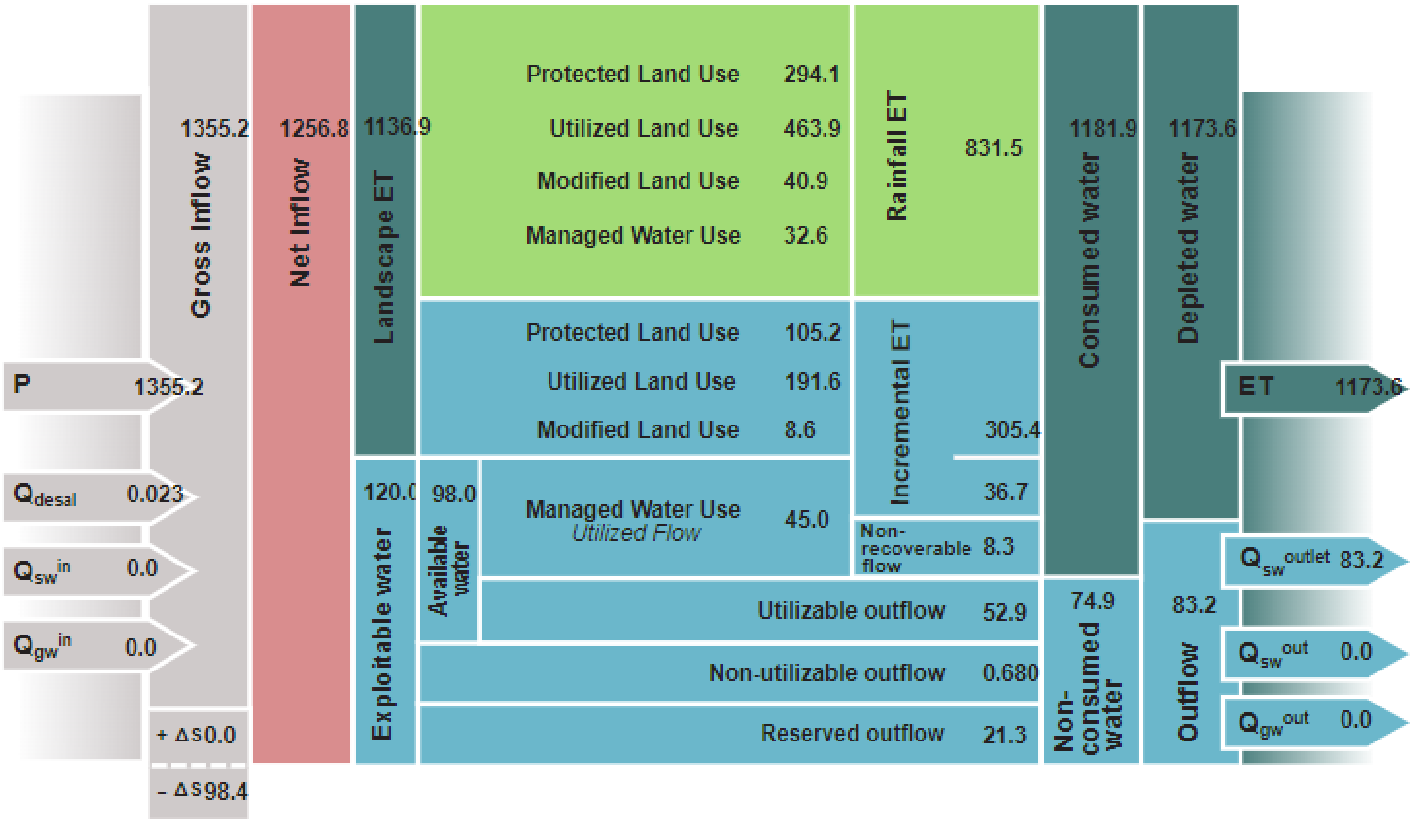
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2008



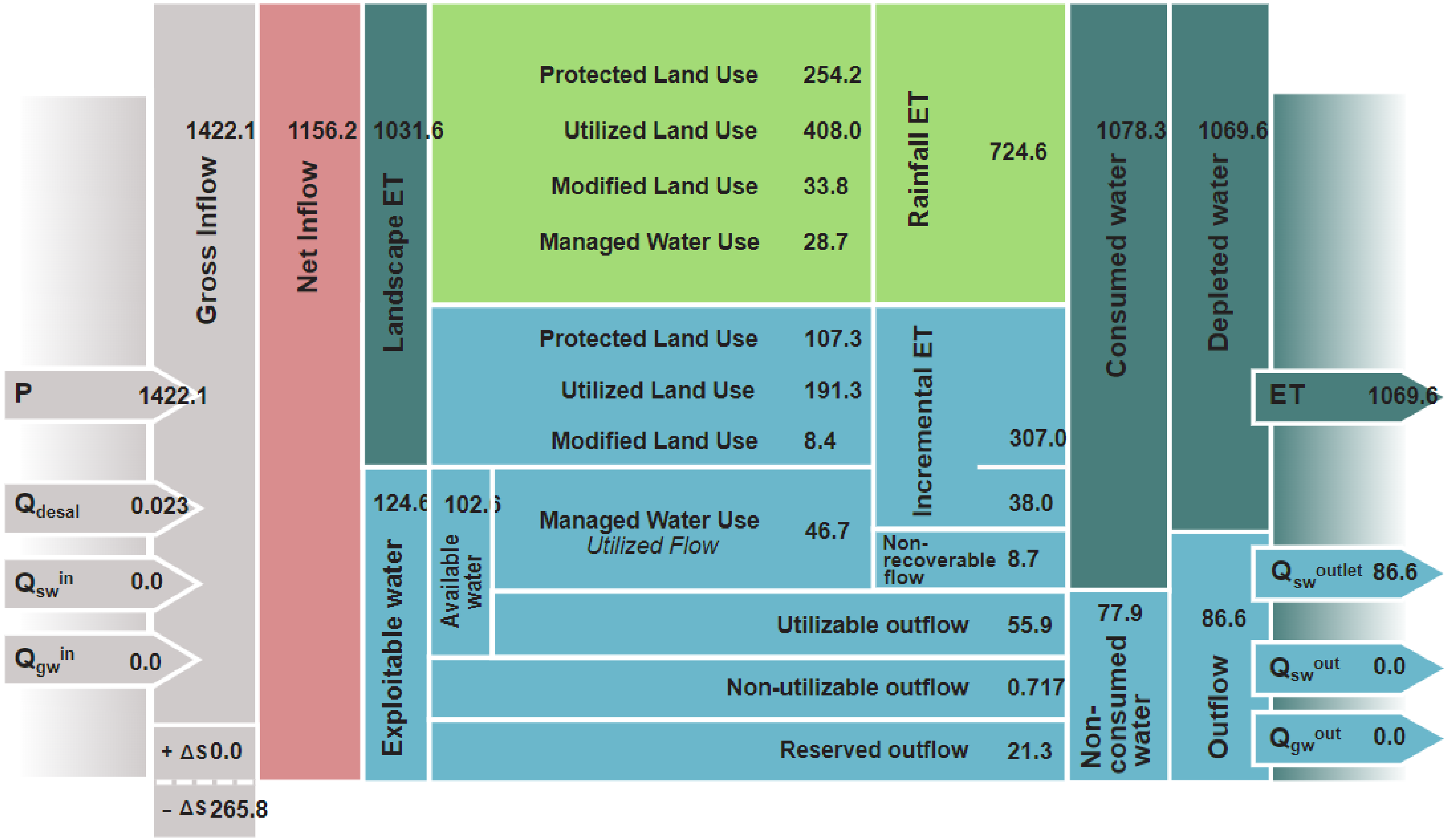
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2009



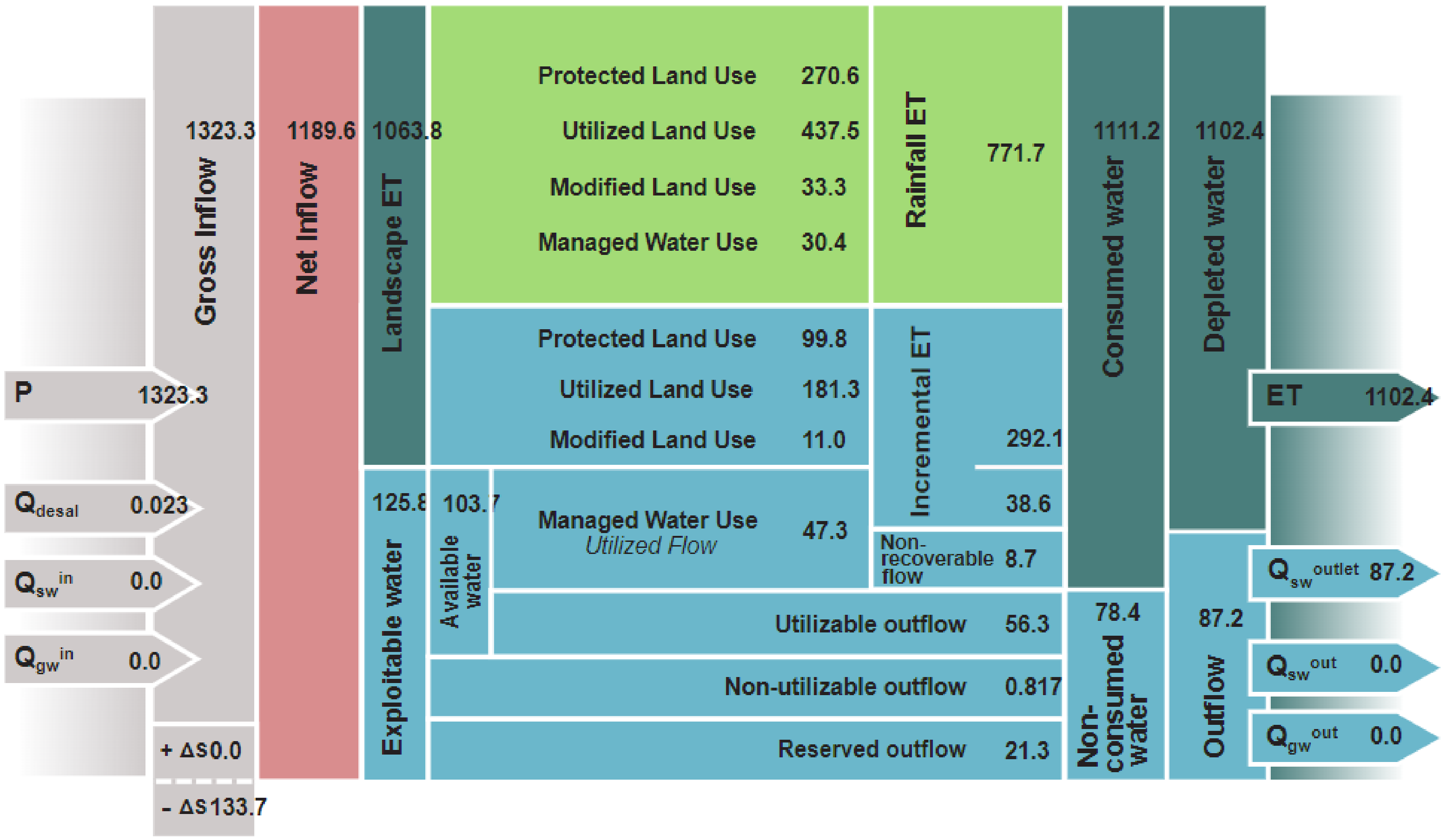
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2010



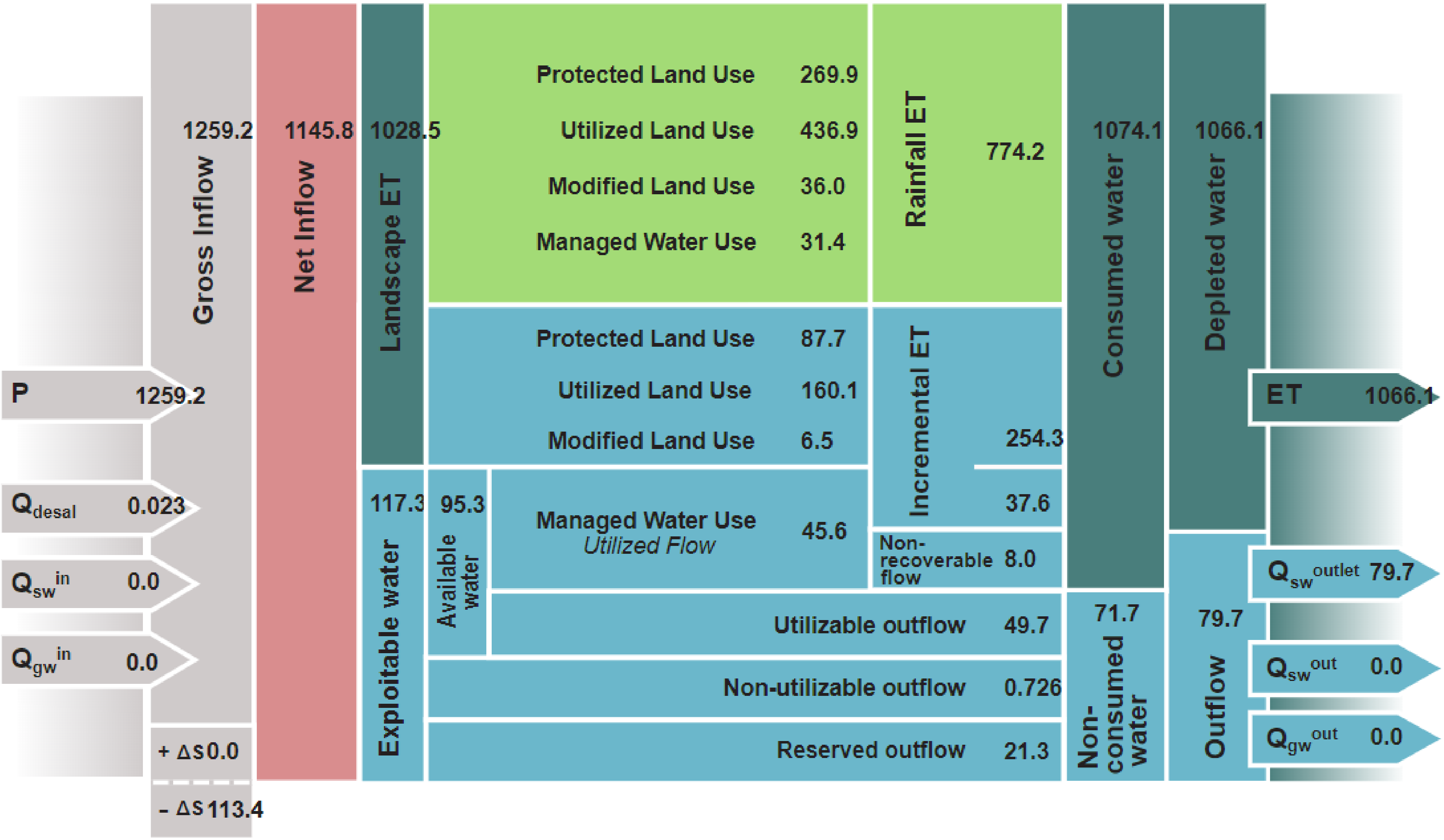
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2011



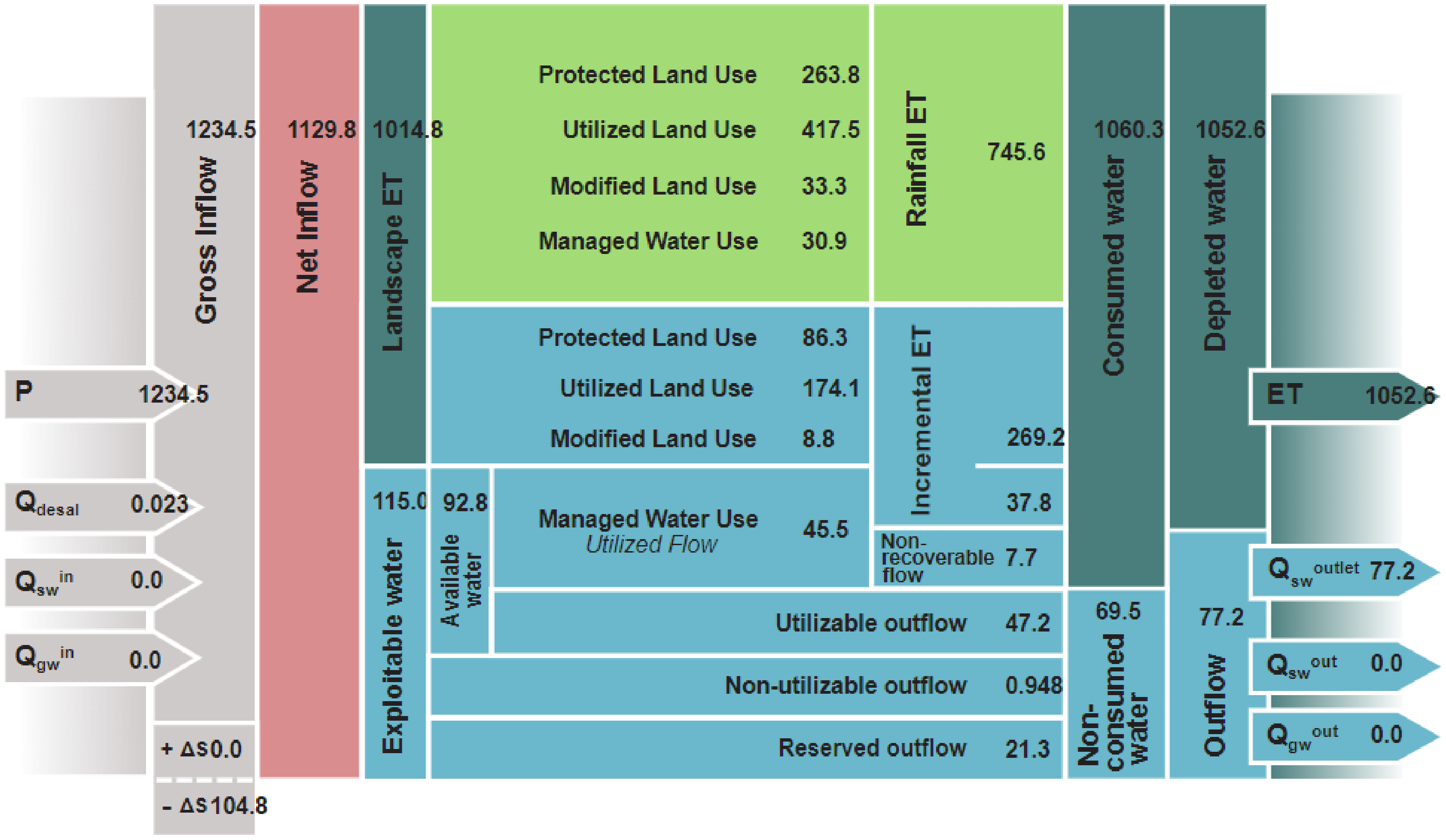
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2012



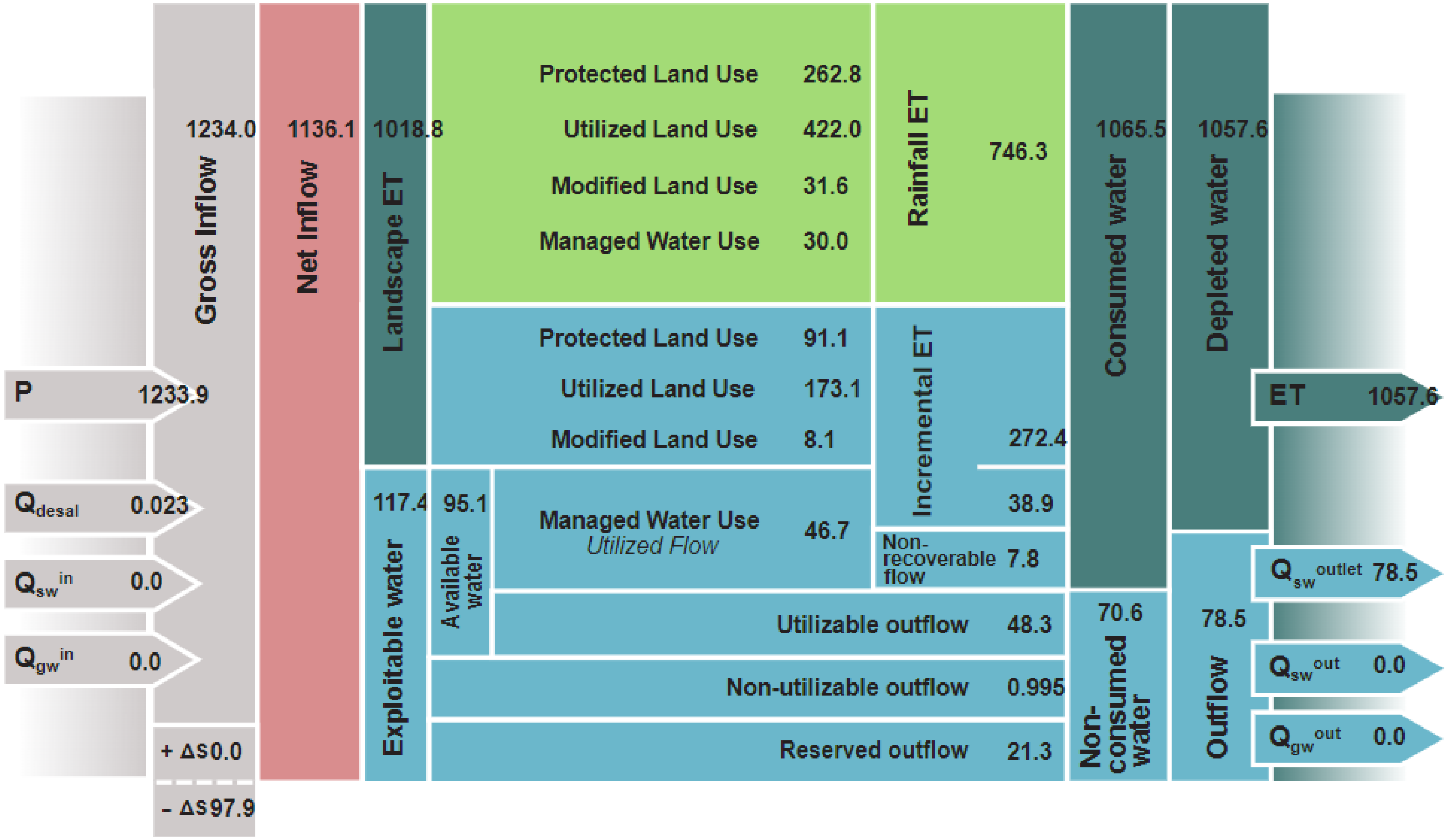
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2013



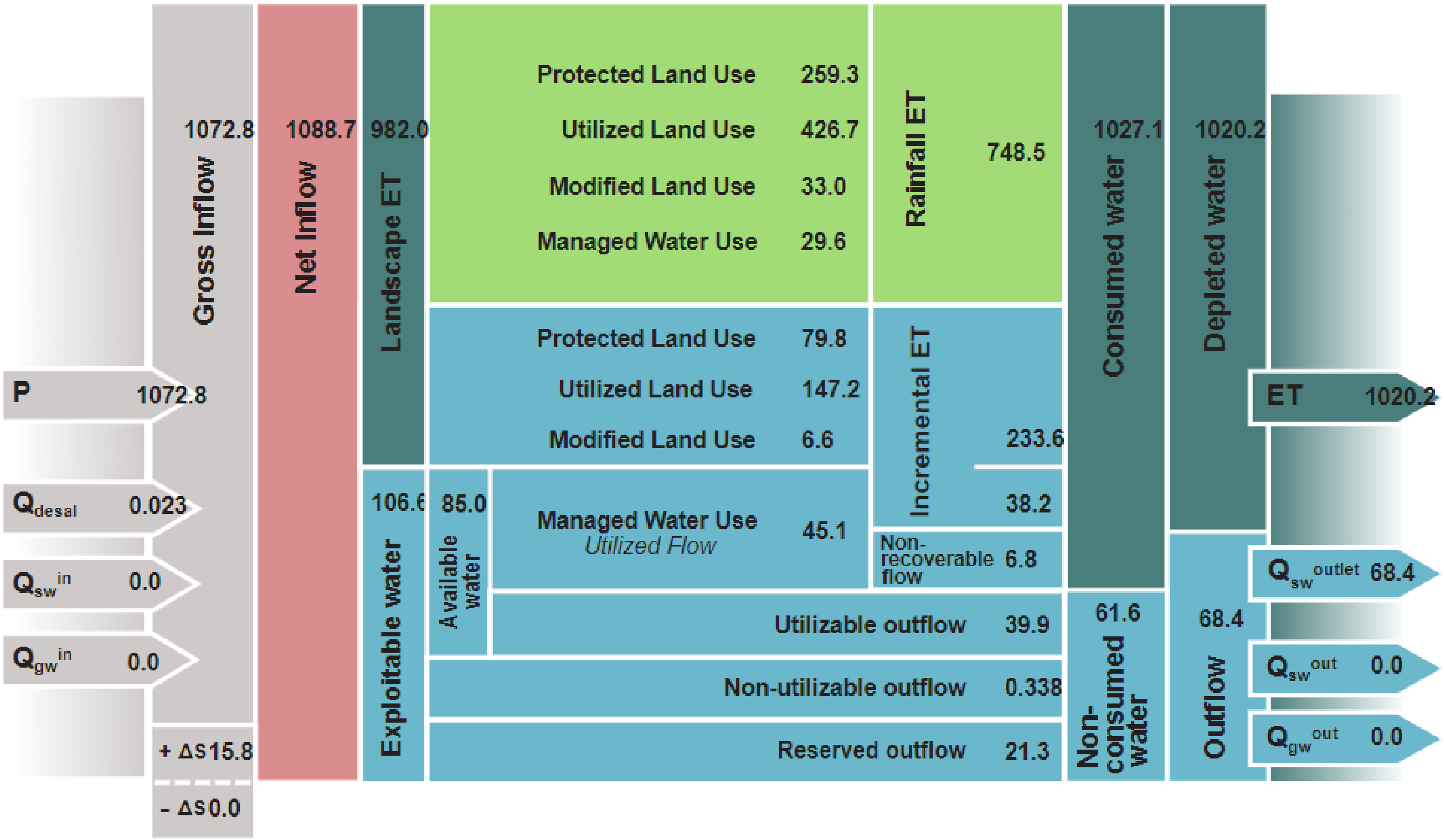
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2014



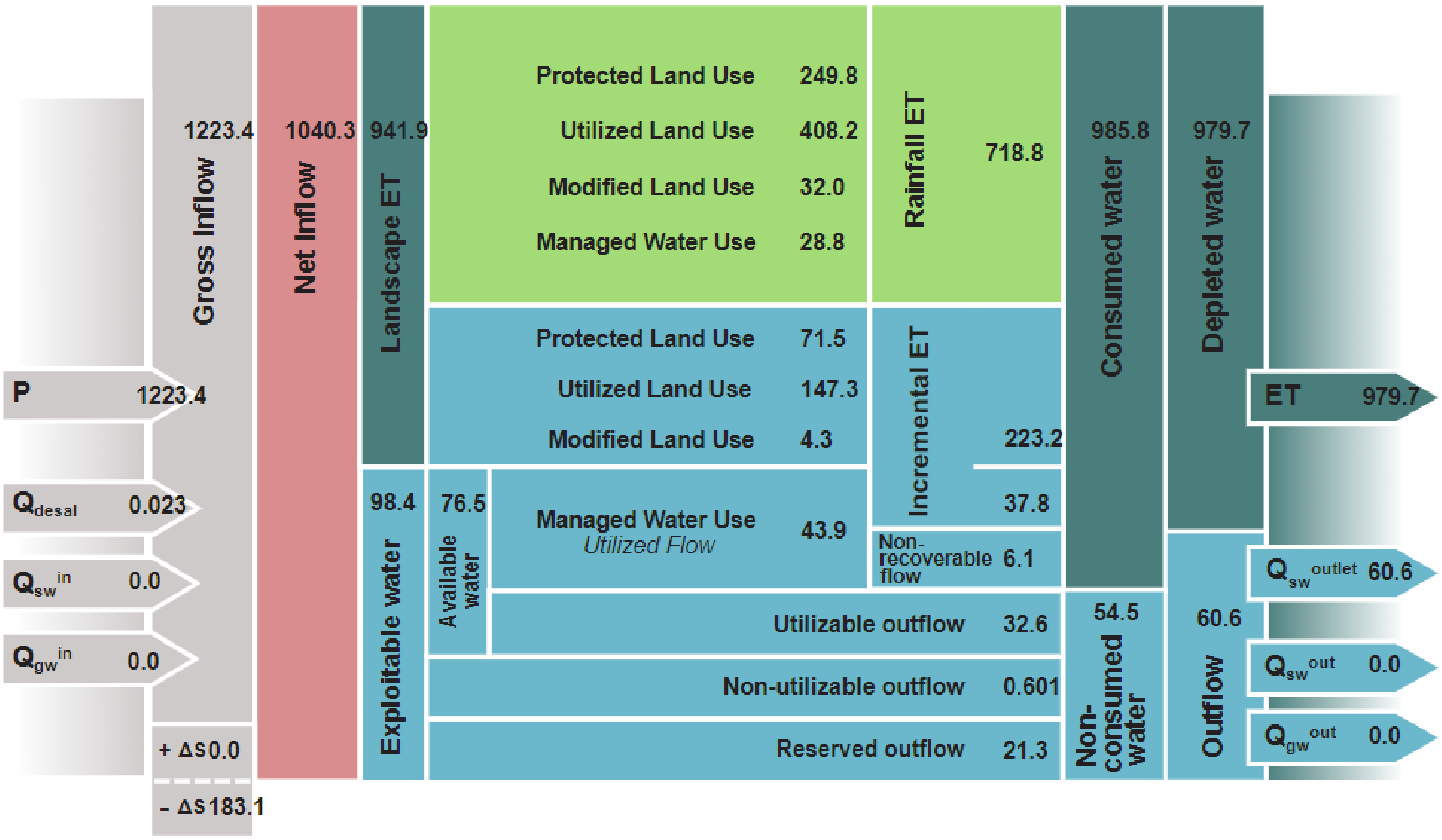
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2015



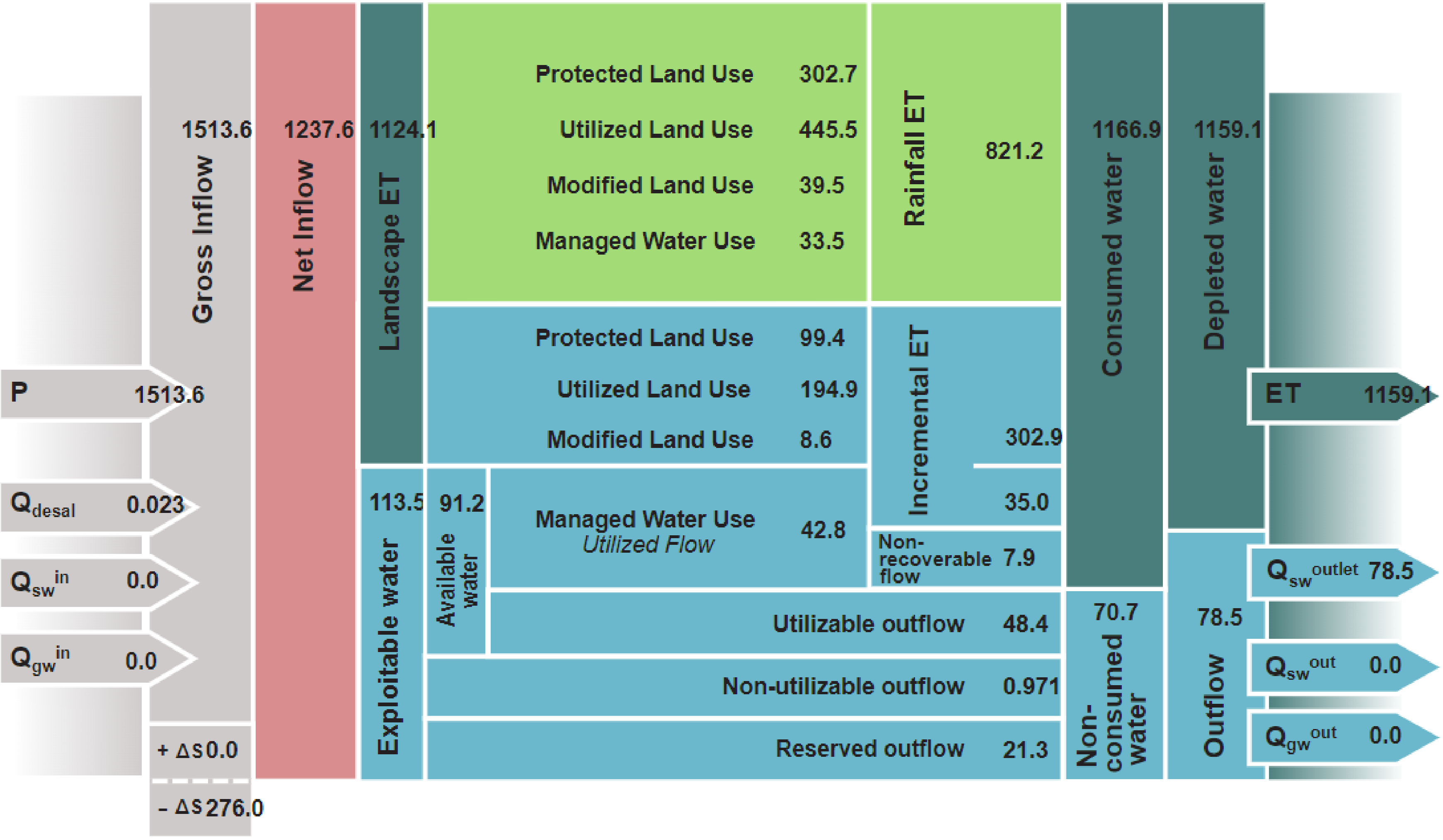
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2016



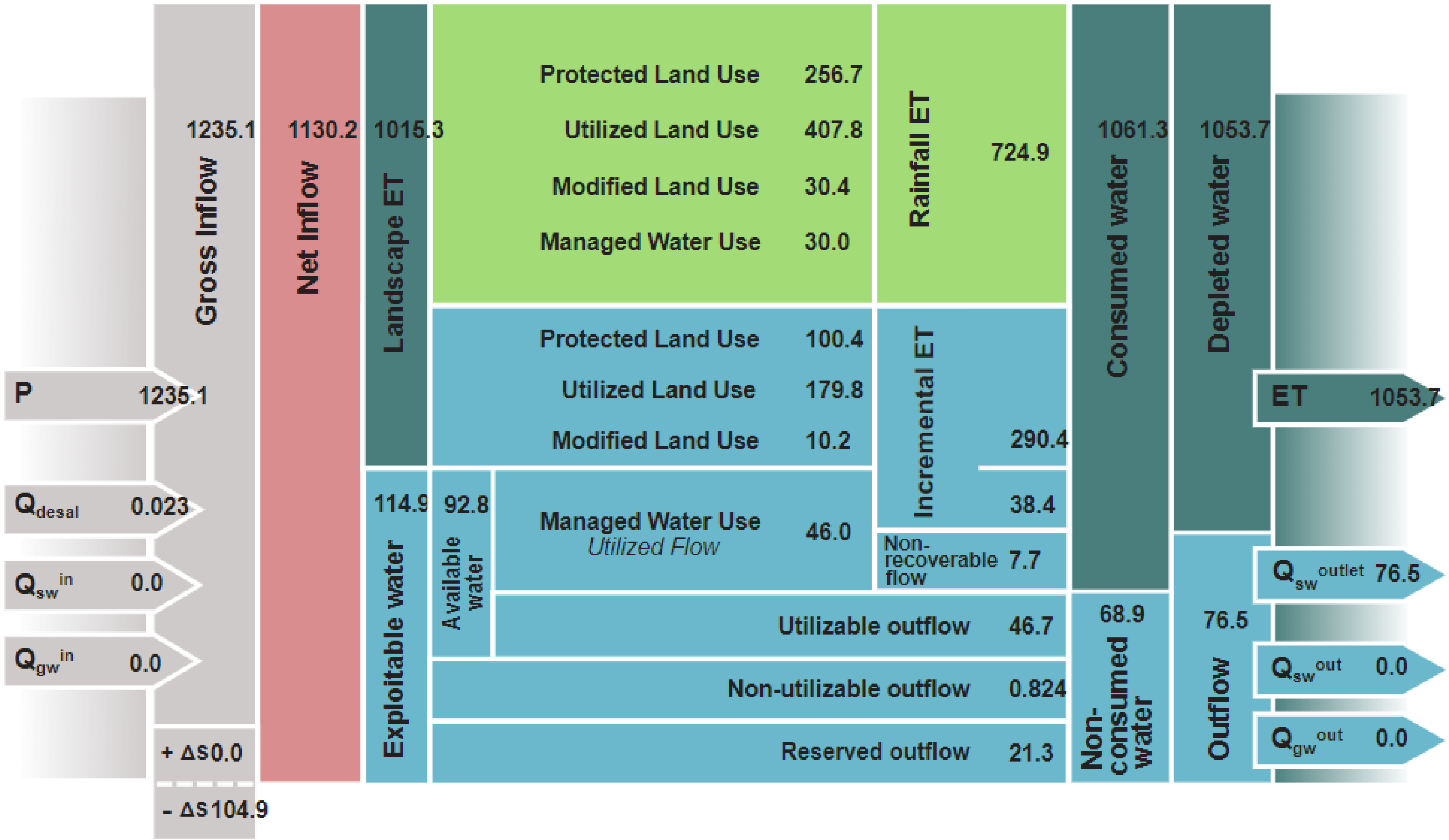
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2017



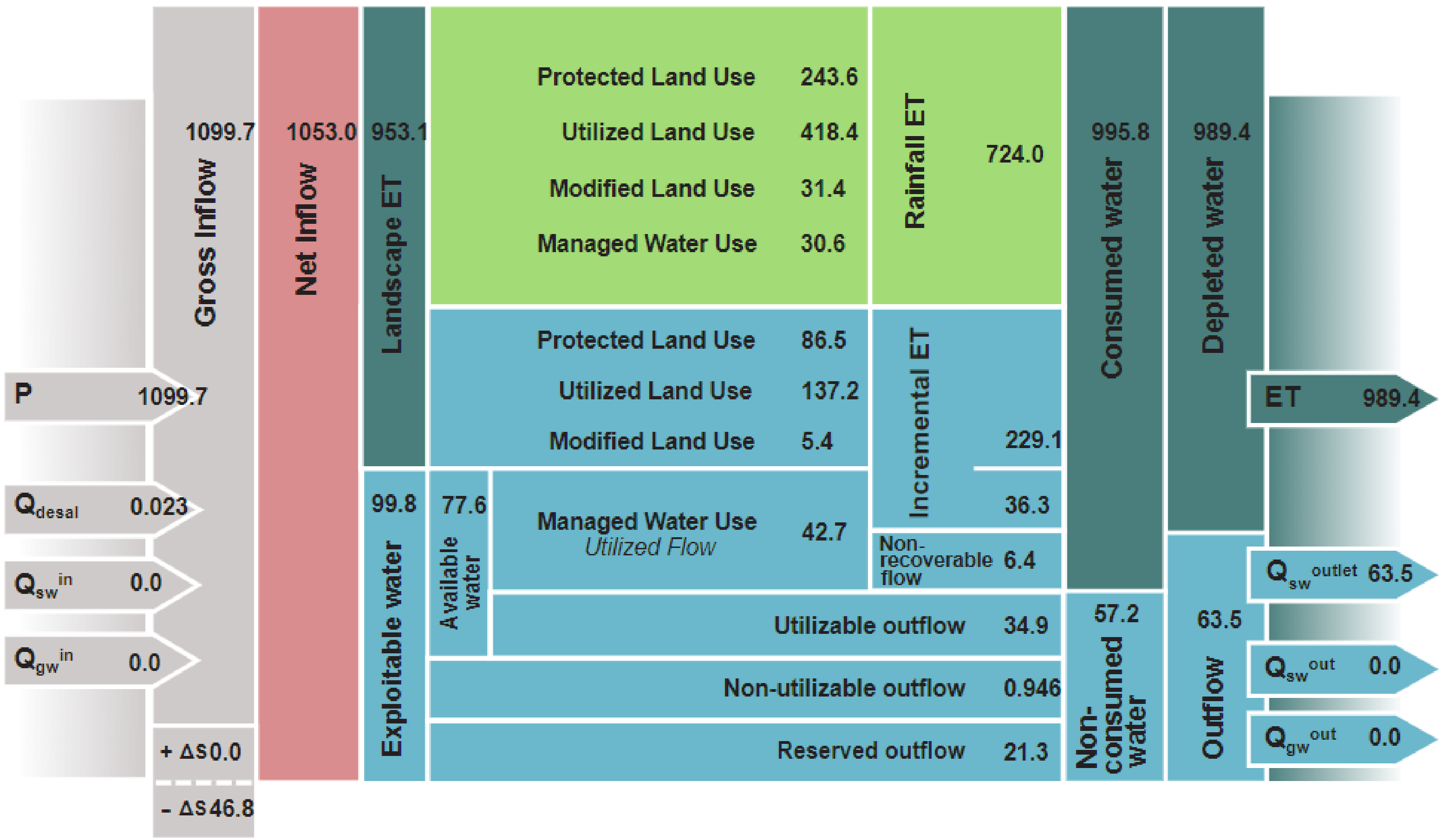
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2018



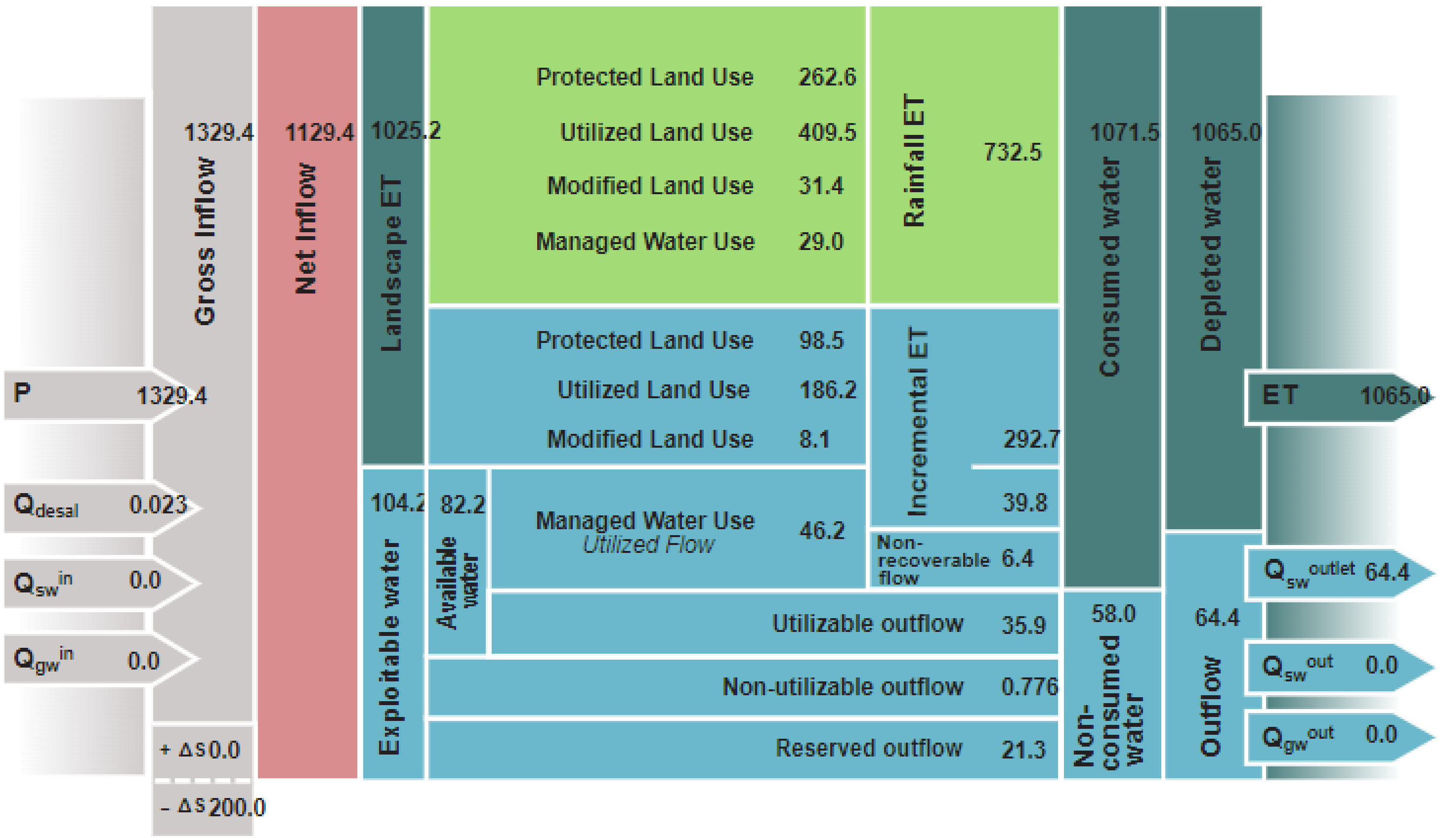
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2019



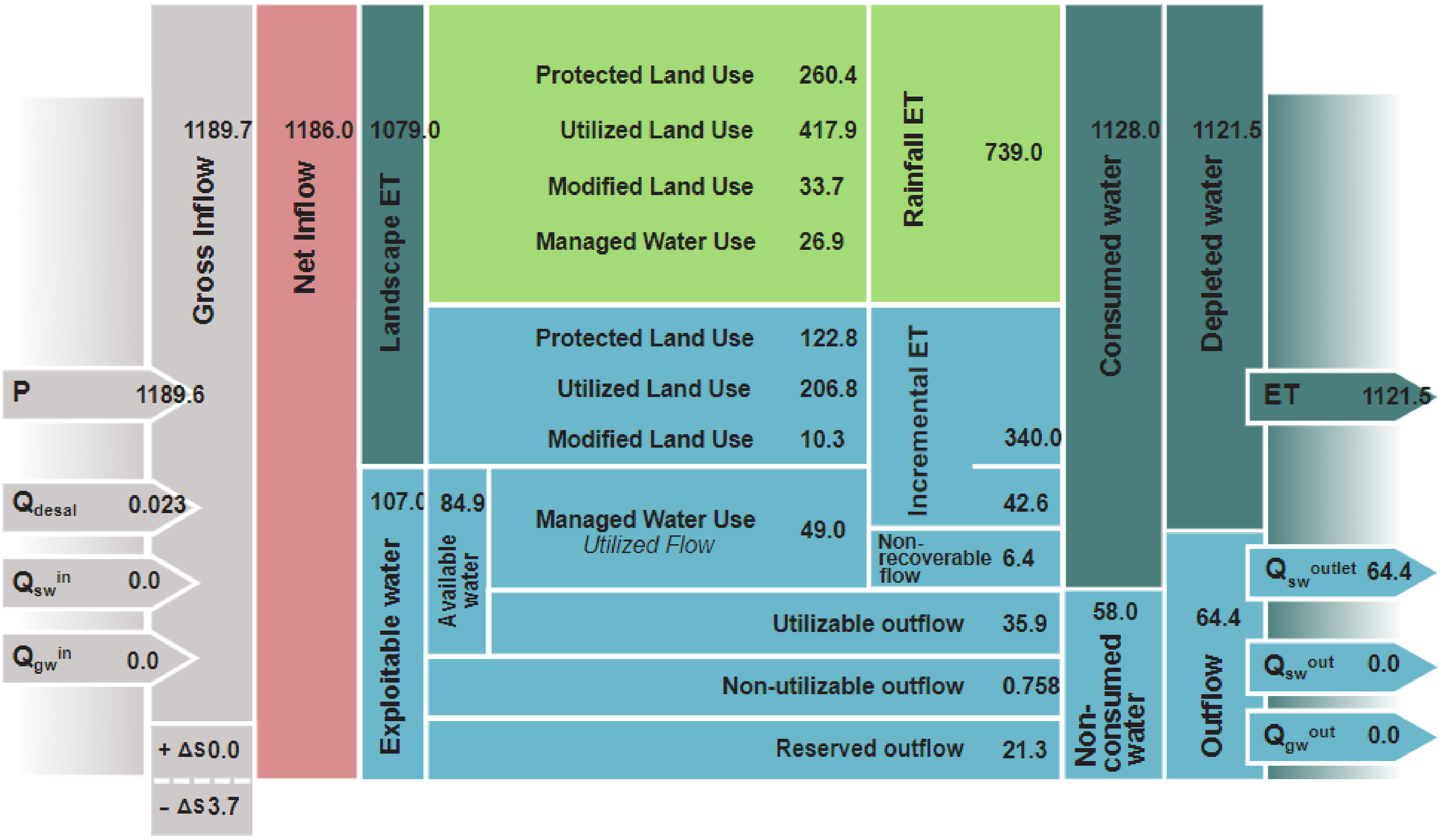
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2020



Sheet 1: Resource Base (km3/year)

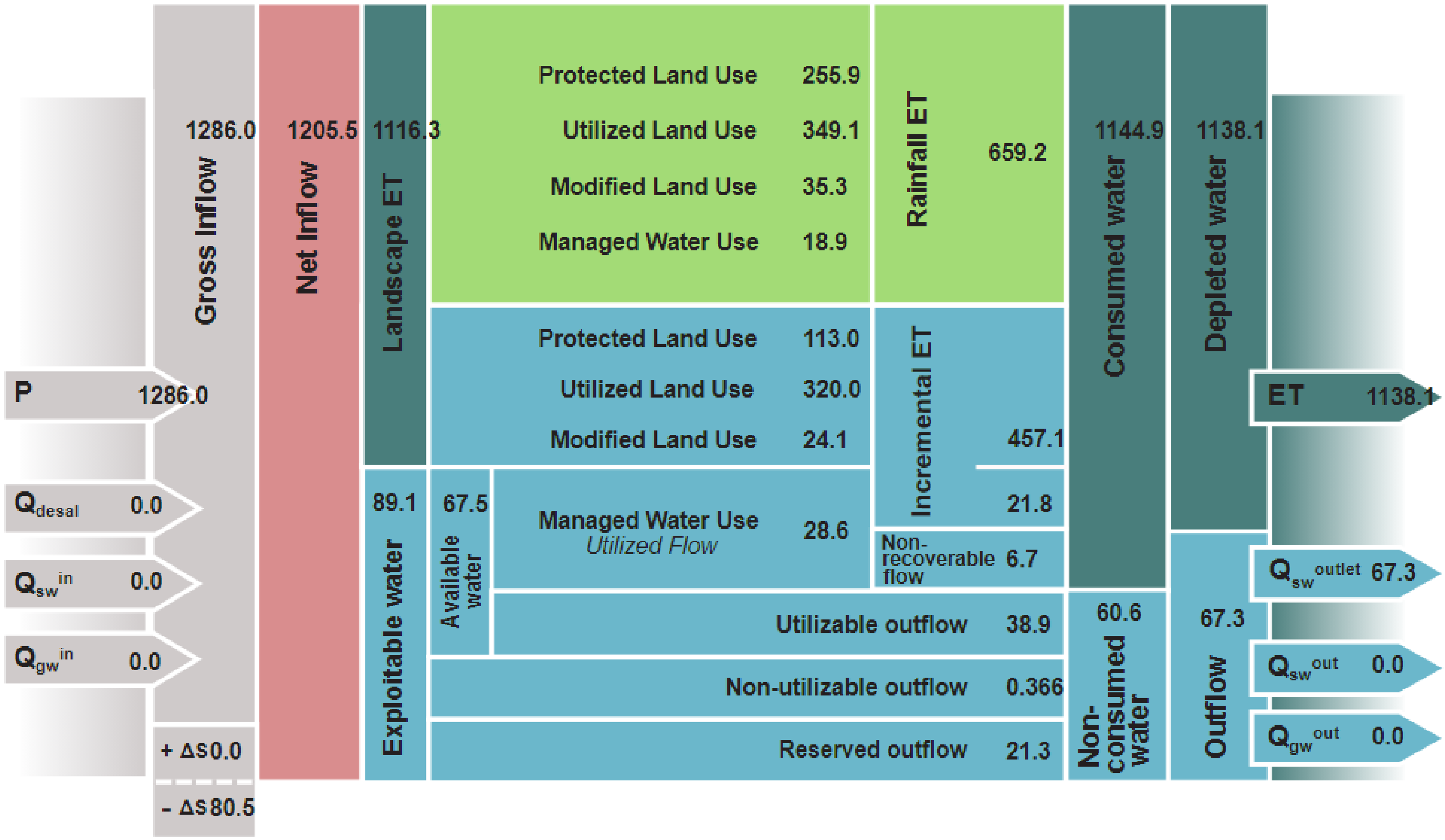
Basin: Zambezi
Period: 2021



Annex 1: Future Scenario Water Accounts (2027-2045)

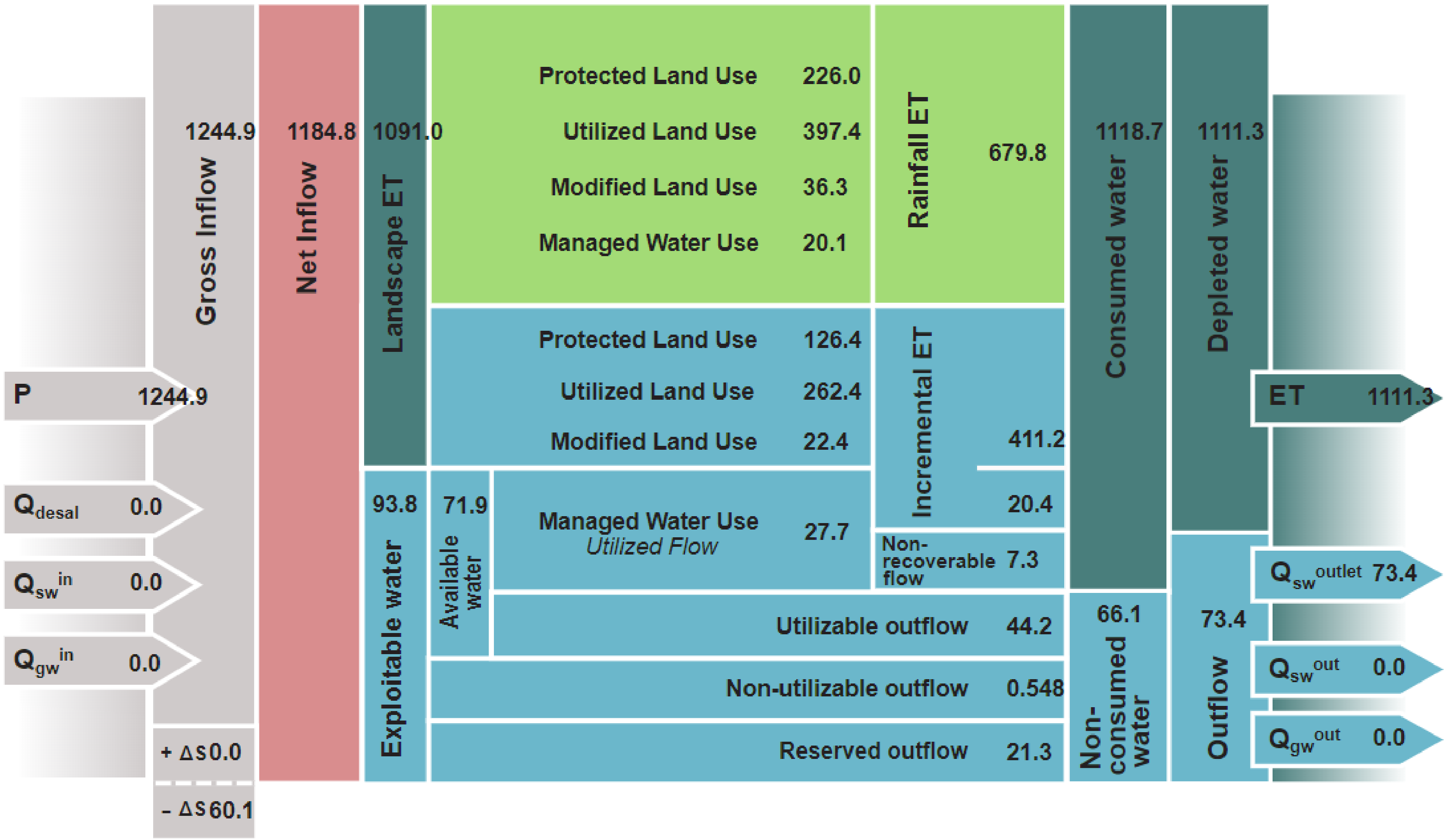
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2027



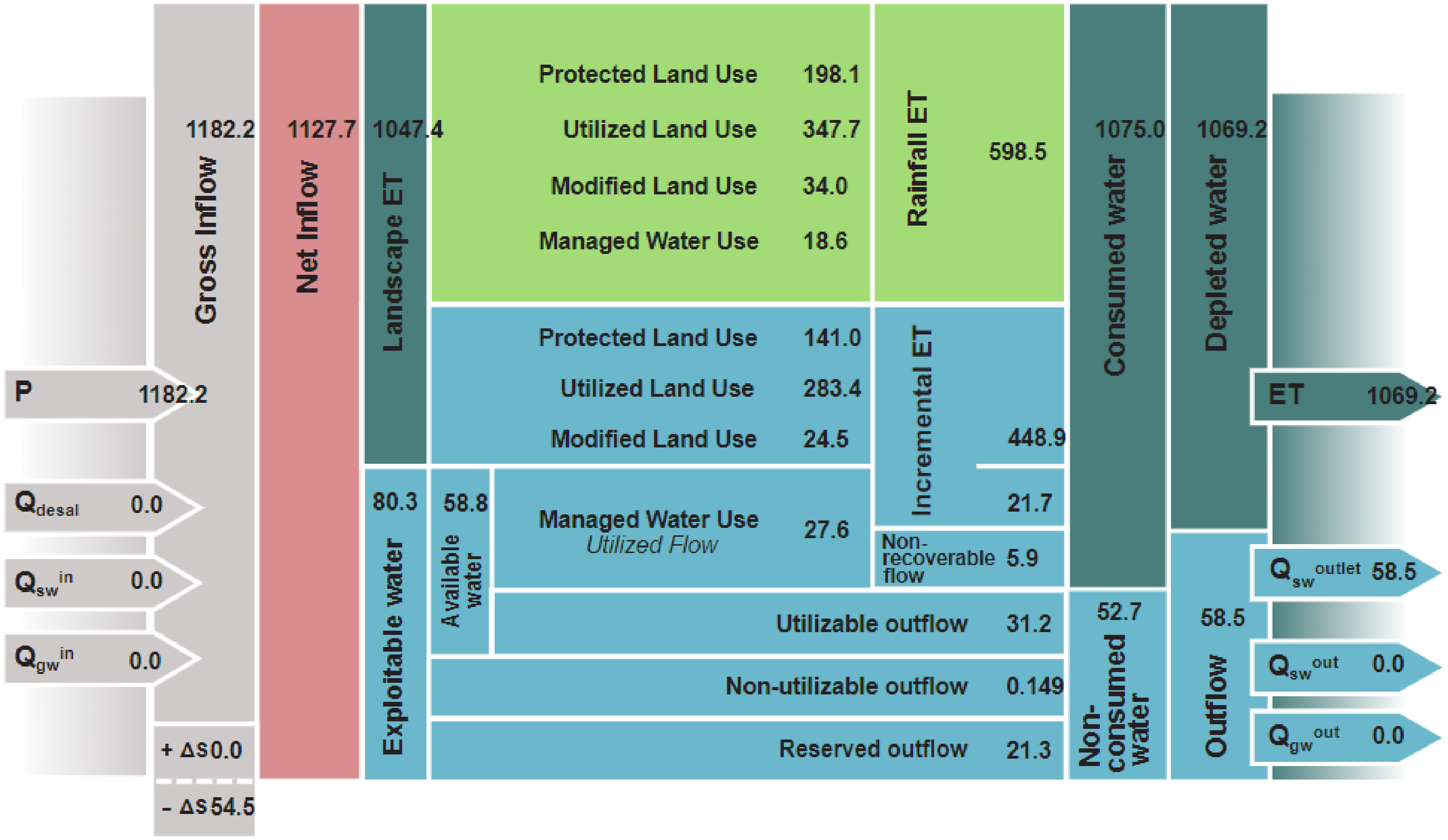
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2028



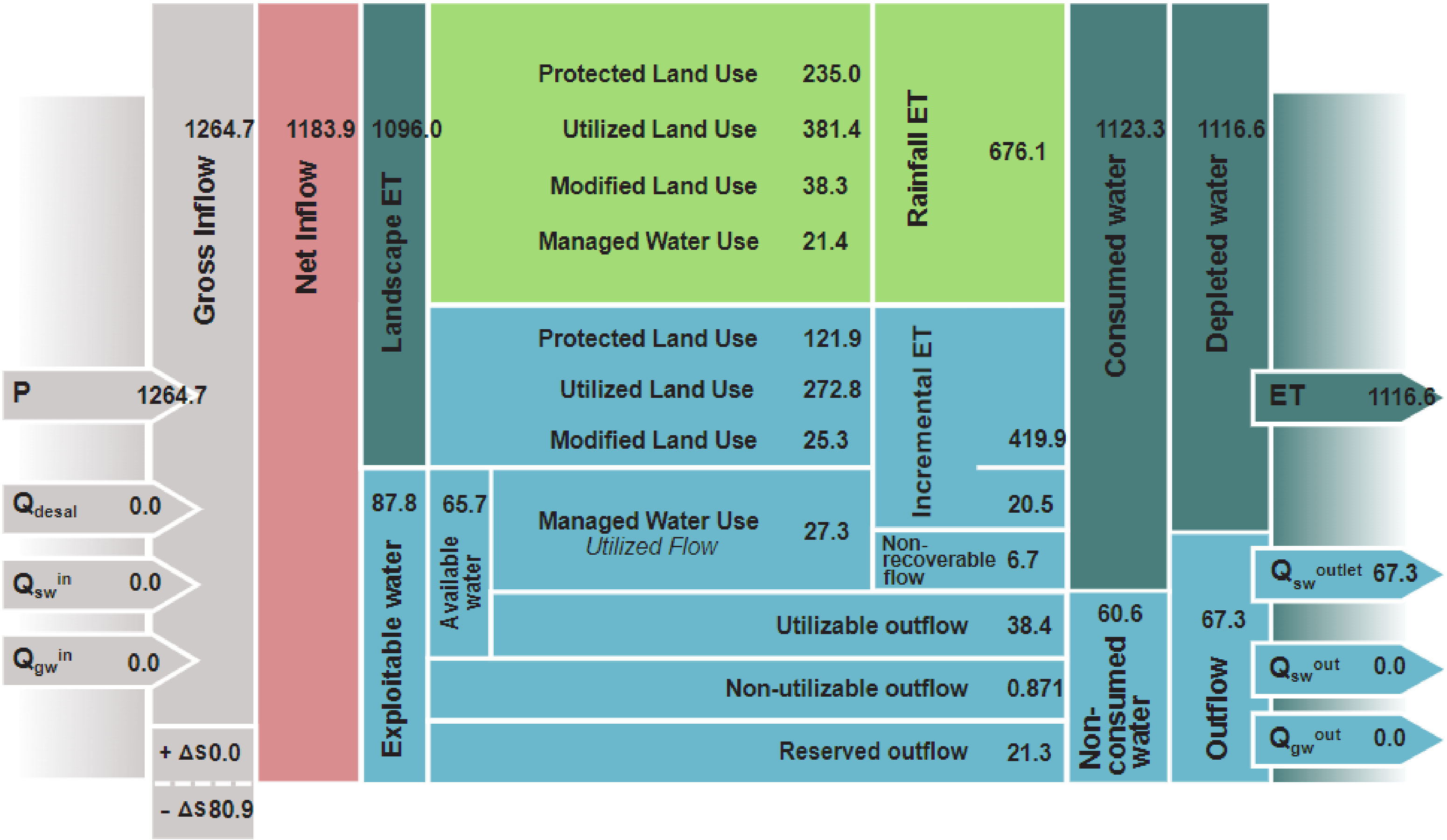
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2029



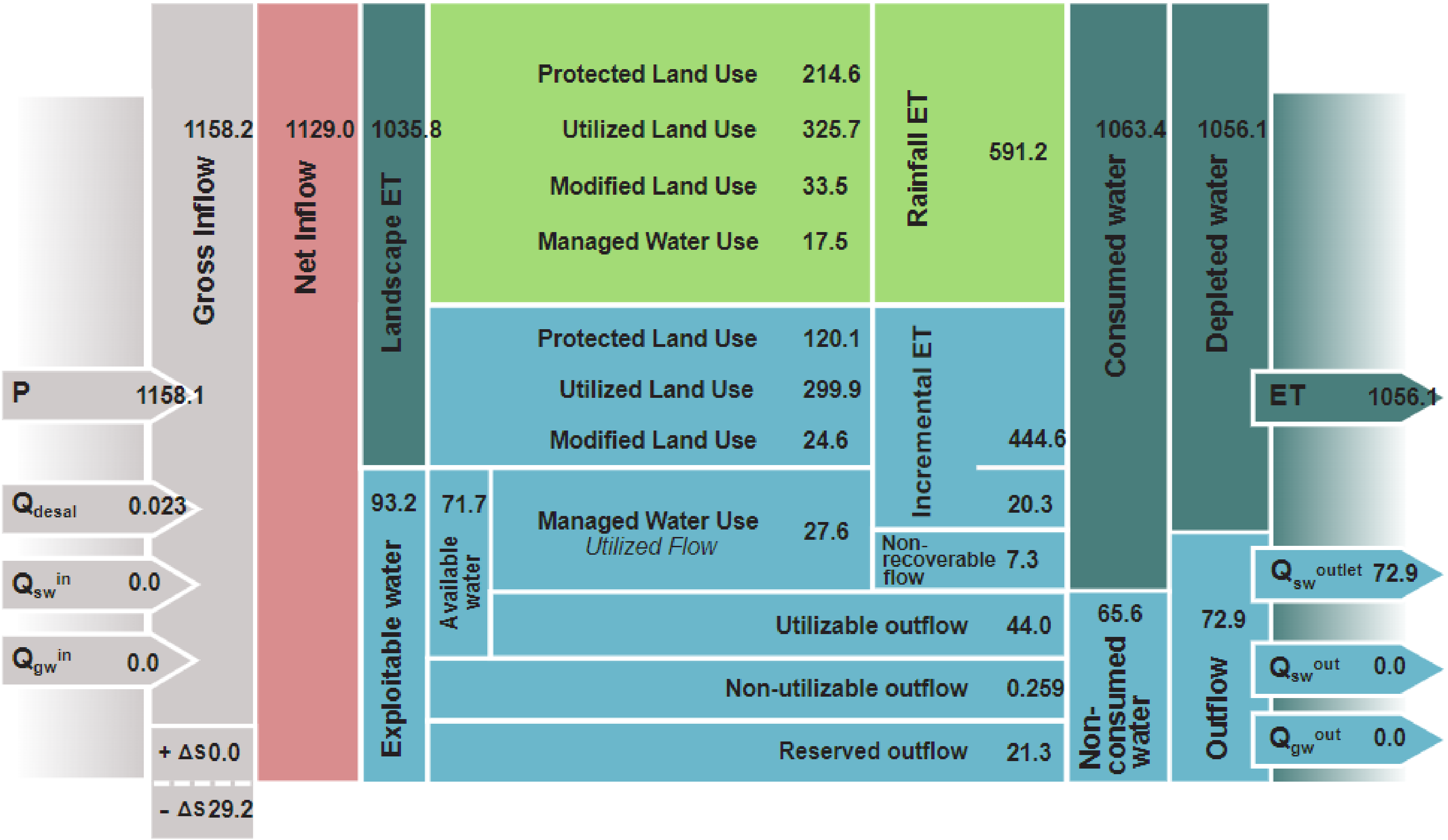
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2030



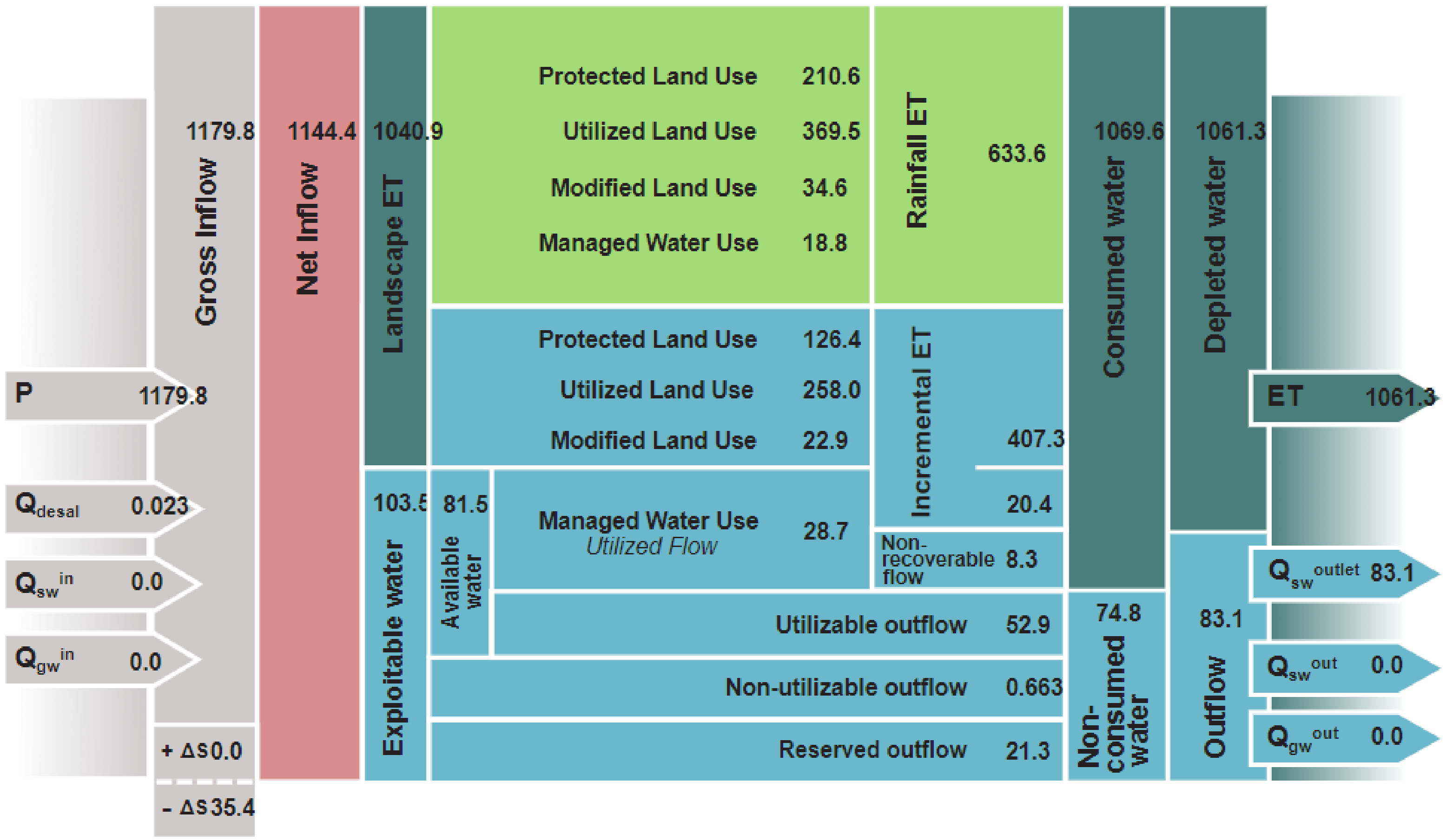
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2031



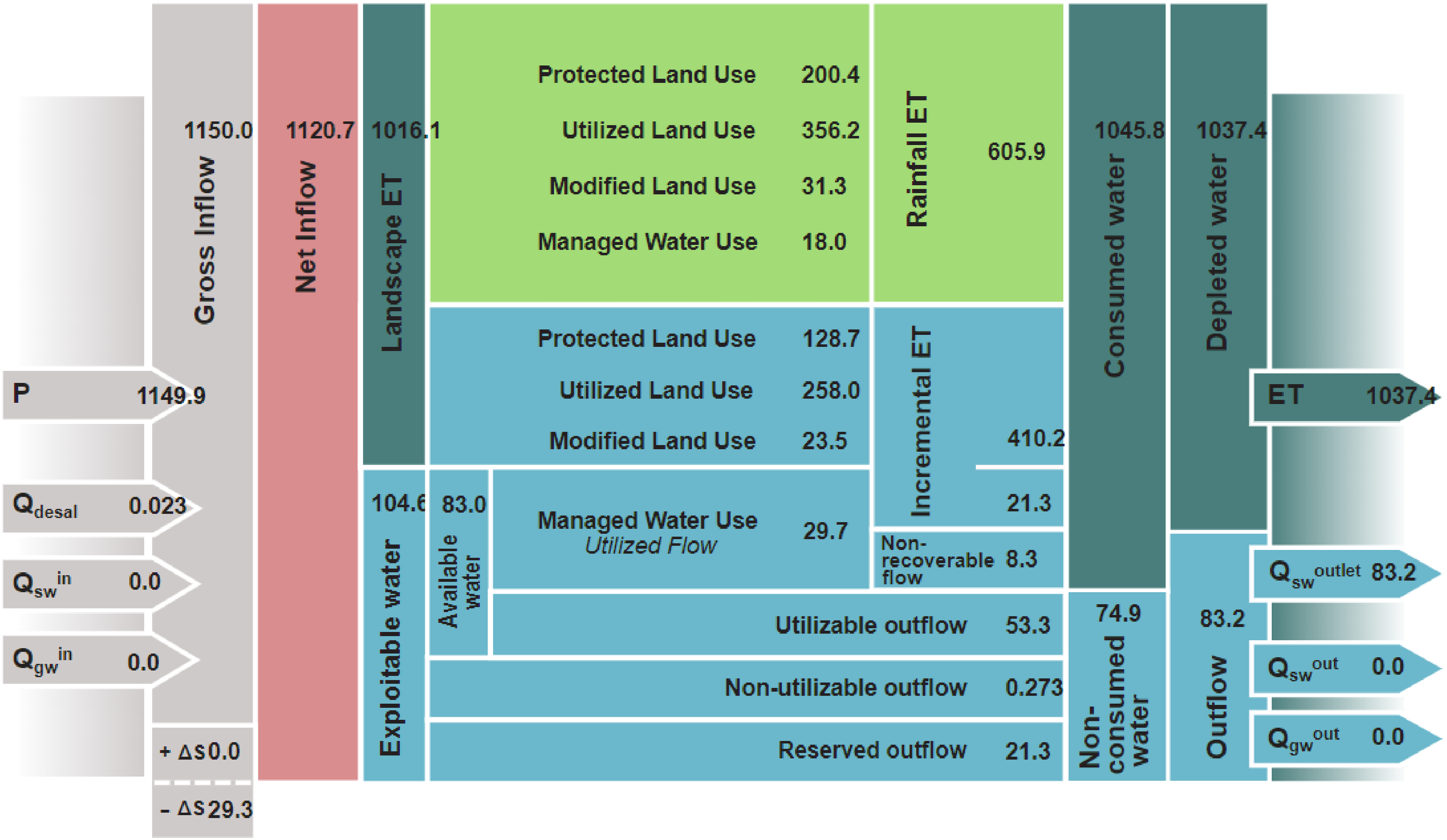
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2032



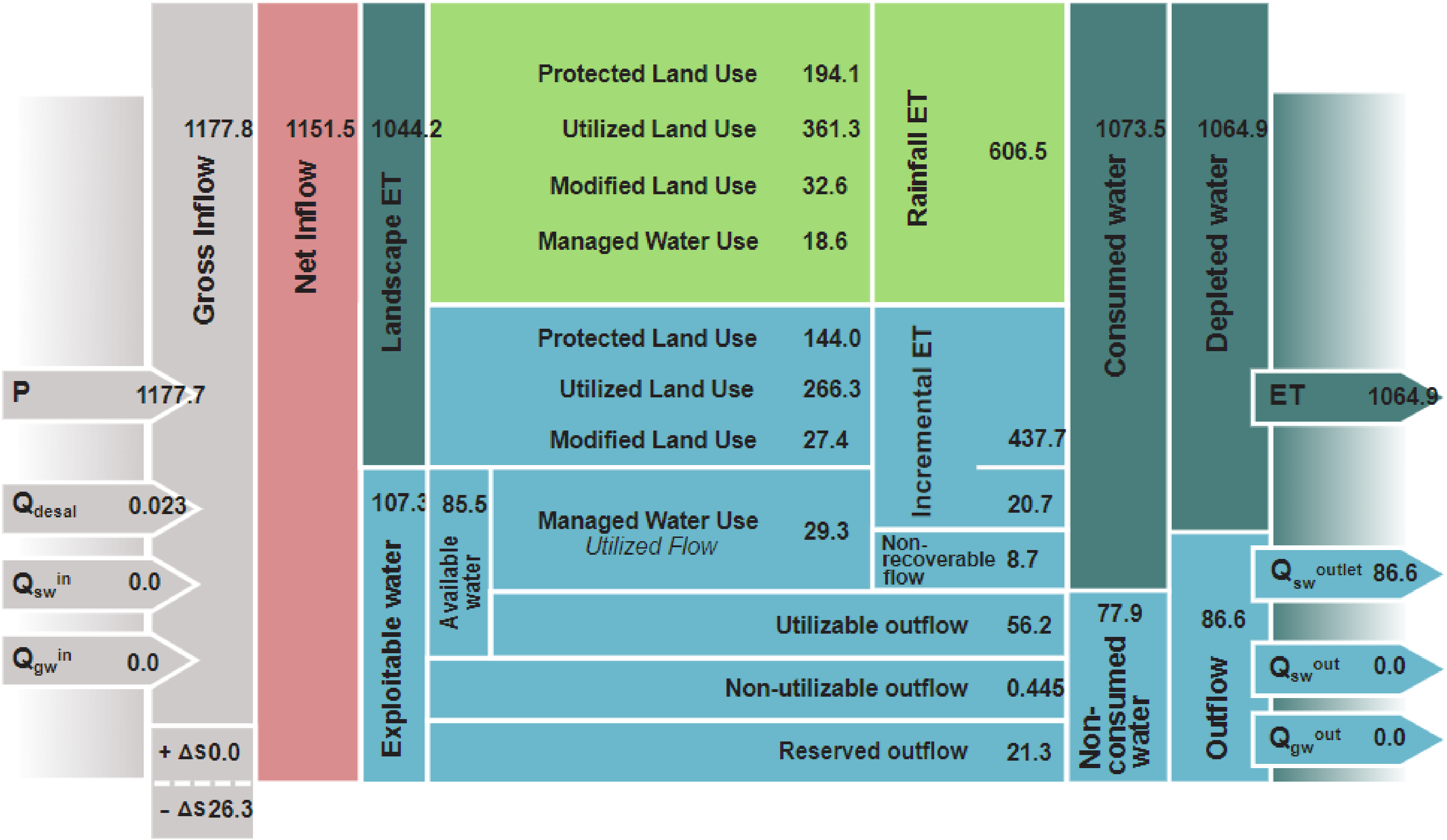
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2033



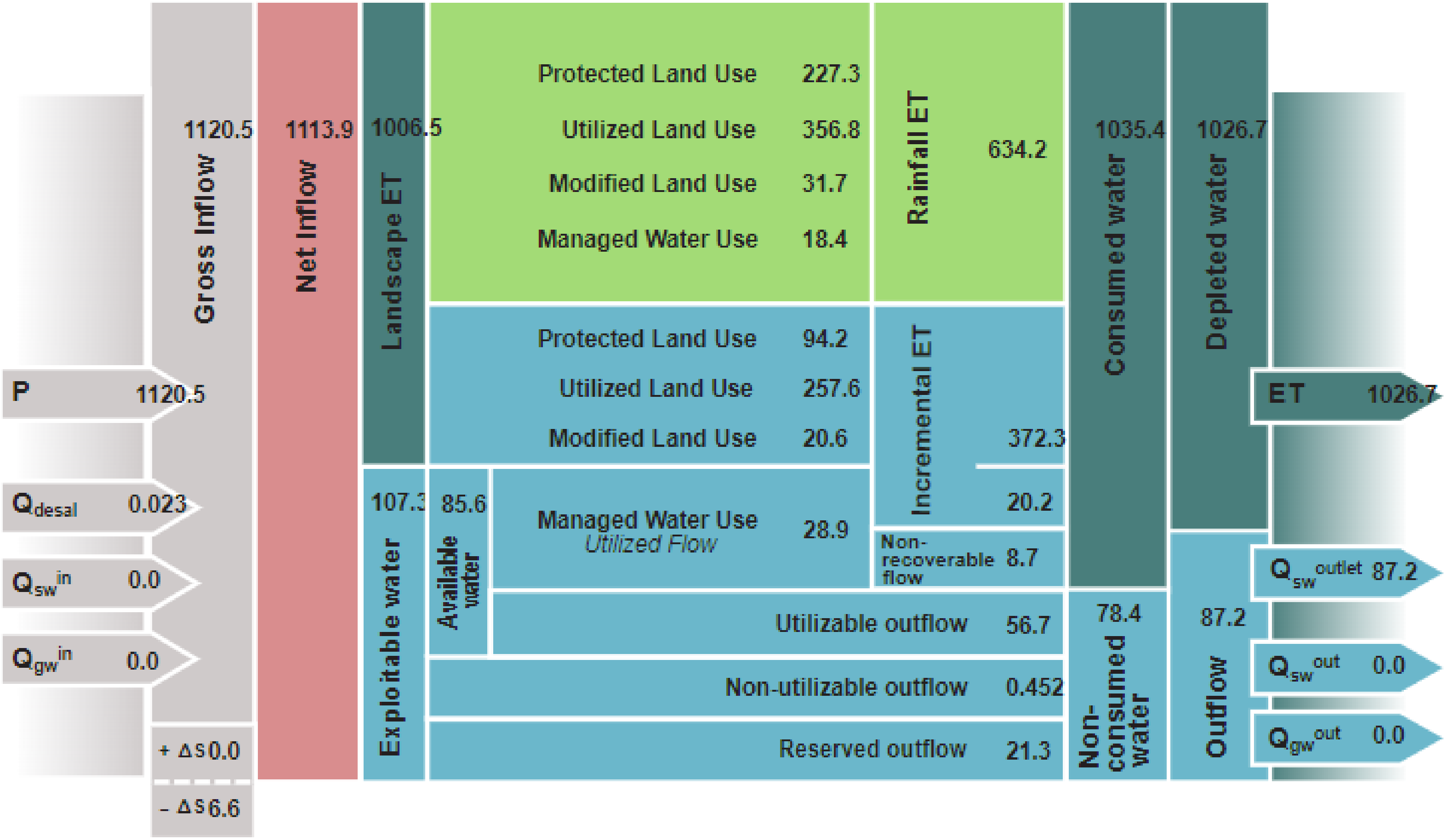
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2034



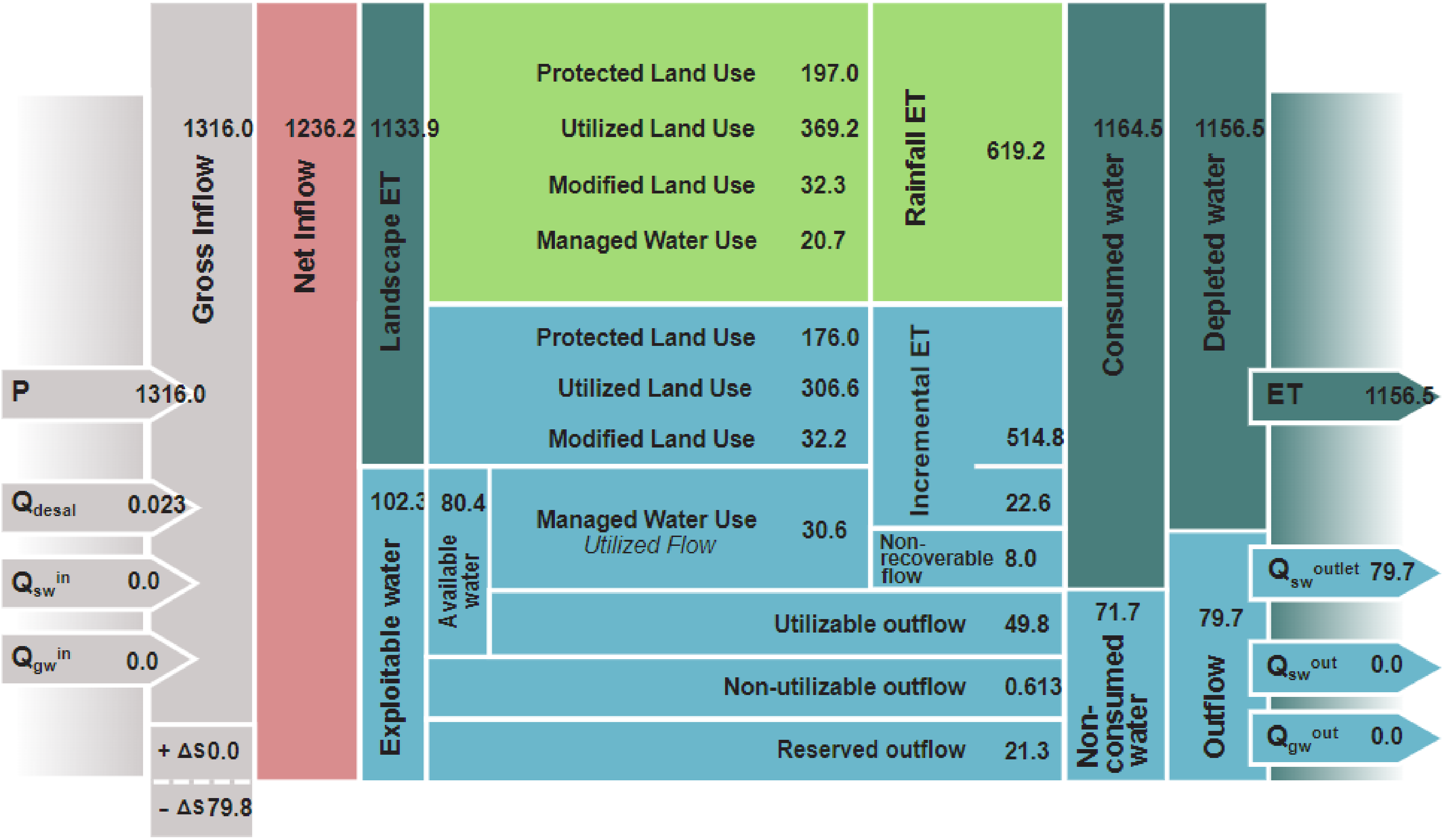
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2035



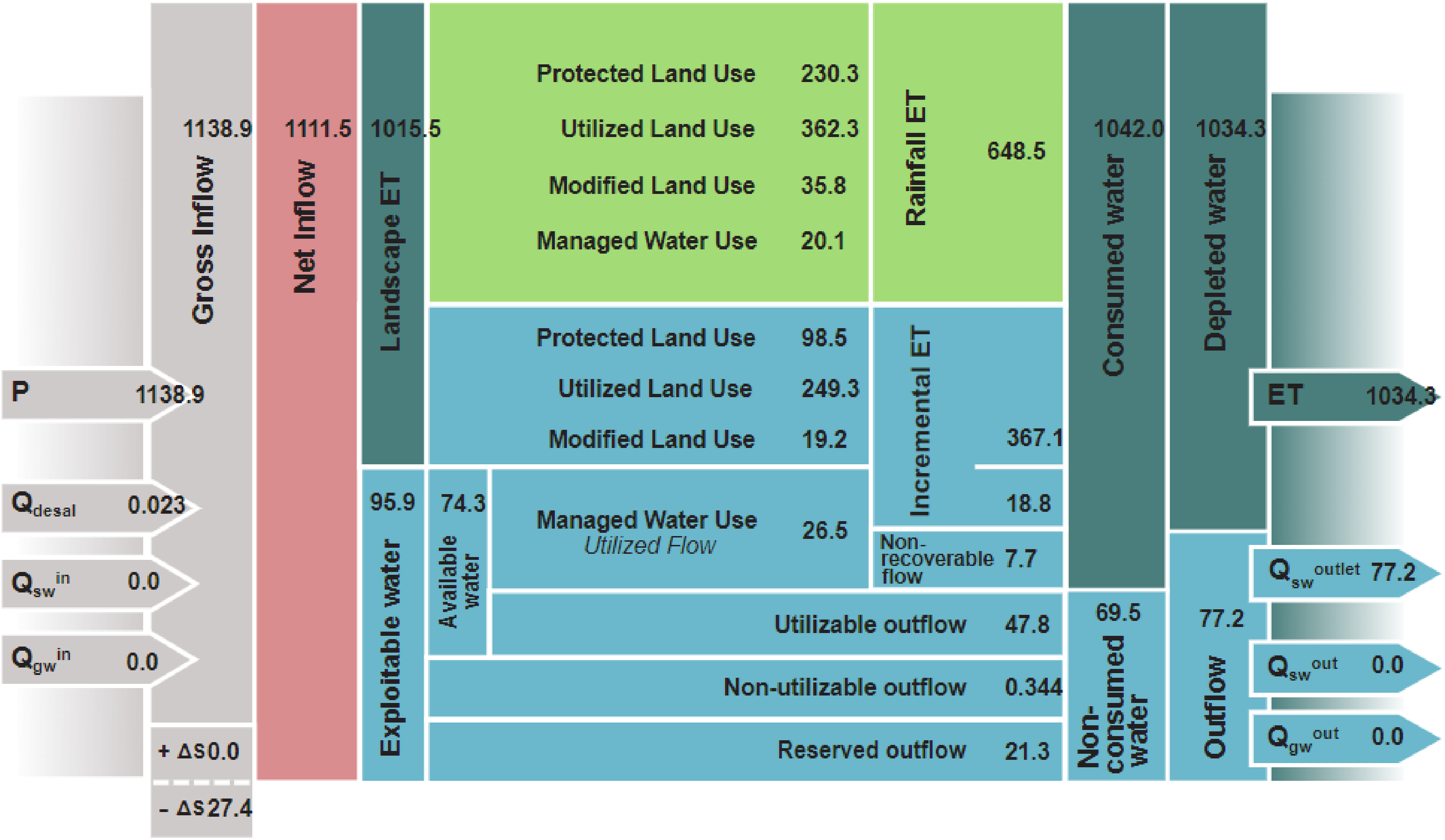
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2036



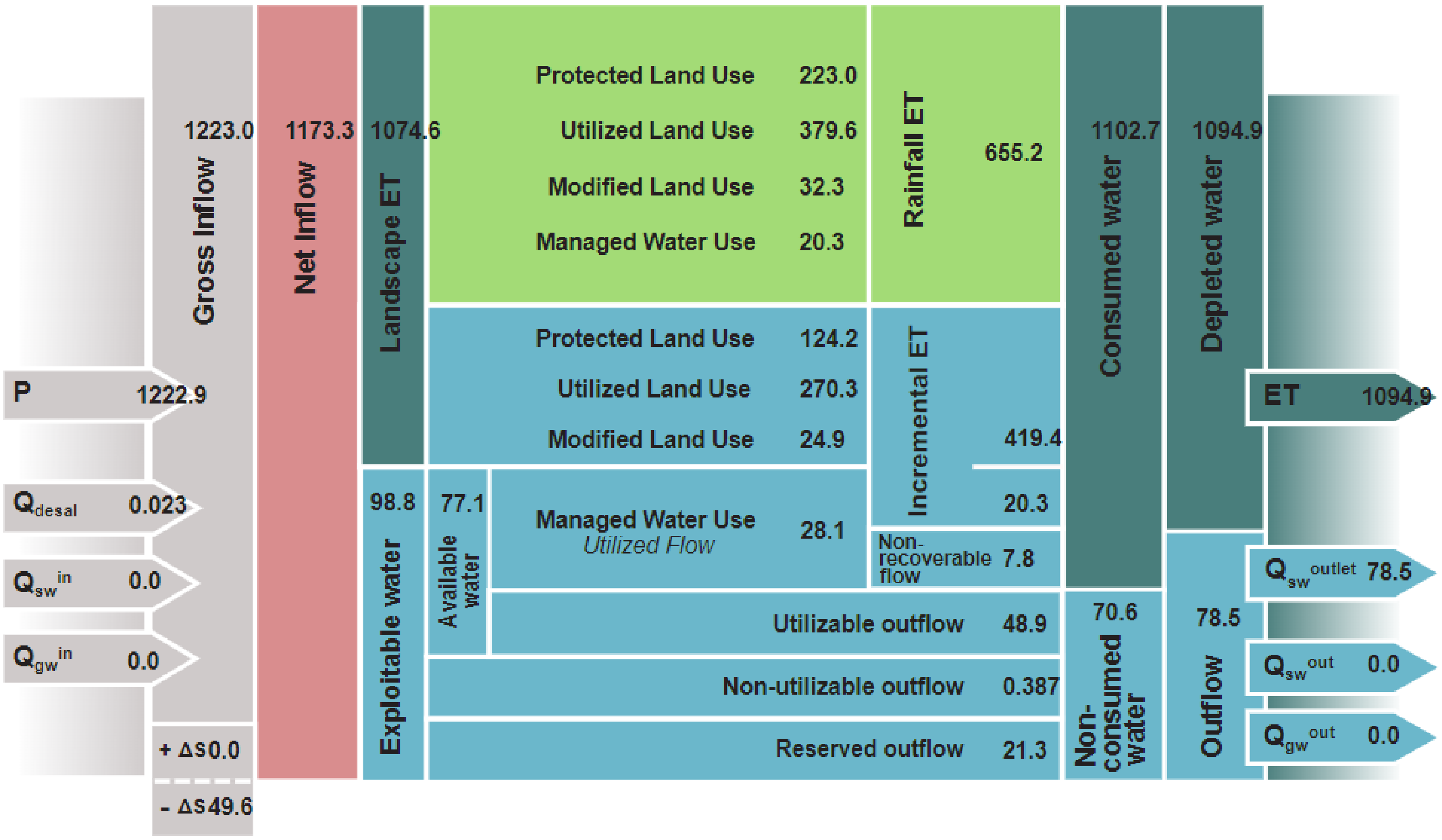
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2037



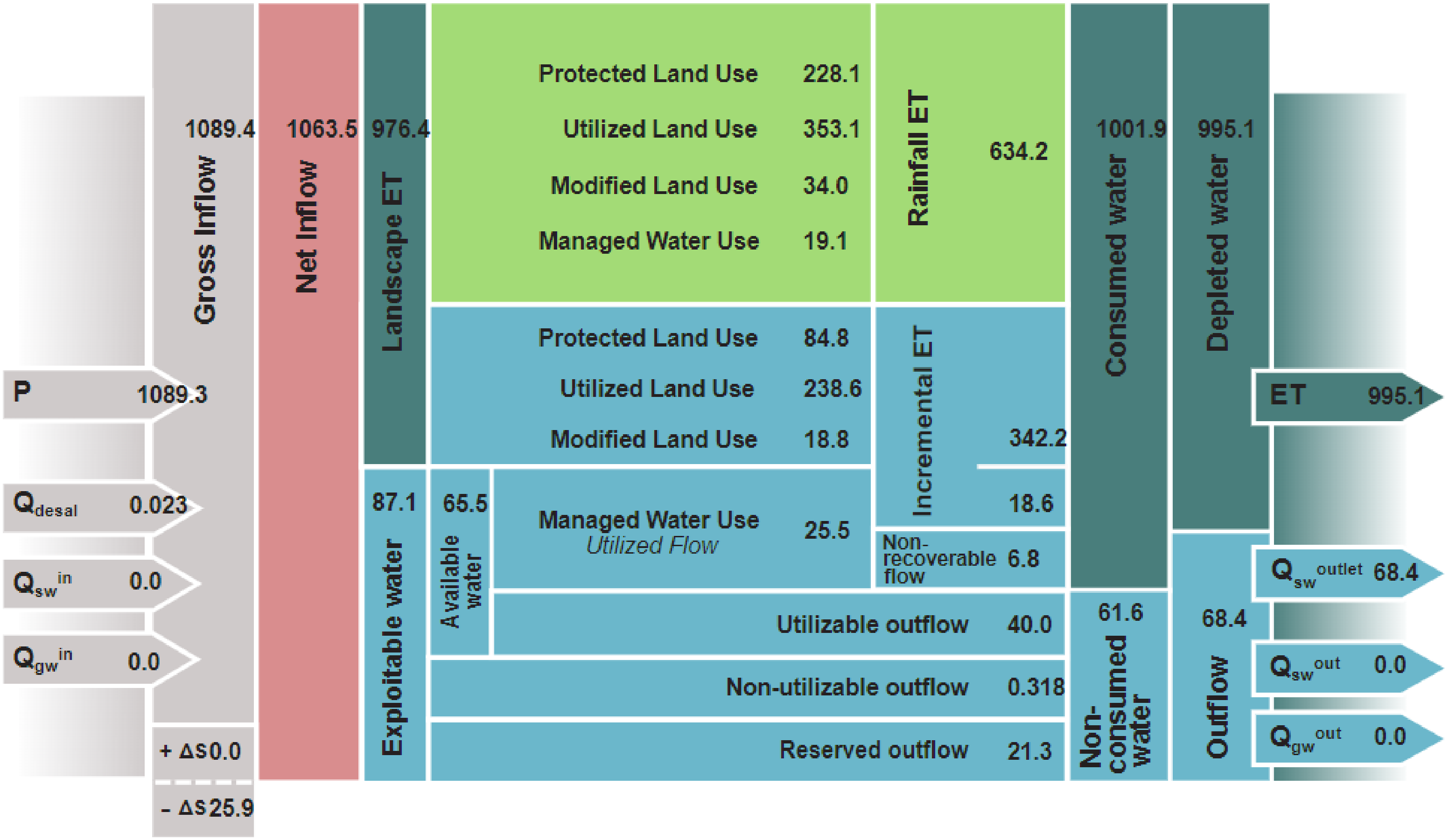
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2038



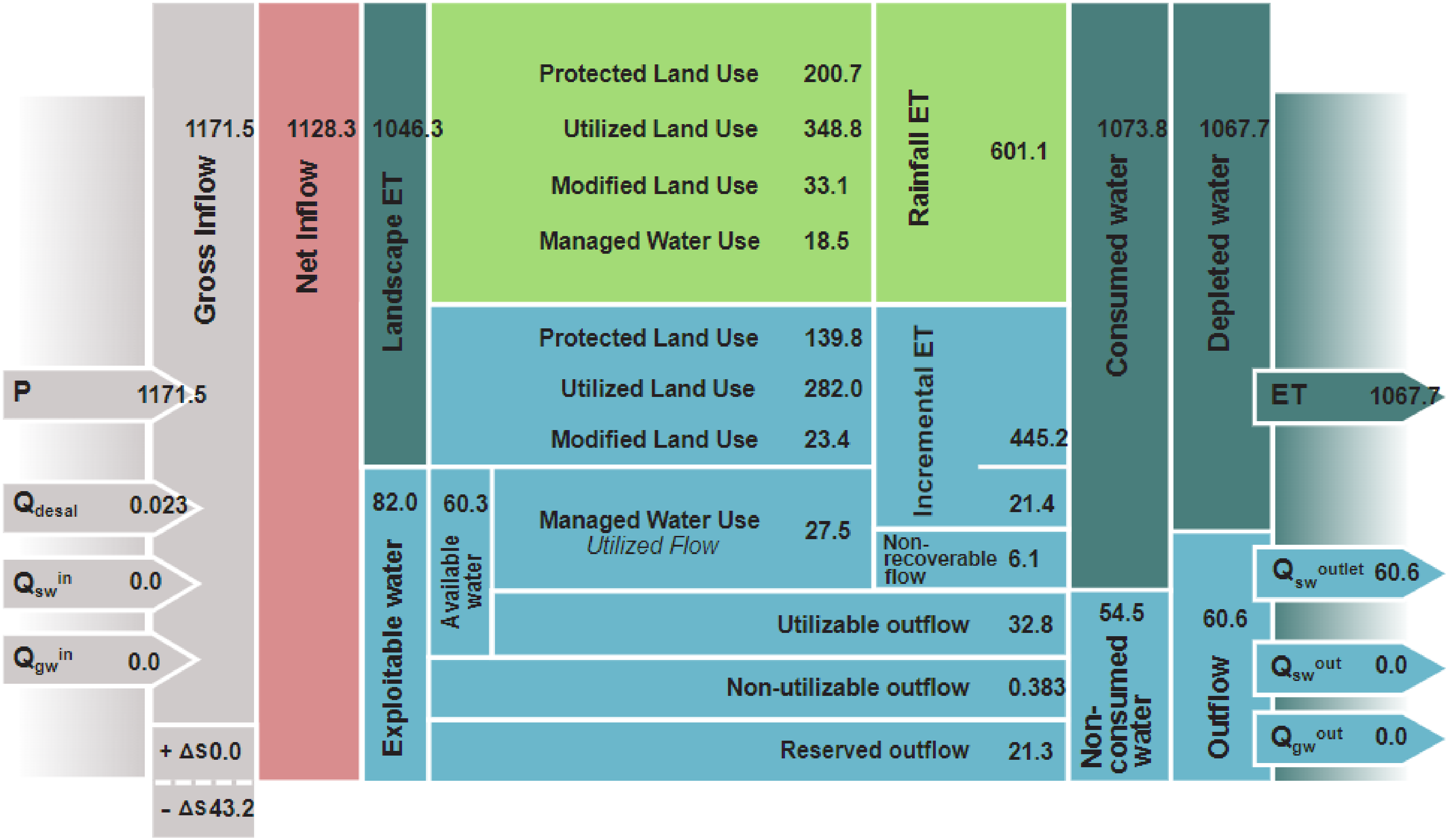
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2039



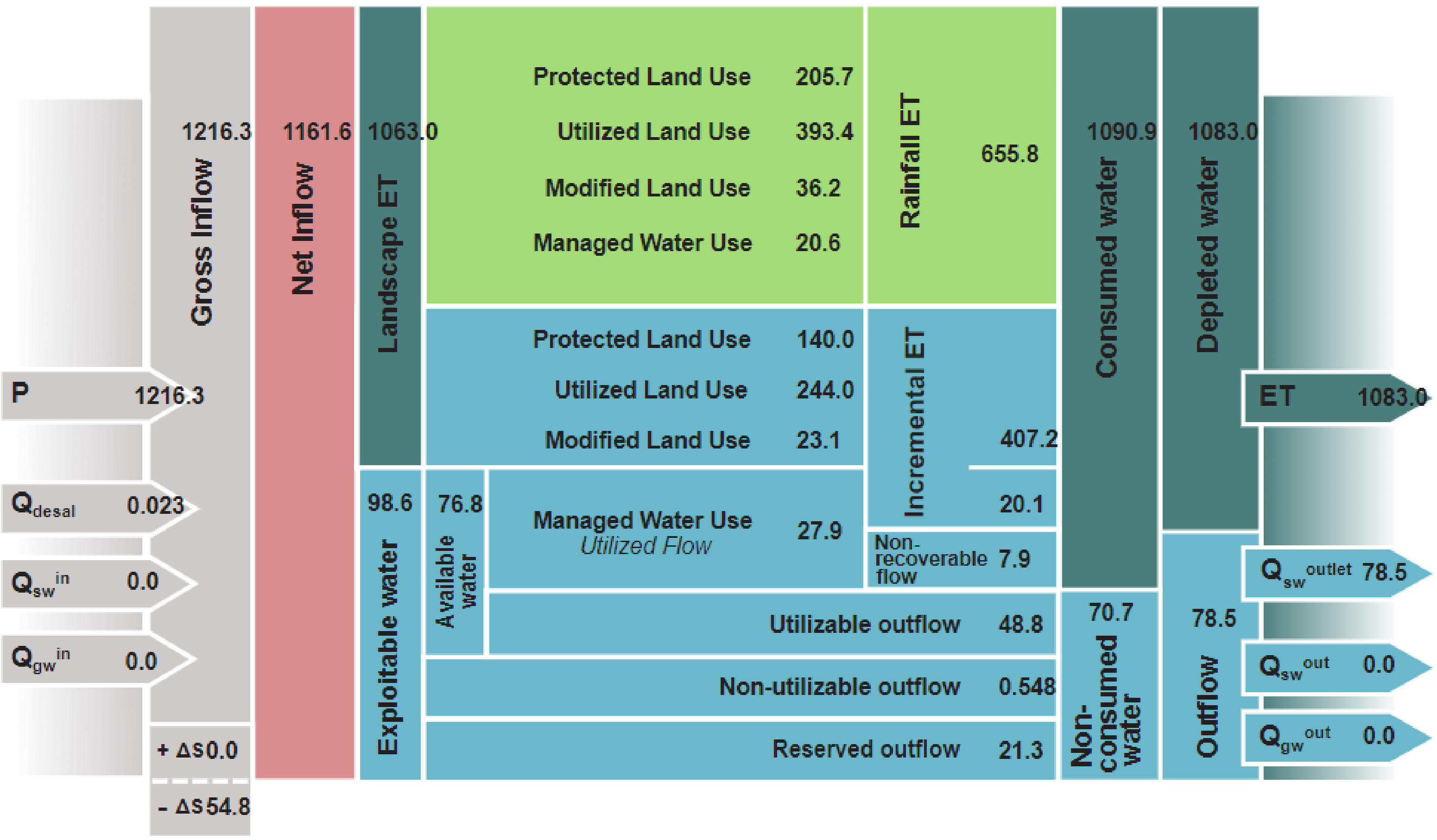
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2040



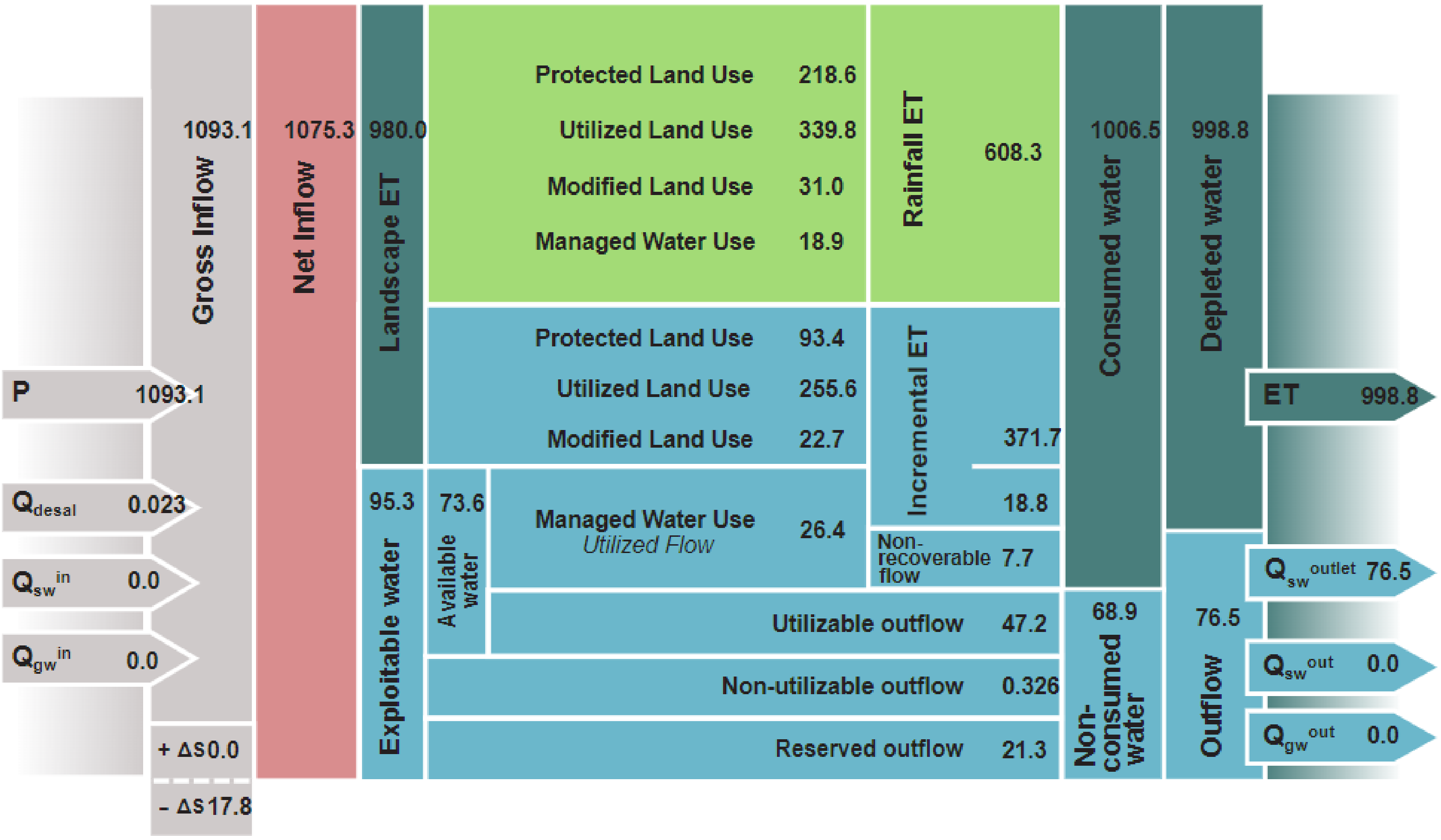
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2041



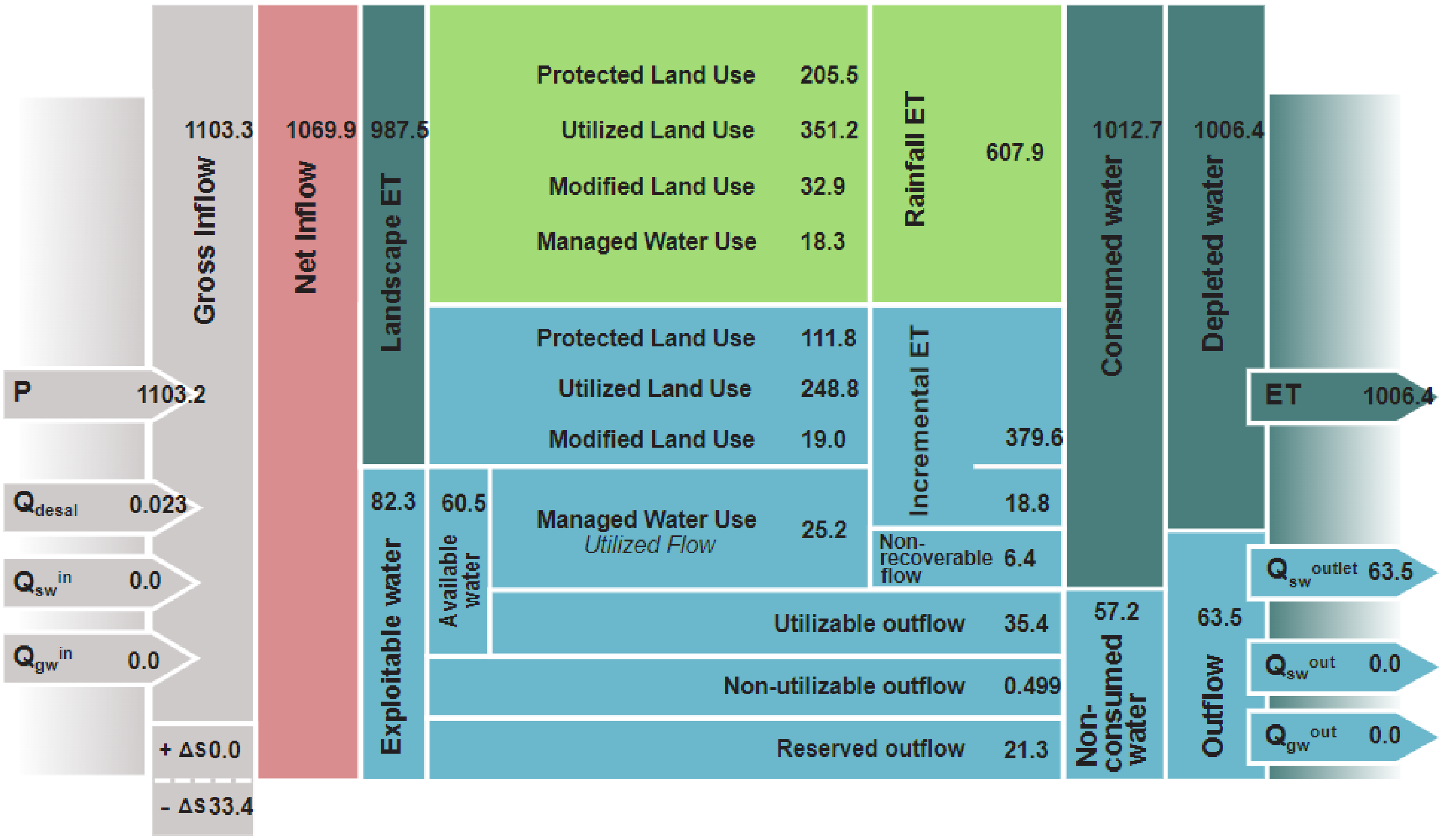
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2042



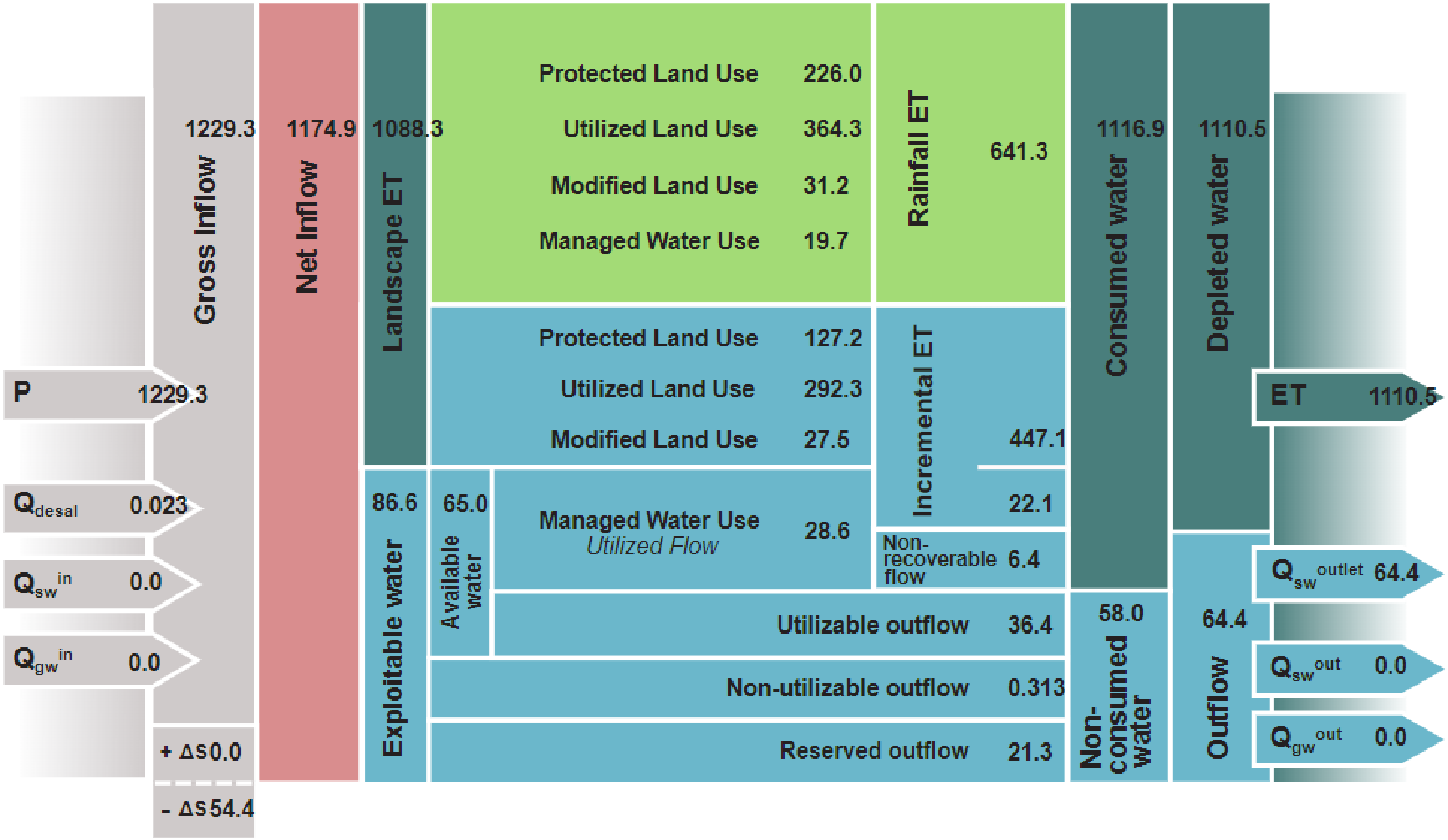
Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2043



Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2044



Sheet 1: Resource Base (km3/year)

Basin: Zambezi
Period: 2045