

NATIONAL WATER ACCOUNTING ATLAS
for Sub-Saharan Africa

Ethiopia

A Comprehensive Assessment of Water Resources Using Earth
Observation and the Scale-Invariant Water Accounting Plus
(SIWA+) Framework, 2003–2024

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Disclaimer

The water accounting results presented in this atlas are based on publicly available satellite data and hydrological modeling. As with any model-based assessment, the results are subject to uncertainties arising from the underlying data and modeling methods. The reported figures should therefore be considered indicative estimates rather than official statistics. Further validation in collaboration with relevant national agencies, using ground-based observations and national datasets, is recommended before the results are used to inform policy decisions, water resources planning, or official reporting.

Moreover, this publication has not been independently peer reviewed. Responsibility for editing, proofreading, layout, opinions expressed, and any possible errors lies with the authors and not the institutions involved.

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Cover image

Satellite mosaic of Africa with Ethiopia highlighted. Image by NASA Earth Observatory, Blue Marble: Next Generation (public domain); boundaries from Natural Earth (public domain).



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Project



Digital Innovations for Water Secure Africa (DIWASA) develops open digital tools, Earth observation data products, and water accounts that give African decision-makers consistent, policy-relevant information on water availability, use, and risk.

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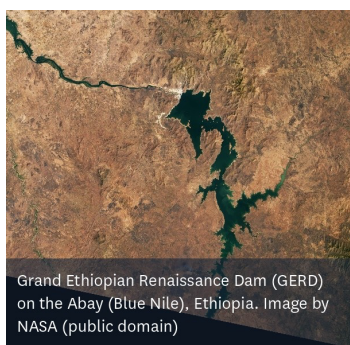
Use of artificial intelligence

During the preparation of this work the authors used Claude (Anthropic) in order to refine the language and formatting of the publication. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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Ethiopia from space. Image by NASA Earth Observatory, Blue Marble: Next Generation (public domain)



Grand Ethiopian Renaissance Dam (GERD) on the Abay (Blue Nile), Ethiopia. Image by NASA (public domain)

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Acronyms and Abbreviations

BDE	Boundary Data Extractor
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station data
DDE	Desalination Data Extractor
DEM	Digital Elevation Model
DIWASA	Digital Innovations for Water Secure Africa
ERWR	External Renewable Water Resources
ESA CCI	European Space Agency Climate Change Initiative
ET	Evapotranspiration
ET_a	Actual Evapotranspiration
EWR	Environmental Water Requirement
EWS	Environmental Water Stress
FAO	Food and Agriculture Organization of the United Nations
GERD	Grand Ethiopian Renaissance Dam
GLEAM	Global Land Evaporation Amsterdam Model
GMIA	Global Map of Irrigation Areas
GPP	Gross Primary Production
HydroSHEDS	Hydrological data and maps based on SHuttle Elevation Derivatives at multiple Scales
IODISE	Inflow–Outflow Discharge Extractor
IRWR	Internal Renewable Water Resources
IWMI	International Water Management Institute
LAI	Leaf Area Index
MODIS	Moderate Resolution Imaging Spectroradiometer
MSWEP	Multi-Source Weighted-Ensemble Precipitation
MWU	Managed Water Use
NASA	National Aeronautics and Space Administration
NDM	Net Dry Matter
NPP	Net Primary Production
PCR-GLOBWB	PCRaster Global Water Balance model
ROSE	Rapid Optimized Sheet Extractor
SDG	Sustainable Development Goal
SIWA+	Scale-Invariant Water Accounting Plus
SSEBop	Operational Simplified Surface Energy Balance Model
TRWR	Total Renewable Water Resources
TWT	Transboundary Water Tracker
UN DESA	United Nations Department of Economic and Social Affairs
USAID	United States Agency for International Development
USGS	United States Geological Survey
VegET	Vegetation Evapotranspiration model (USGS)
WA	Water Accounting
WA+	Water Accounting Plus
WaPOR	FAO Water Productivity through Open access of Remotely sensed derived data portal
WPL	Water Pollution Level
WSSI	Water Self-Sufficiency Index

FOREWORD

Message from the Director General



Ask a district water officer, a farmer, or a minister what they need most to manage water better, and many will give a similar answer: reliable numbers. How much water is there? Where does it go? Is this year unusual, or part of a trend? In much of Africa, these basic questions are still hard to answer. Gauging stations have closed, records have gaps, and national figures are often years old or calculated in ways that can't be compared with the country next door.

That gap matters more every year. Populations are growing, cities and irrigation schemes are expanding, and rainfall is becoming harder to predict. Decisions about dams, irrigation, water supply, river sharing, wetlands, and ecosystem restoration are being made now, and many of them will shape the next fifty years.

This atlas series is our attempt to help close that gap. Our team at IWMI combined satellite observations with hydrological modeling and a water accounting method called SIWA+—Scale-Invariant Water Accounting Plus—to produce a consistent picture of each country's water, year by year, from 2003 to 2024. We used the same approach for every country in sub-Saharan Africa. So, a planner in one capital can compare their situation with a neighbor's, and a basin organization can add up the numbers across borders.

This volume covers Ethiopia. I hope it proves useful to the people who make and influence water decisions there. That includes government officials drafting plans, river basin authorities, donors deciding where to invest, and the researchers who will test and improve these estimates. We see this as a starting point, not a final word. We welcome corrections, local data, and challenges to our assumptions.

Many people contributed to this work. I want to thank my colleagues in IWMI's Water Data Science for Action group for their care and persistence. I also thank the Leona M. and Harry B. Helmsley Charitable Trust, whose support through the Digital Innovations for Water Secure Africa (DIWASA) project made the atlas possible. I am grateful as well to our national partners for their guidance and collaboration.

Good water management starts with knowing what you have. I hope this atlas helps Ethiopia do exactly that.

A handwritten signature in black ink, which appears to read 'Mark Smith'.

Mark Smith
Director General
International Water Management Institute (IWMI)

Summary

Ethiopia's highlands feed the Abay (Blue Nile), Tekeze–Atbara, and Baro–Akobo–Sobat, which together supply most of the Nile's flow, as well as the Omo, Awash, Wabi Shebelle, and Genale–Dawa systems. Yet national level abundance masks acute scarcity in time and space.

This atlas applies the Scale-Invariant Water Accounting Plus (SIWA+) framework, driven by satellite observations and continental hydrological modeling, to produce a consistent national water account for Ethiopia for 2003–2024.

Where the water goes. Ethiopia received on average about 946 km³ of rainfall per year (about 838 mm). Roughly 72% (685 km³) returned to the atmosphere as evapotranspiration (ET), and about 118 km³/year (12.5%) left the country as river outflow. Exploitable water was estimated at 124.9 km³/year, of which about 19.5 km³ must remain in rivers to sustain environmental flows and 43.8 km³ remained as utilizable outflow.

A water exporter. With a Water Self-Sufficiency Index (WSSI) of 0.97–1.00, Ethiopia generates virtually all of its renewable water internally and passes most of it on: about 44% of its outflow goes to Sudan, 25% to Kenya, 21% to Somalia, and 10% to South Sudan.

Rainfed livelihoods. Rainfed croplands (206,000–239,000 km²) consume about 75 km³/year, compared with about 1.9 km³/year for irrigated croplands. Irrigated area (36,100 km² in 2024) is expanding, mostly as supplemental irrigation. Domestic water withdrawal per person roughly halved between 2003 and 2024 for both urban and rural populations as population growth outpaced supply.

Defined by variability. Per capita water availability averaged about 1,079 m³/person/year, placing Ethiopia in the Falkenmark “water stress” class. In nine of the 22 years, however, it fell below the 1,000 m³ scarcity threshold, reaching about 650 m³ in the 2009 drought. Water yield varied more than two-fold, from 176 km³ (2015) to 383 km³ (2019), and environmental water stress averaged about 59%.

Priorities. (i) Raise green-water productivity in rainfed areas; (ii) invest in storage and climate-resilient farming to buffer variability while safeguarding environmental flows as irrigation expands; and (iii) use shared, transparent water accounts as a basis for benefit-sharing with downstream neighbors.

ETHIOPIA IN NUMBERS · 2003–2024 AVERAGE

946 km³/year

Rainfall (about 838 mm/year)

124.9 km³/year

Exploitable water

118 km³/year

Transboundary outflow

9 of 22 years

Below 1,000 m³/person
(water scarcity)

01

CHAPTER 1

Background and Approach

Why water accounting matters, and how the SIWA+ framework turns satellite observations and hydrological modeling into consistent national water accounts.

Irrigated fields of the Amibara scheme, Middle Awash Valley, Afar Region, Ethiopia, seen from space. Landsat 8/9 image by NASA and USGS (HLS L30, January 2024; public domain)

1 Background and Approach

1.1 Why Water Accounting Matters for Africa

Water underpins food production, energy generation, public health, livelihoods, ecosystems, and economic growth. Across Africa, these uses compete for a resource that is highly variable in space and time.

Many regions face recurrent extremes of too little or too much water, while demand rises with population growth, urbanization, and agricultural expansion. Yet decision-makers often lack clear, consistent, and policy-relevant information on how much water is available, where it is, who uses it, and whether current consumption is sustainable. *In situ* monitoring networks are sparse or declining in many countries, and national assessments are infrequent and difficult to compare across borders.

Water accounting (WA) addresses this gap. It brings diverse information together into a coherent framework that tracks water stocks, flows, uses, and depletion within a defined domain, in the same way that national economic accounts track income and expenditure. Remote-sensing-based approaches such as Water Accounting Plus (WA+; Karimi et al. 2013) make this possible even where ground data are scarce, strengthening the evidence base for efficient, equitable, and sustainable water management.

Water accounting turns fragmented data into a single, consistent picture of where water comes from, where it goes, and how much remains.

1.2 How This Atlas Supports Planning, Monitoring, and Investment

This atlas makes water accounting accessible for policy and practice. It presents a spatially explicit, consistent, and evidence-based picture of water fluxes and stocks at national, basin, and subnational levels, using the same methods and data for every country in sub-Saharan Africa, so results can be compared and aggregated.

PLAN

Identify where water is sufficient, where deficits or seasonal imbalances are most pronounced, and where interventions are likely to deliver the greatest benefit.

MONITOR

Provide a common reference for tracking trends in rainfall, evapotranspiration, river flows, cultivated area, and water use, while supporting reporting on relevant Sustainable Development Goal (SDG) 6 indicators.

INVEST

Help governments, river basin organizations, development partners, and financiers target resources and plan risk-informed infrastructure.

In short, the atlas translates data into strategic insight for better planning, stronger monitoring, and more effective investment in water security, climate resilience, and agricultural transformation.

1.3 The Scale-Invariant Water Accounting Plus (SIWA+) Framework

Conventional WA+ is designed for hydrological basins. However, planning, budgeting, and reporting (for example, against SDG 6) take place within administrative boundaries, which rarely coincide with basins. To bridge this gap, the atlas applies the Scale-Invariant Water Accounting Plus (SIWA+) framework (Owusu et al. 2025), an extension of WA+ that estimates water accounts for any boundary, whether a district, country, catchment, or continent.

The WA+ model is first run for a large domain, here continental Africa. The results are then partitioned to extract accounts for any boundary within it. Because water crossing the boundary is explicitly quantified using routed river discharge, inflows and outflows are properly accounted for while detailed analysis remains possible at smaller scales. The SIWA+ framework is built around four modules (Figure 1.1); its main features are summarized in Box 1.1.

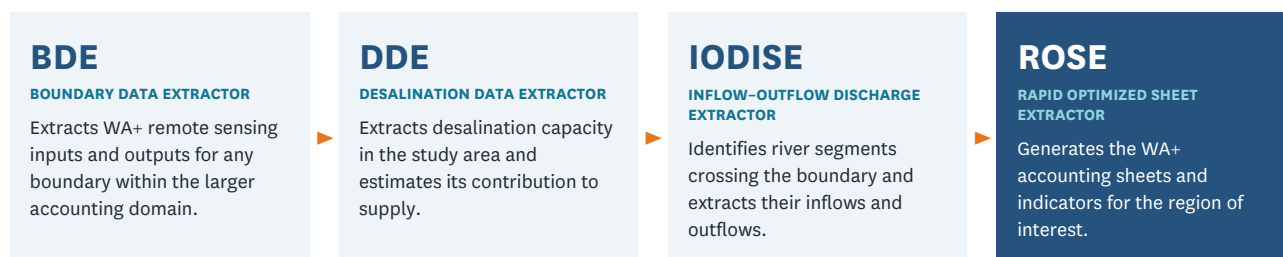
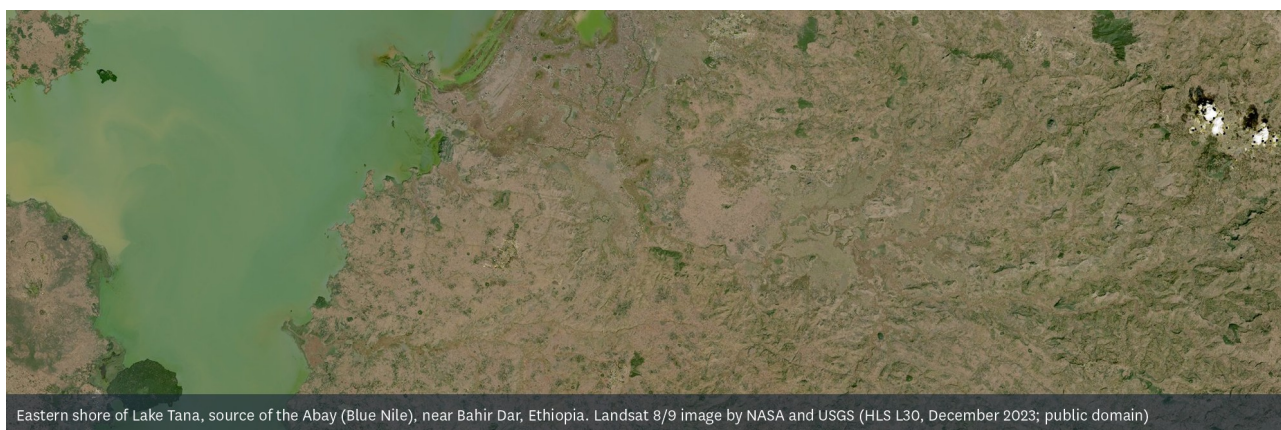


Figure 1.1. The four SIWA+ modules. A continental WA+ run is partitioned to any boundary, with cross-boundary river flows explicitly accounted for.

Box 1.1. What makes SIWA+ different

- *Any boundary*: accounts for countries, provinces, and basins from a single, consistent continental run.
- *Transboundary by design*: inflows and outflows are traced for more than 64,000 river segments (Akpoti et al. 2024).
- *Open data*: built entirely on open satellite and modeled products, so accounts can be reproduced and updated.
- *Comparable*: the same methods and data for every country allow regional comparison and aggregation.



Eastern shore of Lake Tana, source of the Abay (Blue Nile), near Bahir Dar, Ethiopia. Landsat 8/9 image by NASA and USGS (HLS L30, December 2023; public domain)

1.4 Input Data

The SIWA+ framework combines multiple harmonized datasets (satellite and hydrological model outputs) to generate nationally consistent water accounts where in situ observations may be incomplete or unevenly distributed. The input datasets are summarized in Table 1.1.

Table 1.1. Input data used in the SIWA+ framework

Variable	Unit	Product	What it represents
DYNAMIC DATA			
Precipitation (P)	mm	CHIRPS v2	Main source of water in a basin
Actual evapotranspiration (ET_a)	mm	SSEBop v5	Water leaving the domain as vapor
Reference evapotranspiration	mm	GLEAM v3.6a	Evaporative demand under ideal (non-limiting) conditions
Leaf area index (LAI)	m ² /m ²	MODIS MOD15A2H	Leaf cover; used to estimate interception loss
Net primary production (NPP)	kg/m ² /year	MODIS MOD17A3HGF v6.1	Plant growth after subtracting the carbon used for respiration
Gross primary production (GPP)	kg/m ² /year	MODIS MOD17A2HGF v6.1	Total carbon fixed by photosynthesis
Net dry matter (NDM)	kg/ha	Derived from GPP and NPP	Total plant biomass produced, excluding water
Land cover	n/a	ESA CCI Land Cover v2	Forests, cropland, settlements, etc.; governs how water is used and moves across the landscape
STATIC DATA			
Saturated soil moisture	m ³ /m ³	HiHydroSoil v2.0	Maximum water the soil can hold when all pores are filled
Digital elevation model (DEM)	m	HydroSHEDS (30 arc-second)	Slopes and drainage patterns that determine where water flows
Irrigated areas	%	FAO Global Map of Irrigation Areas (GMIA)	Location of irrigated agriculture
Reserved flow	n/a	Environmental water requirement (Smakhtin et al. 2004)	Share of flow to be reserved for the environment
Grey water footprint	n/a	Water pollution levels (WPL)	Share of flow needed to dilute pollutants to meet water-quality standards
Population	persons/ha	WorldPop 2015 (adjusted)	Drives domestic water demand

Source: Owusu et al. (2025). Note: CHIRPS = Climate Hazards Group InfraRed Precipitation with Station data; DEM = digital elevation model; ESA CCI = European Space Agency Climate Change Initiative; GLEAM = Global Land Evaporation Amsterdam Model; MODIS = Moderate Resolution Imaging Spectroradiometer; n/a = not applicable; SSEBop = Operational Simplified Surface Energy Balance model.



Fields in the Amibara irrigation scheme, Awash Valley, Afar Region, Ethiopia. Landsat 8/9 image by NASA and USGS (HLS L30, January 2024; public domain)

1.5 Water Accounting Terminology

Table 1.2 defines the main water accounting components used throughout this atlas, and the data or calculation used to derive each.

Table 1.2. Water accounting components, definitions, and calculation procedures

Component	Definition	Calculation / data
INFLOWS AND STORAGE		
Precipitation (P)	Rainfall over the domain	CHIRPS v2, selected after evaluating eight gridded rainfall products
Inflow (Q_{in})	Surface water entering from upstream countries through rivers and shared water bodies	Routed discharge for >64,000 river segments, from the United States Geological Survey (USGS) VegET model coupled with mizuRoute (Akpoti et al. 2024)
Desalination (Q_{desal})	Desalinated water supply	DDE module; zero for Ethiopia (landlocked)
Gross inflow	Total water entering the domain	$P + Q_{in} + Q_{desal}$
Change in storage (ΔS)	Net change in soil, groundwater, and surface storage; negative values indicate a gain in storage	$\Delta S = ET_a + Q_{SW\ outflow} - \text{Gross inflow}$
Net inflow	Gross inflow corrected for the change in storage	$\text{Gross inflow} + \Delta S$
EVAPOTRANSPIRATION		
Total actual ET (ET_a)	Total actual evapotranspiration	SSEBop v5 (Table 1.1)
Blue ET (ET_{blue})	ET from blue water sources: lakes, rivers, reservoirs, groundwater (including deep-root uptake) and irrigation, calculated as the sum of natural blue ET, Blue (N), from natural landscapes, and managed water use blue ET, Blue (M), from the managed water use (MWU) class	Soil water balance model
Green ET (ET_{green})	ET from rainfall stored in the unsaturated soil	$ET_a - ET_{blue}$
Landscape ET (ET_{land})	ET from natural and rainfed landscapes, excluding MWU classes	Zonal statistics of ET _a over WA+ land-use classes
ALLOCATION AND USE		
Exploitable water	Water that can potentially be used within the domain	$\text{Net inflow} - ET_{land}$
Reserved outflow (RO)	Surface water set aside for environmental needs and navigation	$EWR_f \times \text{mean } Q_{SW\ outflow}$ (Smakhtin et al. 2004)
Utilized flow (U_{flow})	Blue ET from managed water use classes (irrigated crops, managed reservoirs, and domestic and urban use)	$\text{Blue (M)} + \text{domestic water (DW)} + \text{NRF}$
Non-recoverable flow (NRF)	Non-consumed water lost to further use through pollution	$\text{Grey water fraction} \times Q_{SW\ outflow}$
Utilizable outflow (UO)	Water physically available for further use after current demand is met	$\text{Exploitable} - RO - U_{flow} - \text{non-utilizable outflow (NUO)}$
Available water	Water remaining after reserved and non-utilizable outflows	$\text{Exploitable} - RO - \text{NUO}$
Consumed water	Water depleted from the domain through evapotranspiration	$ET_{land} + U_{flow}$
Non-consumed water	Water remaining after consumption	$UO + RO + \text{NUO}$
Outflow (Q_{SW outflow})	Surface water leaving the country	Same model chain as Q _{in}

1.6 Water Availability Indicators

The key water availability indicators used in this atlas are presented in Table 1.3.

Table 1.3. Water availability indicators derived in this study

Indicator	Description	Formula
Water yield (mm or km³)	Water remaining after landscape evapotranspiration; the maximum potentially available for human use and the environment	$P - ET_a$
Per capita water availability (m³/person/year)	Freshwater resources available per person in the domain	$\text{Available water} \div \text{population}$
Environmental water stress (EWS, %)	Pressure on the water that ecosystems need. Values near 100% mean very little water is left for the environment; values near 0% mean little pressure	$U_{\text{flow}} \div (\text{Exploitable} - RO) \times 100$

Source: Mekonnen et al. (2026).

1.6.1 Falkenmark water stress classification

Per capita availability is interpreted using the widely applied thresholds of Falkenmark (1989), in m³/person/year:

> 1,700 No stress	1,000–1,700 Water stress	500–1,000 Water scarcity	< 500 Absolute scarcity
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▲ Ethiopia 2003–2024 average: ~1,203 m³/person/year

1.6.2 Water Self-Sufficiency Index (WSSI)

The Water Self-Sufficiency Index (WSSI) measures how self-sufficient a country is in the renewable water generated within its borders. It is the complement of the external dependency ratio reported by FAO AQUASTAT and UN-Water for transboundary assessments. Those databases provide a single long-term value, whereas dependency varies with the seasons and between years, which matters for national planning. The WSSI is therefore computed here at monthly and annual time steps.

1. *Internal renewable water resources (IRWR)*: water generated within the country as surface runoff (Veget hydrological model) and groundwater recharge (PCRaster Global Water Balance model, PCR-GLOBWB).
2. *External renewable water resources (ERWR)*: water generated outside the country and entering through upstream rivers (routed discharge).
3. *Total renewable water resources (TRWR)*: $TRWR = IRWR + ERWR$.
4. *WSSI*: ranges from 0 (fully dependent on external water) to 1 (fully self-sufficient).

$$WSSI = 1 - \frac{ERWR}{IRWR + ERWR}$$



Lake Tana sub-basin, Amhara Region, Ethiopia. Image by NASA Earth Observatory, Blue Marble: Next Generation (public domain)

For a headwater country such as Ethiopia, the WSSI is close to 1 all year; for downstream countries, it can swing sharply with the seasons.

1.7 Data Processing and Visualization

This section briefly describes the methods used to generate the figures in Chapter 2 (sections 1.7.1–1.7.5).

1.7.1 Rainfed and irrigated cropland mapping

Cropland pixels were partitioned using the Budyko-based framework of Owusu et al. (2024), driven by remotely sensed precipitation (Multi-Source Weighted-Ensemble Precipitation, MSWEP), potential evapotranspiration (FAO WaPOR), and actual evapotranspiration (SSEBop) at 300 m resolution. For each cropped pixel, the Budyko model estimates the ET that rainfall alone could sustain; the excess of observed ET over this expectation is the blue ET.

Pixels with negligible blue ET are classified as rainfed. Irrigated pixels are split into *formal* (intensive) irrigation where annual blue ET exceeds 100 mm, and *supplemental* irrigation below this threshold. Validated against 861 independent points across Africa, the classification achieved 73% overall accuracy, with high precision and specificity for the irrigated class.

The maps therefore show where irrigation is likely to occur, based on the blue water footprint of cropland; they are not an inventory of schemes. Plots smaller than about 1 ha may be missed, and cropland in valley bottoms, floodplains, and wetland margins with shallow groundwater or seasonal flooding may be mapped as irrigated. The maps are best suited to national and regional patterns and trends; for scheme-level planning, they should be combined with national irrigation inventories and field data.

1.7.2 Transboundary flow classification (IODISE)

Administrative boundaries often span several catchments, so one region can have many inflows and outflows. The IODISE module overlays the boundary on the river network: a segment is an *inflow* if it starts outside and ends inside the boundary, and an *outflow* if the reverse. Segments entirely inside or outside are excluded.

Where a river forms the boundary it may cross repeatedly, creating spurious points. The module resolves this by tracking where each river finally enters or leaves, classifying it as a *shared inflow* or *shared outflow*. For each country, the mean discharge separates major from minor rivers.

1.7.3 Transboundary flow visualization (Sankey diagram)

Sankey diagrams were generated with the Python-based Transboundary Water Tracker (TWT) Tool, which reads flows from the river network attributes, organizes them into source–destination pairs and draws links whose widths are proportional to the volume transferred.

Inflows and outflows are model estimates rather than gauged flows. Where data is available, the simulated discharge was validated against observed river flows at gauging stations across Africa (Akpoti et al. 2024). However, gauging stations with long, publicly available records are sparse along the borders, so the validation may not fully represent conditions at national scale. The simulated flows rely on satellite-based inputs, so errors in these inputs could propagate into the flow estimates. In addition, the model does not explicitly account for reservoir operations, water abstractions, or water losses as rivers pass through lowland wetlands. As a result, the simulated inflows and outflows may over- or underestimate actual river flows.

1.7.4 Water accounting composition (sunburst chart)

The sunburst chart summarizes the mean annual water balance as a hierarchy of inflows, ET, exploitable water, outflows, use, and storage change. Segment size is proportional to volume; concentric rings break each component into sub-components. For storage change, positive values indicate depletion and negative values indicate a gain in storage.

1.7.5 Water use analysis

Long-term average green ET, blue ET, and rainfall were computed for each ESA CCI land cover class using zonal statistics. IWMI's rainfed and irrigated cropland maps were used to estimate cropland water use.

02

CHAPTER 2

National Water Accounts for Ethiopia

Where Ethiopia's water comes from, where it goes, who uses it, and how secure it is:
results for 2003–2024.

2 National Water Accounts for Ethiopia

2.1 Country at a Glance

Ethiopia, in the Horn of Africa (Figure 2.1), covers about 1.1 million km² and is home to around 132 million people (UN DESA 2024). Its landscapes and climates range from cool, humid highlands to hot, arid lowlands.

1.13 M km²

Area (study boundary)

132 M people

Population, 2024 (UN DESA 2024)

838 mm/year

Mean annual rainfall

118 km³/year

Total annual outflow

124.9 km³/year

Exploitable water

1,203 m³/person/year

Per capita availability

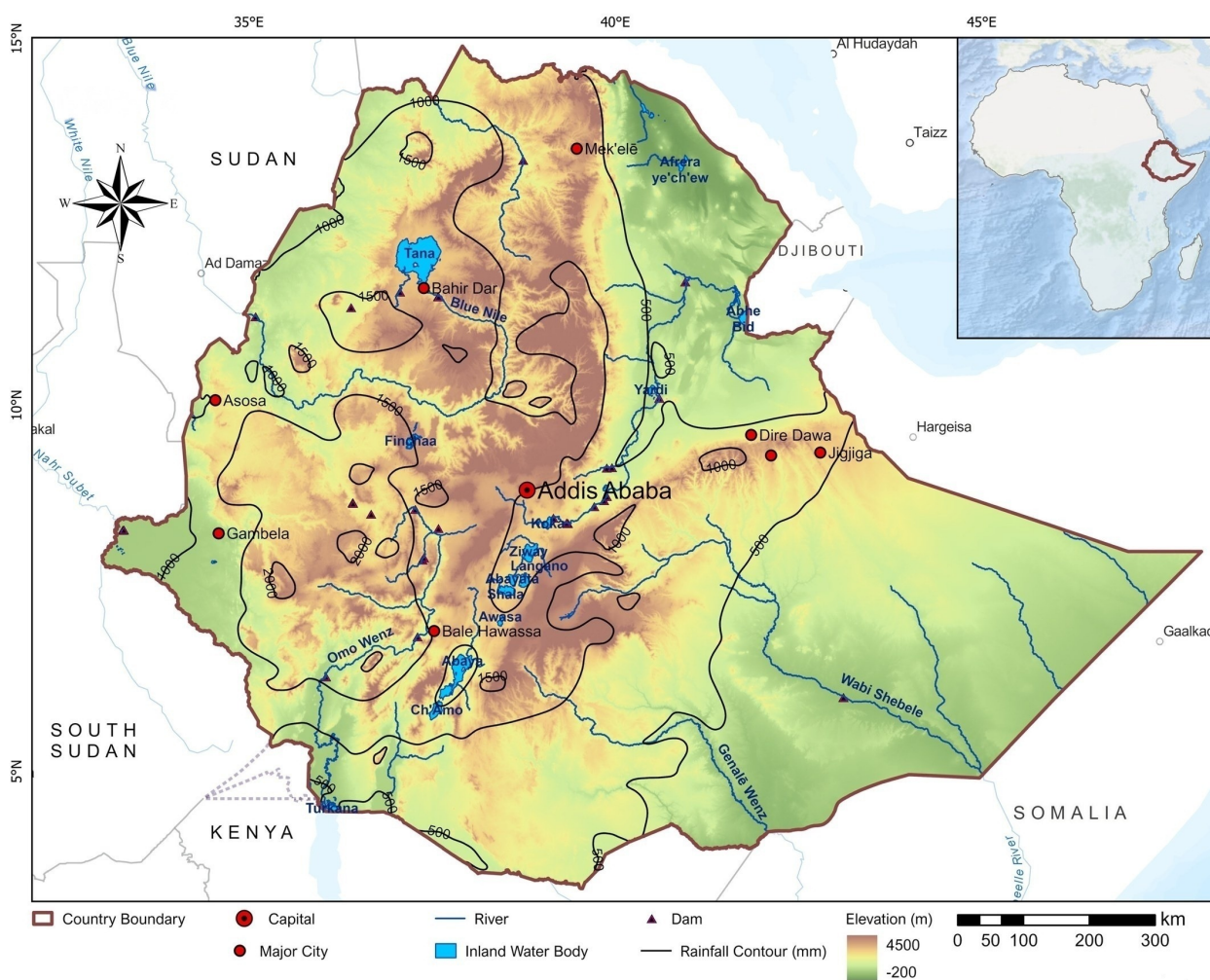


Figure 2.1. Location map of Ethiopia showing relief, major rivers and water bodies, and mean annual rainfall contours (2003–2024). Data sources: World Bank Official Boundaries; HydroSHEDS v1.0 (USGS/WWF); FAO AQUASTAT; DIVA-GIS (accessed February 2026).

2.1.1 Climate and hydrology

Ethiopia's climate is highly variable and strongly shaped by topography. The Ethiopian Highlands, often called the “water tower of Africa,” generate most of the country's runoff and sustain its major river systems, while the eastern and northeastern lowlands are largely arid to semi-arid.

Rainfall is highly seasonal, averaging about 838 mm per year (Figure 2.1). Most falls during the main rainy season, *Kiremt* (June–September), with a shorter *Belg* season (February–May) in parts of the country. This seasonality creates a mismatch between water availability and demand, particularly for agriculture. The western highlands are relatively water-rich, whereas the eastern and northeastern regions frequently experience water scarcity and recurrent drought.

Ethiopia manages its surface water through 12 river basins, which form part of four transboundary systems: the Nile, the Rift Valley, the Shebelle–Juba, and the North East Coast (Box 2.1). Rivers draining the Ethiopian Highlands, namely the Abay (Blue Nile), Baro–Akobo–Sobat, and Tekeze–Atbara, supply about 85% of the Nile’s annual flow, and the Abay alone contributes around 60%. Other key basins include the Omo–Gibe, Awash, and the Rift Valley lakes, which support hydropower, irrigation, and important ecosystems.

Box 2.1. Ethiopia’s 12 river basins

Abay (Blue Nile) · Afar–Danakil (Denakil) · Awash · Aysha · Baro–Akobo · Genale–Dawa · Mereb · Ogaden · Omo–Gibe · Rift Valley Lakes · Tekeze (Setit–Atbara) · Wabi Shebelle

A country with abundant water in total, but where the timing and location of rainfall determine who has enough.



Nile River Basin. [Satellite image source to be confirmed]

2.2 Land and Water Use

Agriculture dominates Ethiopia's landscape and is the primary driver of freshwater withdrawals. Rainfed cultivation covers the vast majority of cultivated land, while irrigated areas (both formal and supplemental) remain comparatively small but are expanding. Understanding where and how land is cultivated is essential context for interpreting the national water accounts.

2.2.1 Cultivated area trends (2019–2024)

Rainfed croplands covered approximately 206,000–239,000 km² between 2019 and 2024 (Figure 2.2). Irrigated area fluctuated between about 12,000 and 45,000 km²; in 2024, it totaled 36,100 km², of which 19,600 km² was supplemental and 16,500 km² formal irrigation. Supplemental irrigation supports crops during dry spells, while formal irrigation is concentrated along major rivers and established schemes, with some expansion in recent years. Box 2.2 explains how to interpret the year-to-year changes.

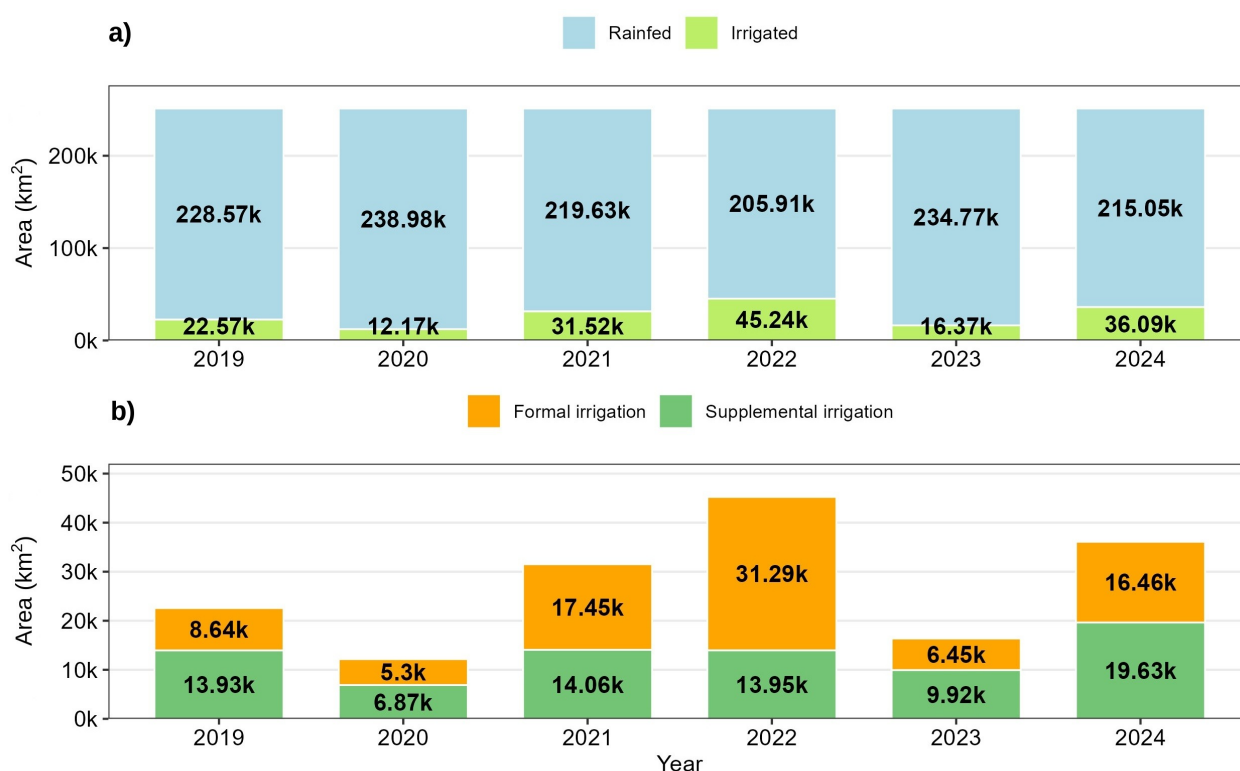


Figure 2.2. Changes in cultivated area in Ethiopia, 2019–2024: (a) total rainfed and irrigated area; (b) irrigated area by type (formal and supplemental). Pixels with negligible blue ET are classified as rainfed. Irrigated pixels are split into formal (intensive) irrigation where annual blue ET exceeds 100 mm, and supplemental irrigation below this threshold. Source: IWMI rainfed and irrigated cropland maps (Owusu et al. 2024).

Box 2.2. Reading the trend

Year-to-year changes in mapped irrigated area partly reflect rainfall: in wet years, the blue-water signal used to detect irrigation is weaker. Multi-year averages are therefore more robust than single-year changes.

2.2.2 Spatial distribution of irrigated and rainfed areas

Supplemental irrigation is widely dispersed, often in scattered smallholder plots used during dry spells. Formal irrigation is concentrated along major river corridors and established schemes (Figure 2.3). The Awash Valley, the Rift Valley Lakes basin, and parts of the Baro–Akobo lowlands host the largest formal irrigation infrastructure.

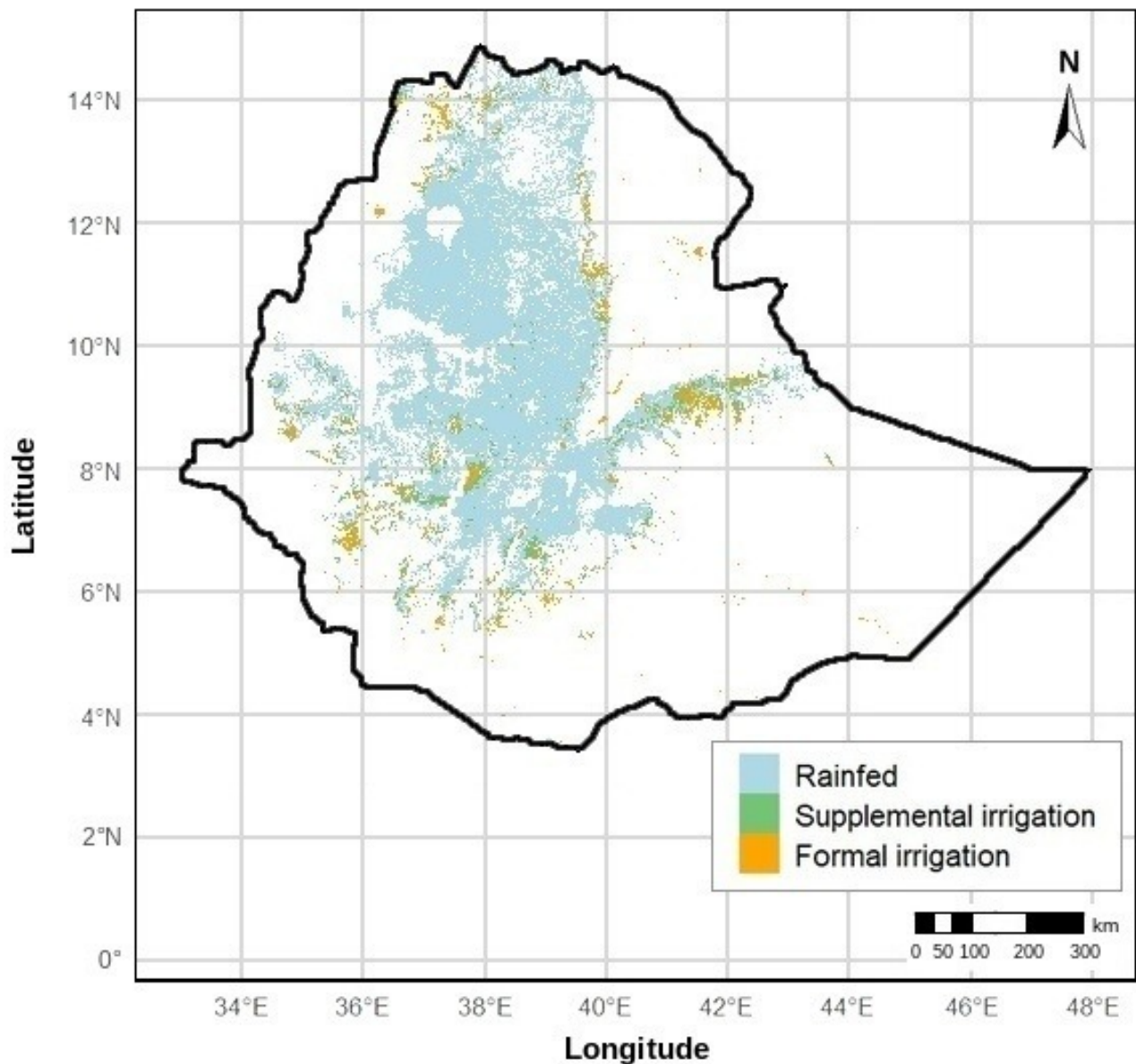


Figure 2.3. Spatial distribution of irrigated and rainfed areas in Ethiopia, 2024. Source: IWMI rainfed and irrigated cropland maps (Owusu et al. 2024).

IRRIGATED AREA, 2024

36,090 km²

Total irrigated

19,630 km²

Supplemental irrigation

16,460 km²

Formal irrigation

Irrigation covers roughly 14% of Ethiopia's cultivated land in 2024, and more than half of it is supplemental.



Farmland in the highlands north of Gondar, Amhara Region, Ethiopia. Photo by Mike Cotterill (Wikimedia Commons, CC0)

2.3 Water Flows and Transboundary Context

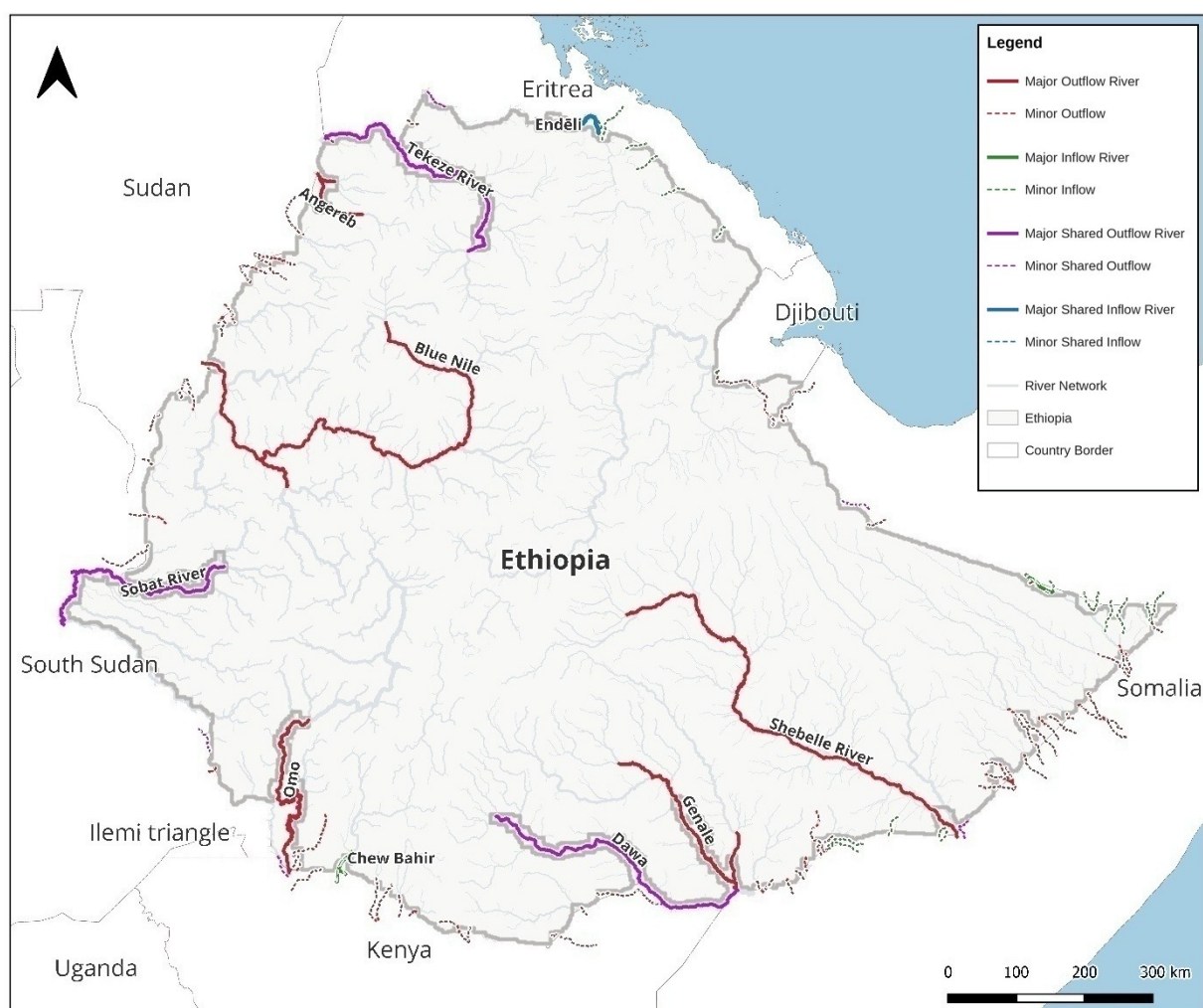
Ethiopia is overwhelmingly an upstream nation. Most of its river flow is generated internally from rainfall and crosses borders to supply downstream countries, most prominently Sudan via the Abay (Blue Nile). This transboundary dimension, summarized in Box 2.3, is essential both for national planning and for regional cooperation.

Box 2.3. Ethiopia's transboundary water role

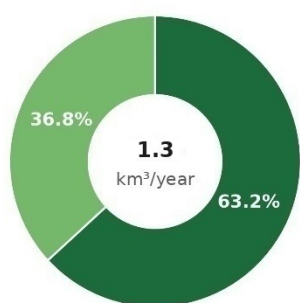
Total annual outflow (km ³ /year)	~118.1
Inflow from upstream countries (km ³ /year)	~1.3
Largest outflow rivers (km ³ /year)	Abay 45.8 · Omo 22.8 · Baro-Akobo-Sobat 22.2
Water Self-Sufficiency Index (-)	0.97-1.00

2.3.1 River network and discharge

Monthly discharge is routed across 2,576 river segments in Ethiopia (Figure 2.4). The major rivers account for 87.4% (103.3 km³/year) of total outflow, dominated by the Abay (45.8 km³/year), followed by the Omo-Lake Turkana system (22.8 km³/year) toward Kenya and the Baro-Akobo-Sobat system (22.2 km³/year) toward South Sudan. Minor rivers contribute the remaining 12.6% (14.8 km³/year). Transboundary inflow is limited: major rivers contribute 63.2% (0.9 km³/year) and minor rivers 36.8% (0.5 km³/year), mainly through small tributaries entering from neighboring countries.



Inflow Contribution by River Size



Major rivers — 0.9 km³/year
Minor rivers — 0.5 km³/year

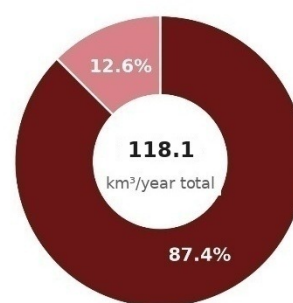
Contribution of Major Rivers

River	Inflow (km³/year)	Outflow (km³/year)
Chew Bahir	0.1	
Angereb		2.7
Blue Nile		45.8**
Dawa		1.5*
Endelli	0.1*	
Genale		7.2
Omo		22.8
Shebelle		12.4
Sobat		11.1*
Tekeze		4.3*

*Indicates shared rivers; only 50% of discharge (inflow/outflow) from each shared river segment is shown in the table.

** Indicates the total basin river discharge (outflow or inflow) at the points where the basin exits from or enters the country.

Outflow Contribution by River Size



Major rivers — 103.3 km³/year
Minor rivers — 14.8 km³/year

Figure 2.4. Major transboundary inflows and outflows of Ethiopia. The pie charts show the contributions of major and minor rivers, and the table summarizes annual inflows and outflows by river. Source: IWMI Transboundary Water Tracker (TWT).

2.3.2 Transboundary water balance

The Sankey diagram (Figure 2.5) shows long-term mean annual inflows and outflows for 2003–2024. Most of the small inflow originates from Somalia (75.0%), followed by Eritrea (13.7%), Kenya (7.4%), Djibouti (2.4%), and Sudan (1.5%). Outflows are far larger: Sudan receives 43.6%, Kenya 25.5%, Somalia 20.6%, and South Sudan 9.8%, with smaller shares to Eritrea (0.5%) and Djibouti (0.03%).

The modeled inflow is negligible (1%) at the national scale and reflects small seasonal streams and rivers shared along the border. The inflow from Somalia comes mainly from seasonal runoff in the flat, ephemeral river systems of the Ogaden, which flow only after short rainfall events.

Inflow 1.3 km³/year

(drawn at 31× the outflow scale)

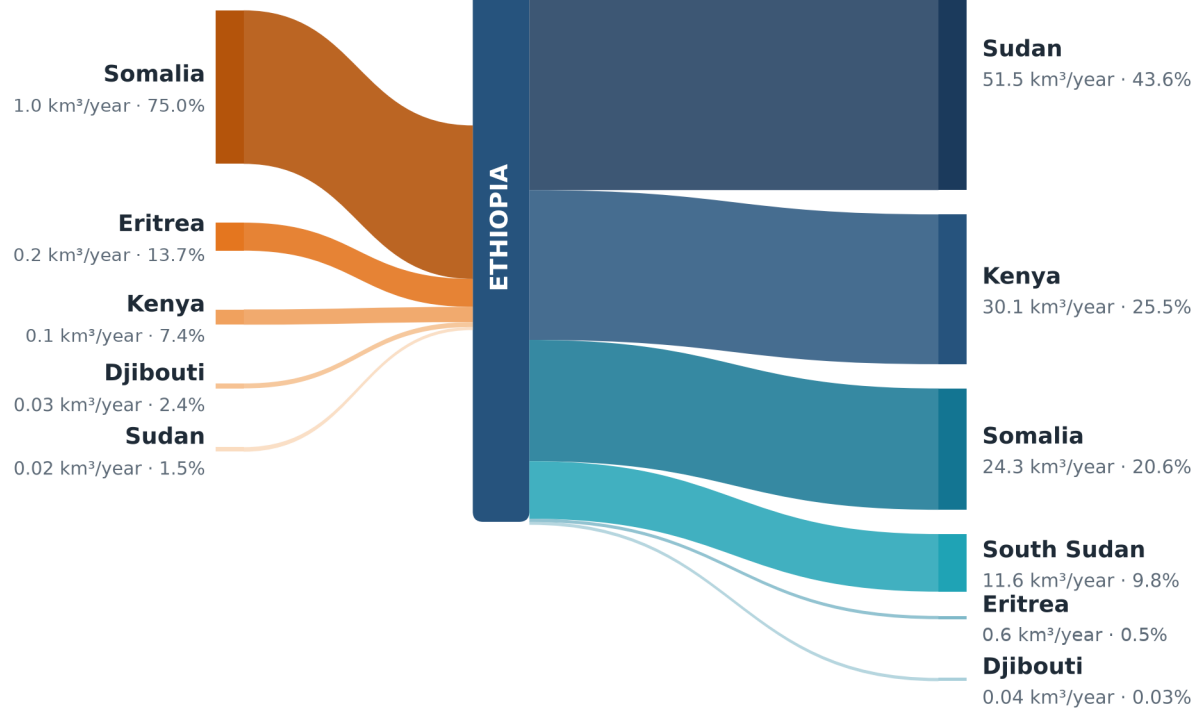


Figure 2.5. Long-term mean annual water inflows and outflows between Ethiopia and neighboring countries, 2003–2024 (km³/year). Band widths are proportional to volume; inflows are drawn at an enlarged scale for legibility. Source: Adapted from IWMI Transboundary Water Tracker (TWT) output.

2.4 National Water Accounts

The national water account traces water from rainfall to use: how much returns to the atmosphere as evapotranspiration, how much remains exploitable, how much is reserved for the environment, and how much is ultimately available for human use.

2.4.1 Long-term average water balance

Over 2003–2024, Ethiopia received about 946.4 km³/year of rainfall, of which approximately 685.0 km³/year (72%) returned to the atmosphere as evapotranspiration, split between green ET (441 km³/year) and blue ET (244 km³/year). Total outflow accounts for about 12.5% of rainfall. Exploitable water is estimated at 124.9 km³/year; of this, 19.5 km³ must remain in rivers to sustain environmental flows and 43.8 km³ remains as utilizable outflow (Figure 2.6; Box 2.4).

The balance is closed by a storage term of –144.7 km³/year, indicating that part of the rainfall is retained in the landscape, for example as soil moisture and groundwater recharge. Because it is computed as a residual, this term also carries the combined uncertainty of the rainfall, ET, and discharge products, and should not be interpreted as a sustained year-on-year gain in storage.

Box 2.4. Balance at a glancekm³/year, 2003–2024 average

Rainfall	946.4
Inflow	1.3
Evapotranspiration	685.0
Outflow	118.1
Storage change	-144.7
Exploitable water	124.9
Reserved (environment)	19.5
Utilizable outflow	43.8

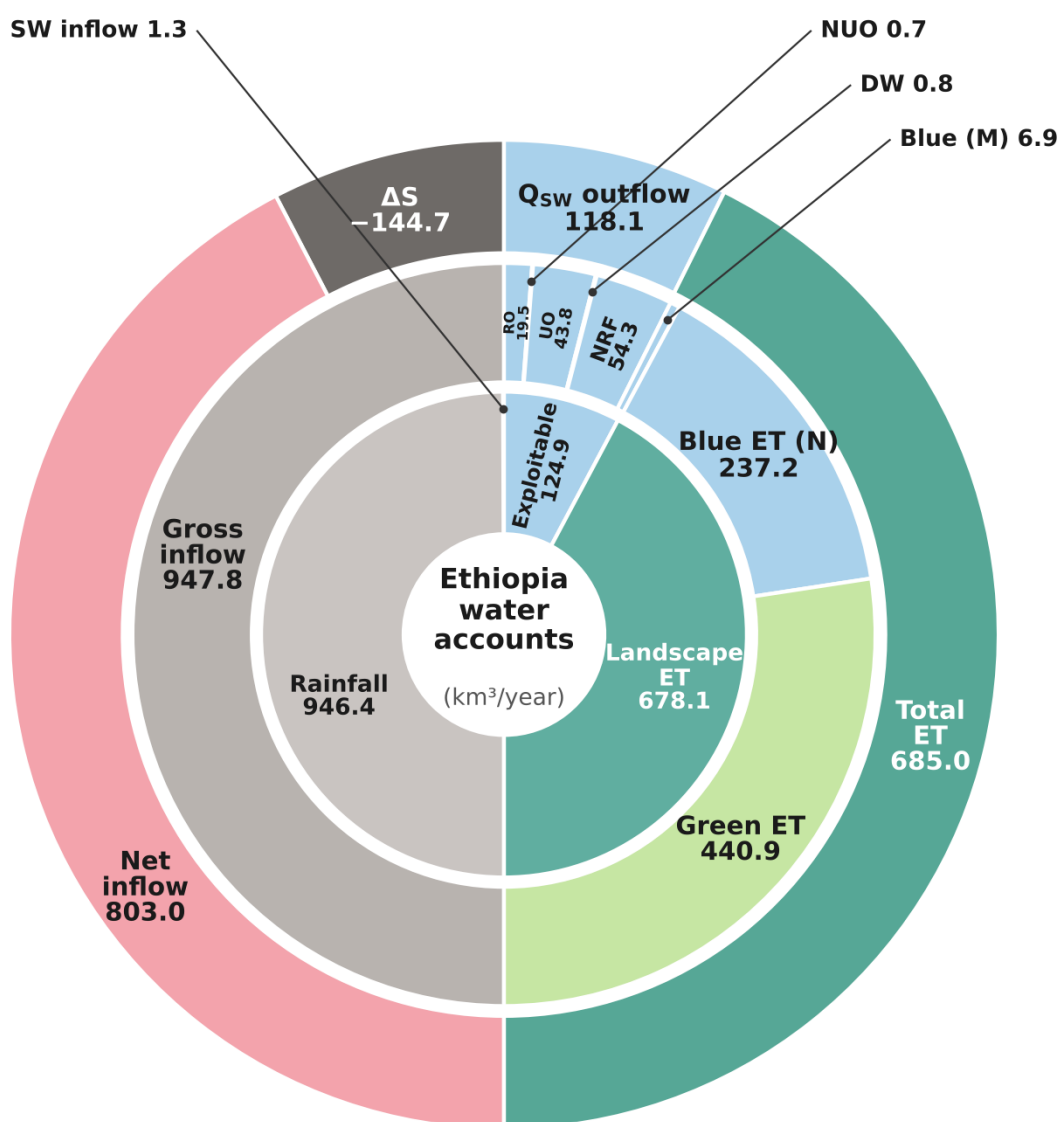


Figure 2.6. Long-term average water accounts for Ethiopia, 2003–2024 (km³/year). Q_{sw} outflow: surface water outflow; Blue (N): natural blue ET; Blue (M): managed water use blue ET; NRF: non-recoverable flow; DW: domestic water; UO: utilizable outflow; RO: reserved outflow; NUO: non-utilizable outflow; SW: surface water inflow; ΔS: change in storage. Source: IWMI SIWA+ water accounts.

2.4.2 Interannual variability (2003–2024)

The water accounts show pronounced interannual variability (Figure 2.7). Rainfall ranged from about 800 km³ in the dry year 2009 to 1,119 km³ in the wet year 2023. Green ET ranged from 388 km³ in 2009 to 506 km³ in 2023, while blue ET increased from 208 km³ in 2008 to 324 km³ in 2024. Storage change was negative in every year, between –76 and –223 km³, indicating recharge of groundwater and other water stores, although this value should be interpreted with care because it is the balancing term of the water accounts that absorbs errors in rainfall, ET, and discharge data. Outflow ranged from 64 km³ in 2009 to 193 km³ in 2023, and available water from 55 km³ to 175 km³ over the same years, more than three times higher, a much larger change than in rainfall. Utilizable outflow, the water still available for further development, was the most variable part of the accounts, ranging from 17 km³ in 2009 to 80 km³ in 2023.

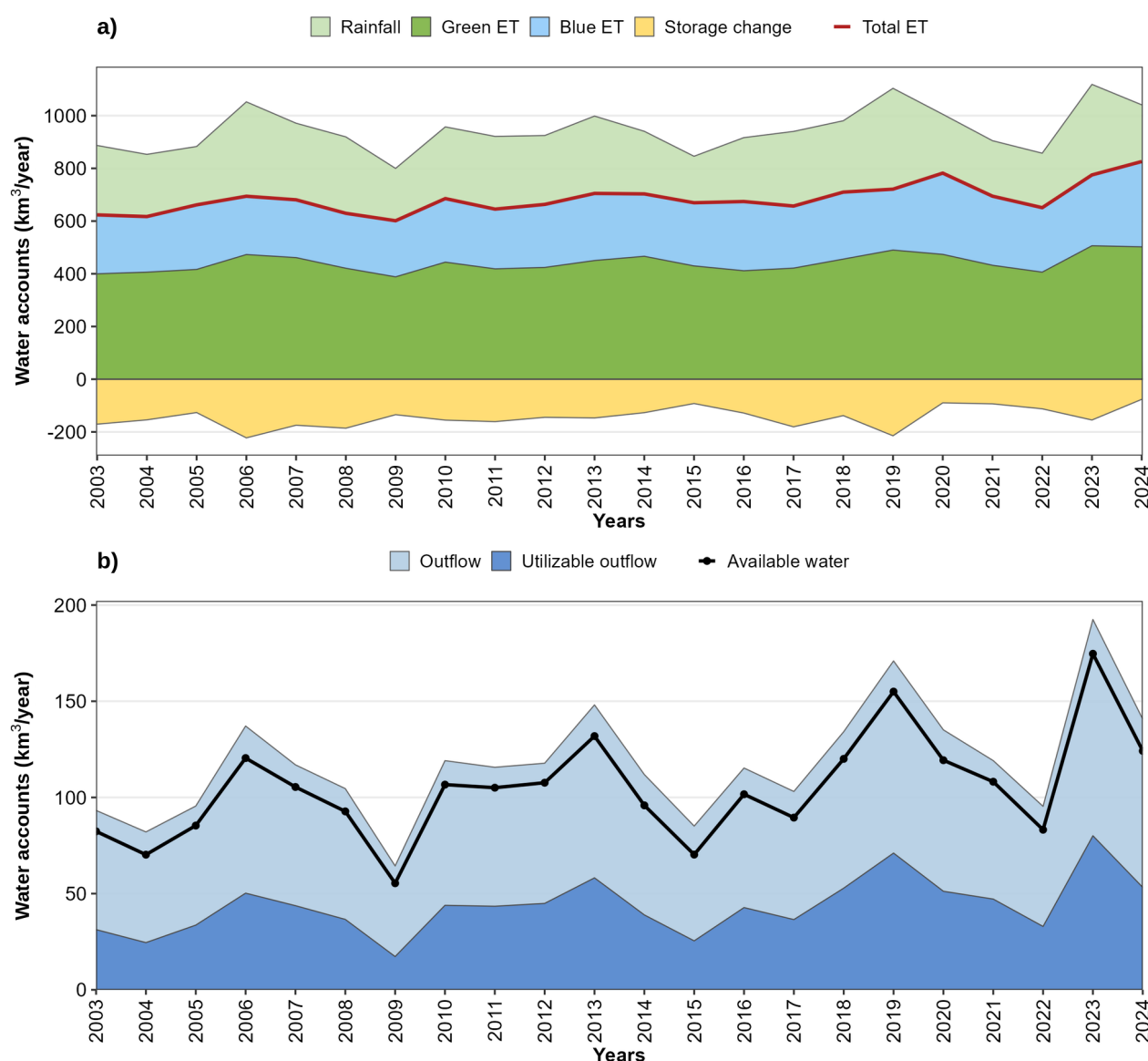


Figure 2.7. Annual water accounts for Ethiopia, 2003–2024 (km³/year). (a) Water use and availability: rainfall, total evapotranspiration (ET) split into green ET (rainfed) and blue ET (from surface water and groundwater), and change in storage. Negative storage change indicates water going into storage and positive storage change indicates water withdrawal. Storage change is calculated as the residual of the water balance, so it also includes the errors of the other terms. (b) Outflow, utilizable outflow, and available water. Source: IWMI SIWA+ water accounts.

2.5 Water Use by Sector

Water use in Ethiopia is dominated by rainfed landscapes. Green ET, driven by rainfall on natural and agricultural land, accounts for about two-thirds of total ET. Blue ET (244 km³/year) is mostly natural: wetlands, open water, and vegetation drawing on groundwater. Managed blue water use for irrigation, reservoirs, and domestic supply is small in volume but strategically important.

2.5.1 Water use by landscape type

Box 2.5. Key water use figures

km³/year, long-term average 2003–2024

Forests	118.0
Rainfed croplands	75.3
Wetlands	6.4
Irrigated croplands	1.9
Managed reservoirs	1.9
Domestic	0.8
Green ET (rainfall)	441
Blue ET (all sources)	244

Forests are the largest water user in the landscape (118 km³/year), followed by rainfed croplands (75.3 km³/year; Box 2.5). Irrigated croplands use 1.9 km³/year, so rainfed systems account for more than 97% of cropland water use. Figure 2.8 shows how rainfall, green ET, and blue ET vary across land cover classes: wetlands and managed water bodies rely heavily on blue water, whereas most croplands, forests, and grasslands depend primarily on rainfall.

Rainfed systems account for more than 97% of cropland water use in Ethiopia.

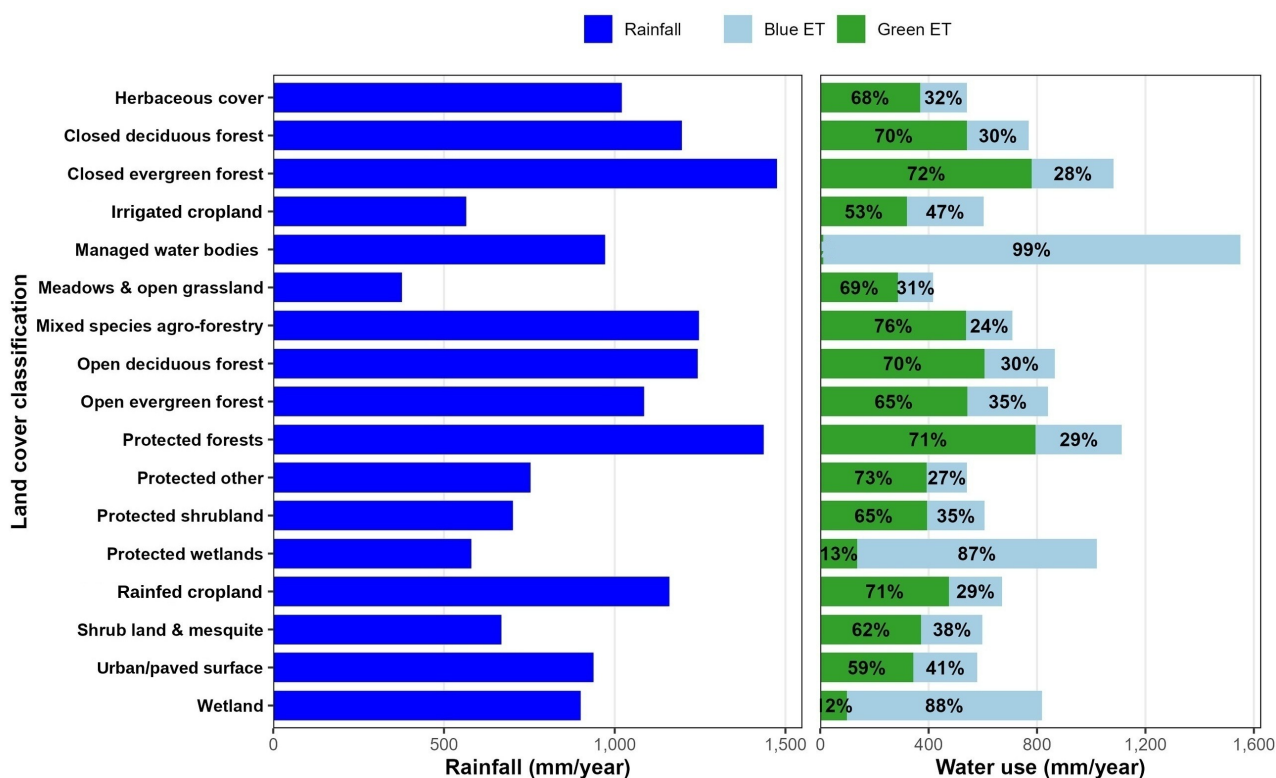


Figure 2.8. Long-term average rainfall (left) and ET (green + blue) (right) by land cover class in Ethiopia (2003–2024). Source: IWMI SIWA+ water accounts; land cover from ESA CCI Land Cover v2.

2.5.2 Green and blue evapotranspiration

The dominance of green ET (441 km³/year) over blue ET (244 km³/year) reflects Ethiopia's fundamental dependence on rainfed systems. Blue ET is concentrated around lakes, wetlands, river corridors, and irrigated areas (Figure 2.9). Improving the productivity of both green and blue water is central to Ethiopia's water and food security agenda.

a)

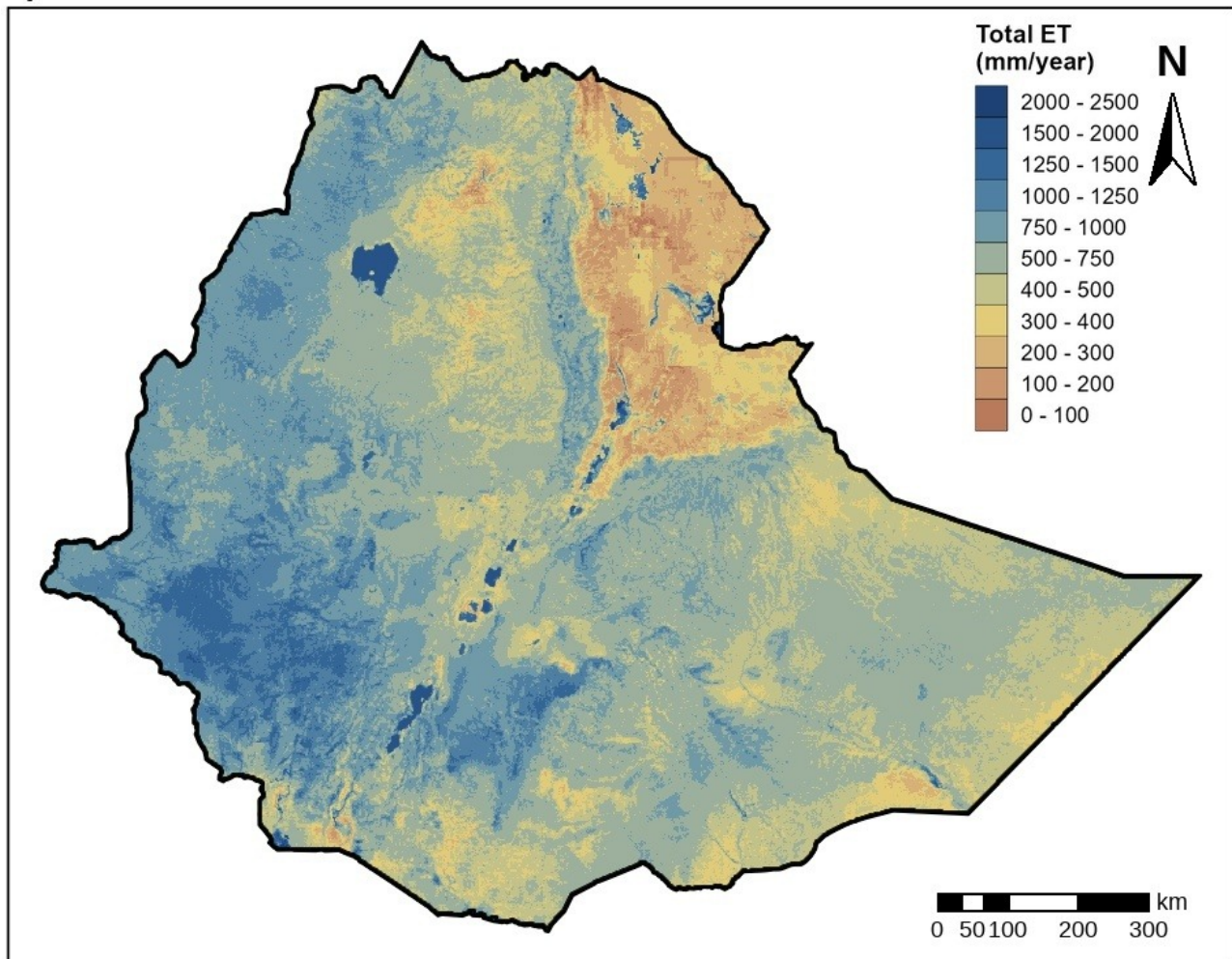


Figure 2.9. Long-term average annual total ET (a) and the contributions of green and blue ET (b) in Ethiopia, 2003–2024. Source: IWMI SIWA+ water accounts.

b)

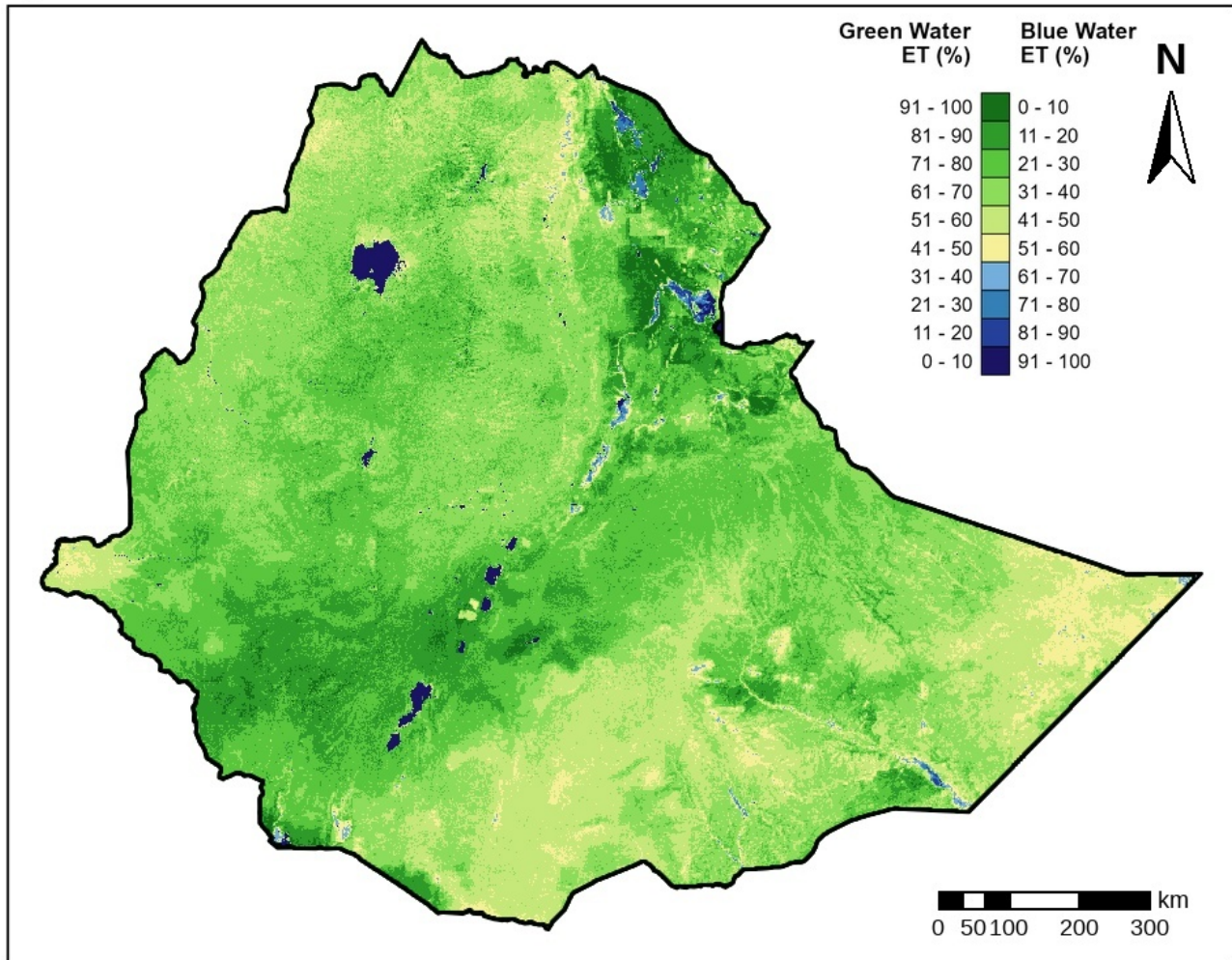


Figure 2.9 (continued). (b) Contributions of green and blue ET in Ethiopia, 2003–2024.

2.5.3 Domestic water use per capita

Per capita domestic water withdrawal declined over 2003–2024 for both urban and rural populations (Figure 2.10). Urban withdrawal fell from about 16 to 7 m³/person/year and rural withdrawal from about 8 to 4 m³/person/year, so each roughly halved and urban residents continue to withdraw about twice as much as rural residents.

The decline is driven mainly by rapid population growth outpacing incremental improvements in water supply infrastructure. At well below 20 m³/person/year, domestic withdrawals remain low by international standards.

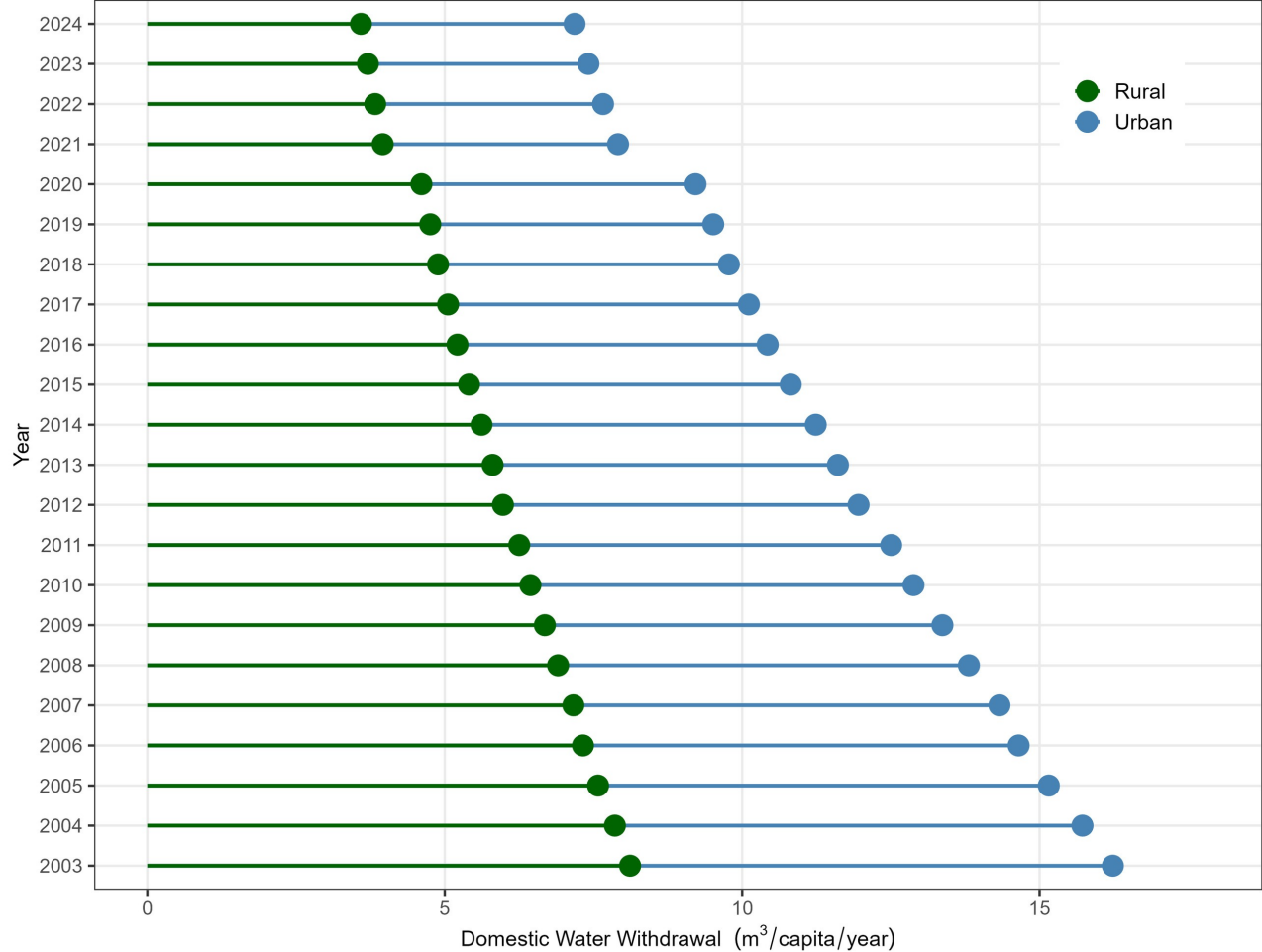


Figure 2.10. Trends in domestic water withdrawal per capita for urban and rural populations in Ethiopia, 2003–2024. Source: IWMI SIWA+ water accounts; population from WorldPop.

2.6 Renewable Water Resources and Self-Sufficiency

Ethiopia's renewable water resources are generated almost entirely within its borders. The WSSI remains between 0.97 and 1.00 throughout the year, indicating minimal dependence on transboundary inflows (Box 2.6). This contrasts sharply with downstream countries such as Egypt and Sudan, which depend heavily on water originating in the Ethiopian Highlands.

Box 2.6. WSSI for Ethiopia

Ethiopia generates 97–100% of its renewable water internally.

Range	0.97–1.00
Lowest (May)	0.97
Highest (July–September)	1.00
Self-sufficiency is lowest in May, when inflows from Somalia peak, and highest when internal runoff dominates.	

2.6.1 Seasonal variability

Water availability is strongly seasonal, following the *Kiremt* rains (June–September). Internal renewable water resources peak in August at 56.8 km³, driven by both surface runoff and groundwater recharge. In the dry season (January–March), IRWR falls below 1 km³ per month (Figure 2.11).

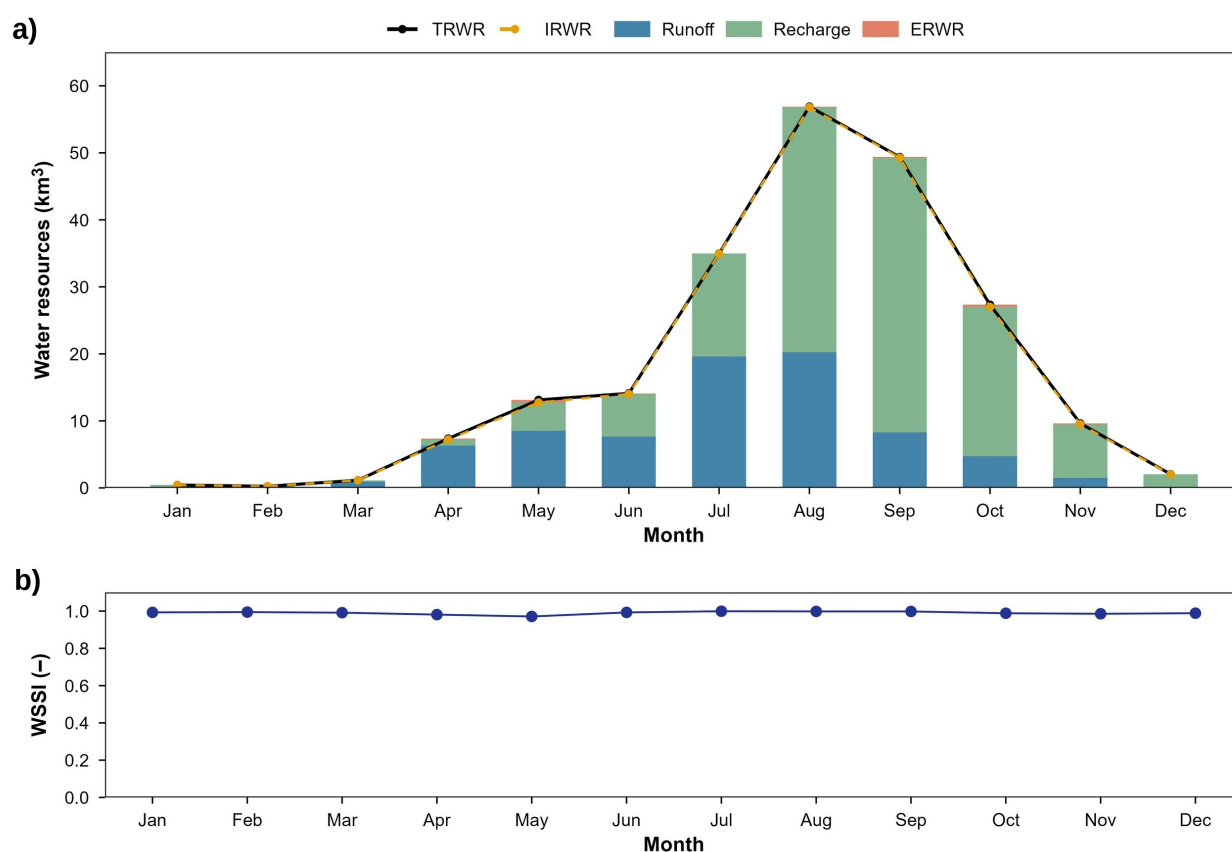


Figure 2.11. Long-term monthly climatology (2003–2024) of (a) inflow, runoff, recharge, internal (IRWR), external (ERWR), and total (TRWR) renewable water resources, and (b) the Water Self-Sufficiency Index (WSSI) for Ethiopia. Source: IWMI SIWA+ water accounts.

2.7 Water Stress Indicators

Three indicators summarize Ethiopia's water security: per capita water availability (a demand-side measure), environmental water stress (a supply-side pressure index), and water yield (the water generated after landscape ET). Together they place Ethiopia in the Falkenmark "water stress" class on average, but with large year-to-year swings around the critical thresholds.

Across 2003–2024, Ethiopia was in the water-stress class in 13 years and in the water-scarcity class in nine years: 2004, 2009, 2014, 2015, 2016, 2017, 2021, 2022, and 2024 (Figure 2.12).

2.7.1 Per capita availability and environmental stress

Long-term average per capita water availability is about 1,079 m³/person/year, above the 1,000 m³ scarcity threshold but well below the 1,700 m³ threshold for water stress. In drought years, it drops sharply, to 652 m³ in 2009, 700 m³ in 2015, and 672 m³ in 2022. This high interannual variability is a defining characteristic of Ethiopia's water system.

Environmental water stress averaged about 59% (range 54–68%), indicating substantial pressure on the flows needed to sustain ecosystems. Water yield averaged 261.5 km³/year, ranging from 176 km³ in 2015 to 383 km³ in 2019.

	Environmental water stress (%)	Water yield (km ³)	Per capita water availability (m ³ /person/year)	Falkenmark water stress classification
2003	62	263	1,146	Water stress
2004	65	236	950	Water scarcity
2005	60	221	1,123	Water stress
2006	58	358	1,541	Water stress
2007	58	290	1,312	Water stress
2008	60	290	1,123	Water stress
2009	68	198	652	Water scarcity
2010	58	272	1,222	Water stress
2011	58	276	1,170	Water stress
2012	58	261	1,166	Water stress
2013	56	294	1,388	Water stress
2014	59	238	981	Water scarcity
2015	64	176	700	Water scarcity
2016	57	242	985	Water scarcity
2017	59	283	845	Water scarcity
2018	56	271	1,104	Water stress
2019	54	383	1,389	Water stress
2020	56	223	1,042	Water stress
2021	56	210	897	Water scarcity
2022	60	207	672	Water scarcity
2023	54	344	1,375	Water stress
2024	57	215	953	Water scarcity

Figure 2.12. Annual environmental water stress, water yield, per capita water availability, and Falkenmark classification for Ethiopia, 2003–2024.
Source: IWMI SIWA+ water accounts; population from WorldPop.

9 years

in water scarcity (<1,000
m³/person)

2.2×

range in water yield, 2015 vs
2019

59 %

mean environmental water
stress

652 m³

lowest per capita availability
(2009)

3 Key Messages for Policy and Planning

01

On the edge of scarcity

Average availability of $\sim 1,079 \text{ m}^3/\text{person}/\text{year}$ places Ethiopia in the water-stress class, and in nine of the 22 years, it fell below the $1,000 \text{ m}^3$ scarcity threshold.

02

Green water is the biggest lever

Rainfed croplands use $75.3 \text{ km}^3/\text{year}$ versus $1.9 \text{ km}^3/\text{year}$ for irrigation (more than 97% of cropland water use). Raising rainwater productivity is the highest-leverage water security intervention.

03

A regional water tower

About $118 \text{ km}^3/\text{year}$ flows to Kenya, Somalia, South Sudan, and Sudan, making Ethiopia a pivotal actor in regional water cooperation, infrastructure investment, and benefit-sharing.

04

Plan for variability

Water yield ranged from 176 to $383 \text{ km}^3/\text{year}$. Storage infrastructure, drought preparedness, and climate-resilient farming systems are priority investments.

05

Domestic supply is falling behind

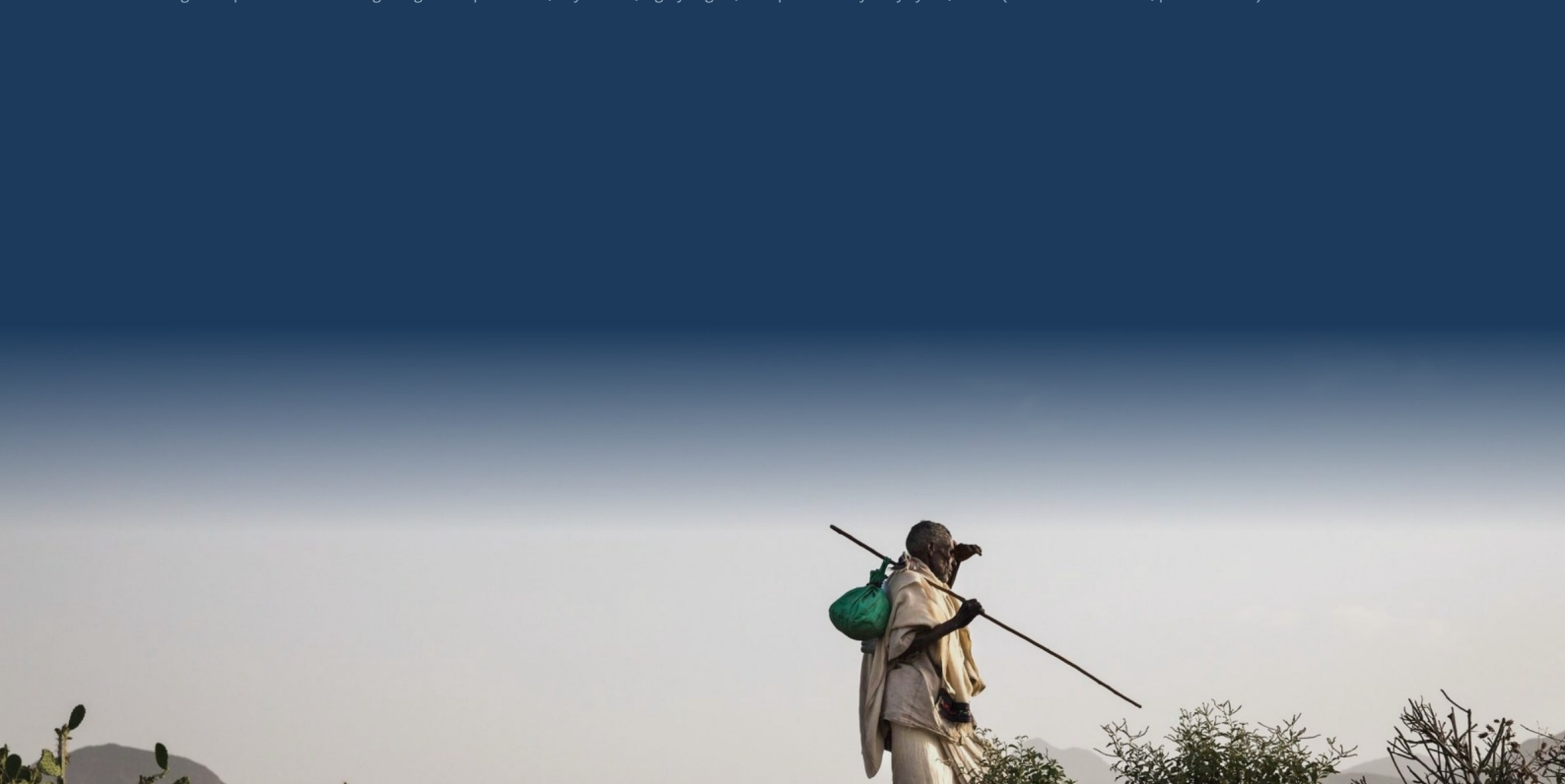
Per capita domestic withdrawal *roughly halved* for both urban and rural populations since 2003, as population growth outpaced supply. Rural residents withdraw about half as much as urban residents.

06

Protect environmental flows

Environmental water stress averages $\sim 59\%$, indicating substantial pressure on ecosystem flows. Safeguarding reserved flows is essential as irrigation expands.

Background photo: A man walking along a hilltop at sunset, Raya Azebo, Tigray Region, Ethiopia. Photo by Kelly Lynch, USAID (Wikimedia Commons, public domain)



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ABOUT THIS ATLAS

The National Water Accounting Atlas series provides consistent, Earth-observation-based water accounts for countries across sub-Saharan Africa, built on the SIWA+ framework. Each country profile quantifies rainfall, evapotranspiration, transboundary flows, water use, and water stress for 2003–2024.



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