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TECHNICAL REPORT

Assessing Hydropower, Irrigation, and Ecosystem Trade-offs in the Omo-Gibe Basin: Evidence Synthesis and Work Plan

Chaturangi Wickramaratne, Meron Teferi Taye, Alemseged Tamiru Haile, Matthew McCartney, John Simaika, and Abdulkarim Seid

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Authors

Chaturangi Wickramaratne, Researcher – Freshwater Ecologist, International Water Management Institute (IWMI), Colombo, Sri Lanka
Meron Teferi Taye, Researcher – Water and Climate Systems, IWMI, Addis Ababa, Ethiopia
Alemseged Tamiru Haile, Senior Researcher – Hydrology-Hydrological Modelling, IWMI, Addis Ababa, Ethiopia
Matthew McCartney, Research Group Lead – Sustainable Water Infrastructure and Ecosystems (SWIE), IWMI, Colombo, Sri Lanka
John Simaika, Senior Researcher – Aquatic Ecology, IWMI, Colombo, Sri Lanka
Abdulkarim Seid, Country Representative – Ethiopia, IWMI, Addis Ababa, Ethiopia

Author contributions

Conceptualization: Matthew McCartney, Chaturangi Wickramaratne; Methodology: Matthew McCartney, Chaturangi Wickramaratne, Meron Teferi Taye; Writing – original draft: Chaturangi Wickramaratne, Meron Teferi Taye; Writing – review & editing: Matthew McCartney, Meron Teferi Taye, Alemseged Tamiru Haile, John Simaika, Abdulkarim Seid; Visualization: Chaturangi Wickramaratne; Supervision: Meron Teferi Taye, Alemseged Tamiru Haile, Matthew McCartney, Abdulkarim Seid; Project administration: Matthew McCartney; Funding acquisition: Matthew McCartney, Abdulkarim Seid

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Front cover photo: Middle reaches of Omo Gibe (photo by Matthew McCartney/IWMI).

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Executive Summary

The Omo-Gibe Basin is central to Ethiopia's development ambitions and to the livelihoods, ecosystems and cultural landscapes of communities across the upper, middle and lower basin. Its river system supports hydropower generation, irrigated and rainfed agriculture, livestock production, fisheries, domestic water supply, biodiversity conservation, tourism potential and other ecosystem services. These uses are not separate: they depend on the same flows, sediment regimes, flood pulses, wetlands, forests and riverine habitats. As hydropower infrastructure, irrigation development, population growth, land-use change and climate variability continue to reshape the basin, decision-making must increasingly consider trade-offs and synergies across energy, food, livelihoods and ecosystem integrity.

Hydropower development in the basin contributes substantially to national energy security and regional power ambitions, with the Gibe cascade forming a major component of Ethiopia's renewable energy strategy. These investments have helped expand electricity access, create opportunities for economic growth and support wider aspirations for industrialisation and poverty reduction. Irrigation, similarly, is critical for food production, income generation, nutrition, employment and reduced dependence on variable rainfall. At both smallholder and large-scale levels, improved irrigation performance could contribute to rural livelihoods and help address multidimensional poverty by strengthening food security, market participation, incomes, education outcomes and living standards.

At the same time, the evidence base points to the importance of continued learning as development in the basin advances. Hydropower and irrigation remain vital for Ethiopia's energy security, agricultural productivity, food and nutrition security and wider socio-economic development. However, their long-term interactions with downstream livelihoods, fisheries, wetlands, sediment dynamics and ecosystem services require careful, updated assessment. Some earlier projections of downstream change have not fully materialised as anticipated, while new observations, including changing lake levels, evolving climate projections, land-use dynamics and emerging stakeholder priorities, suggest that past assumptions should be revisited rather than simply carried forward. This highlights the need for current evidence and stakeholder-informed analysis to identify where unintended risks may arise and how they can be managed within a balanced development pathway.

This report does not seek to duplicate or supersede previous efforts. Rather, it is a rapid synthesis of what has already been done, reviews existing evidence, identifies where assumptions have changed, and builds from previous trade-off analyses and stakeholder engagement processes, including the DAFNE-led trade-off analysis (Giuliani et al., 2022) and the May 2026 IWMI environmental flows workshop, which confirmed sustained institutional appetite for updated basin evidence and flagged water quality as an underexamined dimension. The proposed work recognises that some pathways have already been modelled and negotiated, but that the basin context has evolved where infrastructure status, hydrological observations, climate projections, land-use trends, stakeholder priorities and evidence on ecosystem services all require reassessment. The proposed work here is therefore to update, test and extend it in collaboration with those who hold decision-making power over the basin and those who ultimately bear its benefits or its costs.

The 31-month work plan outlined here (June 2026–December 2028) therefore proposes a staged, participatory process to assess current evidence, surface uncertainties, incorporate stakeholder knowledge and aspirations, and co-develop negotiated pathways for the Omo-Gibe Basin. By examining hydropower, irrigation, fisheries, flood-based livelihoods, biodiversity, sediment dynamics and wider ecosystem services together, the process aims to identify practical opportunities to balance sectoral needs while supporting socio-economic development and rural poverty reduction. The intended outcome is a shared basis for decisions that can help place energy, agriculture, ecosystems and basin-dependent populations on a more sustainable and equitable development trajectory.

Contents

1. Introduction 4

2. Basin characteristics 4

3. Hydropower scheme 6

4. Agriculture 8

4.1 Traditional agriculture 8

4.2 Contemporary rainfed agriculture 9

4.3 Irrigated crop production 10

4.4 Livestock 12

4.5 Fisheries 14

5. Environment 16

5.1 Habitats and biodiversity 16

5.2 Ecosystem services 17

6. Impacts of changing climate and land use 18

6.1 Climate change impacts on temperature, precipitation and streamflow in the Omo-Gibe Basin 18

6.2 Land Use Land Cover Change 19

7. Hydropower-agriculture-environment tradeoffs and challenges 19

8. Next steps – work plan outline (June 2026 – December 2028) 20

References 0

1. Introduction

1.1 Background

The Omo Gibe River Basin located in the southwestern region of Ethiopia is a hydrologically and ecologically critical basin that plays a vital role in the livelihoods of millions of people. This basin supplies vital water resources for household consumption and the production of hydroelectric power, in addition to sustaining agricultural activities. Being Ethiopia‘s second largest river system, the Omo-Gibe basin contributes 90% of the runoff to Lake Turkana (located downstream in Kenya) and accounts for 14% of the country‘s annual runoff, second only to the Blue Nile in runoff volume (Girma et al., 2020). The total average annual flow through the basin is estimated at 16.9 billion m^3 with an annual average streamflow rate of 428.56 m3/s (1987–2019) (FAO 2016; Orkodjo et al., 2022a). It is widely established that the basin is undergoing large anthropogenic transformation, driven by the hydropower cascade (Gibe I-III, with Koysha/Gibe IV under construction) in its middle reaches, and Kuraz Sugar Development Project in its lower reaches, along with population rise and land use changes occurring simultaneously.

1.2 Purpose and report structure

This report is developed under AoW5 (evidence synthesis hub) of the Multifunctional Landscapes program. It forms part of a hydropower–irrigation–ecosystem trade-off assessment package for the Omo–Gibe Basin, intended to evaluate the cumulative impacts of existing and planned dams and irrigation schemes on flow regimes, sediment transport, water availability, and downstream ecosystems. The assessment is to be developed in collaboration with key stakeholders such as the Ministry of Irrigation and Lowlands, the Ministry of Water and Energy, and the Universities of Jimma and Arba Minch.

The report reviews the Omo-Gibe River Basin as a coupled water-energy-food-ecosystem system undergoing considerable change due to agriculture expansion, population growth and urbanisation and infrastructure development (Toma et al., 2022; Sorsa et al., 2025), establishing the rationale for the proposed work. It synthesises evidence on basin characteristics, hydropower development, agricultural expansion, livestock and fisheries, biodiversity, ecosystem services, and the interacting effects of climate and land-use change. The central finding is that hydropower regulation, irrigation growth, deforestation, sedimentation and climate variability are reshaping both upstream water availability and downstream livelihoods, particularly in the lower Omo Valley. Future planning should therefore treat energy, irrigation, livelihoods and ecosystem integrity as connected priorities rather than separate sectors.

The report is organized as follows. Section 2 describes the basin’s physical, climatic and socio-economic characteristics. Sections 3 and 4 examine major water-dependent development sectors, including hydropower, agriculture, livestock and fisheries. Section 5 reviews habitats, biodiversity and ecosystem services, Section 6 synthesizes evidence on climate-change and land-use impacts on hydrology, sediment dynamics and future development risks, Section 7 presents previous efforts on tradeoff assessments and challenges, while the final Section 8 provides the work plan with activities designed towards assessing main sectoral tradeoffs under recent evidence and potentially evolving priorities for the country.

2. Basin characteristics

The Omo-Gibe River Basin is one of Ethiopia's 12 river basins and the country's second largest. It covers an area of 79,000 km^2 with an average elevation of 2,800 m above sea level. It has a length of 550 km and an average width of 140 km and extends over approximately 7% of country’s extent (Fig. 1). Four local regions (Oromia, Central Ethiopia, South West Ethiopia and South Ethiopia) covering 19 zones and 116 woredas are spread across the basin supporting a total population of 14.6 million according to 2017 statistics (Meshesha and Abdi 2019). It should be noted that, prior to 2023, the Southern Nations, Nationalities and Peoples' Region (SNNPR) covered the areas now separated into Central Ethiopia, Southwest Ethiopia, and South Ethiopia regions (Table 1). Within the main regions, the basin accounts for approximately 6% of Oromia's area and 53% of SNNPR's area pre-2023. Post-2023, the basin covers 55%, 70%, and 47% of the area of Central Ethiopia, South West Ethiopia, and South Ethiopia respectively.

The Omo-Gibe basin has a varied climate, ranging from tropical and humid highlands in the north and northwest to hot, dry conditions in the south. Ethiopia is commonly classified into five climatic zones based on altitude and temperature: Wurch, a cold zone above 3,000 m; Dega, a temperate highland zone between 2,500 and 3,000 m; Woina-Dega, a warm zone between 1,500 and 2,500 m; Kola, a hot and arid zone below 1,500 m; and Bereha, a hot and hyper-arid zone (NMSA 2001; Chaemiso et al., 2016). Because elevation within the basin ranges from 719 to 3,086 m above mean sea level, the basin spans across these climatic zones.

The regional climate follows a three-season meteorological year: a rainy Kiremt season (June–September), which delivers the bulk of annual precipitation through intense convective storms; a dry Bega season (October–January), driven by winds from the Arabian desert; and a milder, wetter Belg season (February–May), shaped by moist air masses arriving from the Indian Ocean (Spinage 2012; Zaniolo et al., 2021). Rainfall ranges from about 1,900–

1,950 mm in the central and northern regions to less than 300–450 mm in the southern region (Chaemiso et al., 2016; Lukas et al., 2025; Bayana et al., 2025). Precipitation is generally unimodal in the north and centre of the basin and bimodal in the south. Southern parts of the basin, such as Borana, follow a distinct four-season pattern rather than the national three-season cycle. Bega (December–February) and Kiremt (June–August) are dry, while Belg (March–May) and Meher (September–November) bring the region's rain (Worku et al., 2022).

Table 1 Administrative region coverage of the Omo-Gibe Basin, pre- and post-2023 regional boundary changes

Region (pre-2023)	Region (post-2023)	Region extent (km²)	Area within basin (km²)	% of Basin Area	% of Region Area
Oromia	Oromia	320347	19697	25.3	6.1
SNNPR	Central Ethiopia	15106	8241	10.6	54.6
SNNPR	South West Ethiopia	39035	27176	34.8	69.6
SNNPR	South Ethiopia	48292	22887	29.3	47.4

Thus, the northern portion receives higher rainfall than the downstream southern reaches, where flooding, landslides and sedimentation are important concerns (Chaemiso et al., 2021). Average annual temperature varies from 17–24 °C in the highlands to about 30 °C in the southern lowlands (Chaemiso et al., 2016; Lukas et al., 2025; Bayana et al., 2025). The topography is physically diverse, with deep gorges in the Omo, Gojeb and Gilgel-Gibe rivers and mountainous to hilly terrains across the northern two-thirds of the basin. The headwaters of the Gibe River lie at approximately 2,200 m above sea level. The primary land-cover types include forests, urban areas, agricultural land, water bodies and built-up areas. Widespread cultivation is increasing land pressure in most northern catchments, with flatter, poorly drained bottomlands used for eucalyptus plantations and dry-season grazing (Bayana et al., 2025). The eastern part of the basin is densely populated and intensively farmed, while the south is experiencing rapid deforestation (Tesfaye & Tibebe 2019).

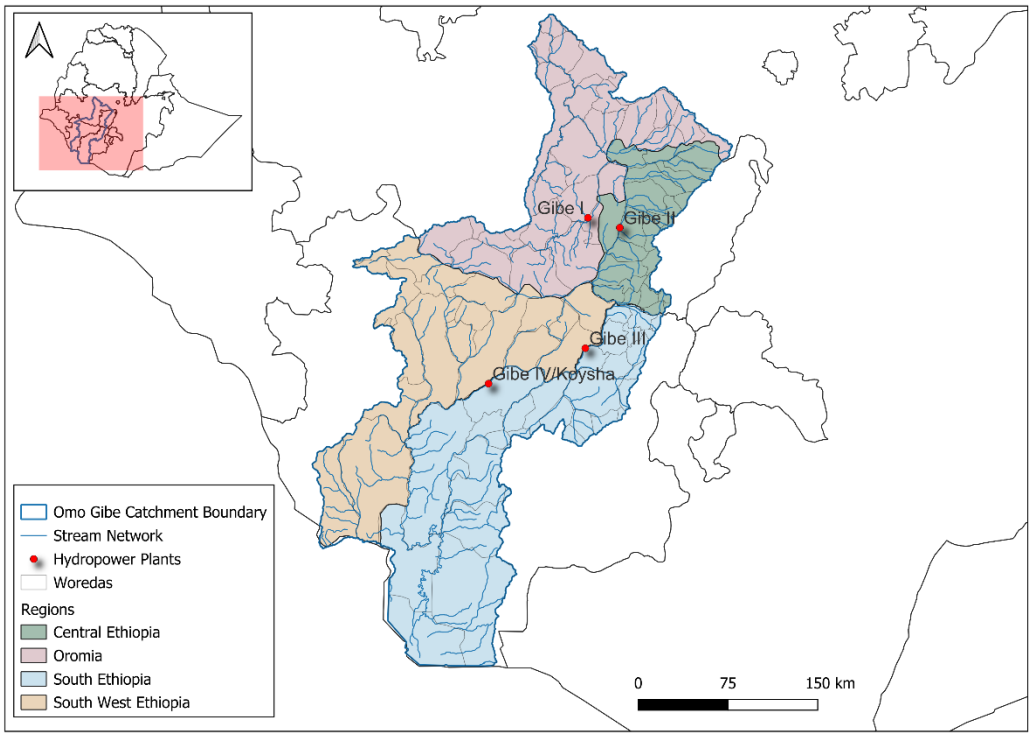


Figure 1 River network, administrative regions and hydropower plant sites within the Omo-Gibe Basin (Source: Authors)

The basin is recognized for its hydropower generation potential, with the three cascading dams, Gilgel Gibe I, Gibe II, and Gibe III, supplying 27% of the country's hydroelectric power. However, irrigation is by far the largest consumptive water use in the basin, accounting for nearly 92% of the 5,443 Mm³ baseline demand estimated for 2017 (Orkodjo et al., 2022a; Orkodjo et al., 2022b) (Fig. 2). This is followed by domestic demand and consumption

at 258 Mm³ (4.75%), hydropower at 91 Mm³ (1.67%), industrial and commercial use at 29 Mm³ (0.53%), livestock at 28 Mm³ (0.51%), recreational use at 4.1 Mm³ (0.08%), and institutions and businesses at 1.2 Mm³ (0.02%) in the basin (Orkodjo et al., 2022b). It should be noted that these figures represent modelled water demand rather than actual consumed or utilised volumes, which are not available. Flow diversions and abstractions across hydropower and irrigation sectors are transforming the river's hydraulic flow regime towards an engineered flow regime aligned with electricity demand and irrigation schedules, with the resulting impacts extending downstream to the Lower Omo Valley.

Modelling by Begashaw et al. (2024) shows that only 28% of precipitation in the upper basin becomes surface runoff and a further 13% recharges groundwater, with the remaining 59% lost to evapotranspiration. This partitioning leaves the basin particularly exposed to effects of climate change and land use/land cover (LULC) change. Climate change affects the function and operation of existing water infrastructures including hydropower, structural, drainage and irrigation systems as well as water management practices (Chaemiso et al., 2016). The basin's land and water resource system is already under pressure from rapid population growth, deforestation, surface erosion, and sediment transport, and climate change compounds these stresses (Chaemiso et al., 2016). As a result, upstream changes in land use and climate (temperature and precipitation) are likely to cascade downstream, driving water variability across the basin.

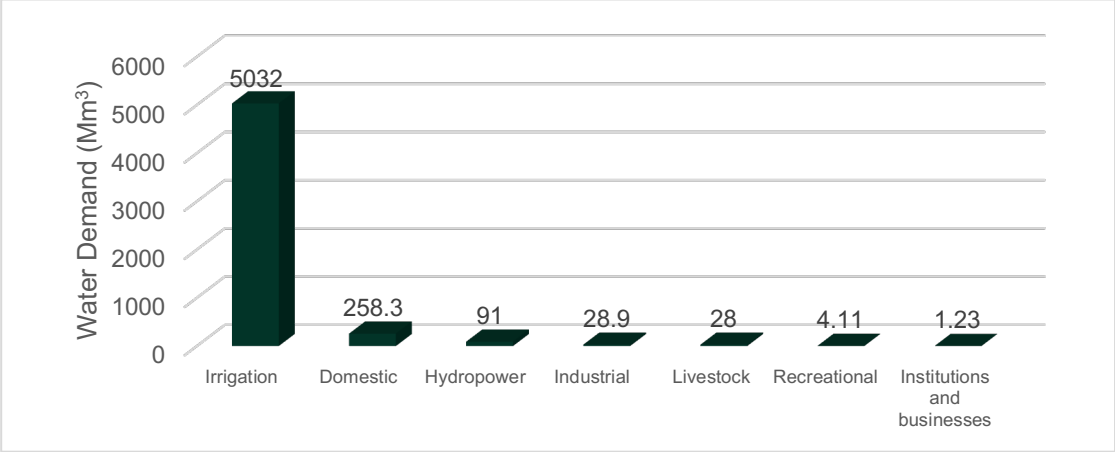


Figure 2 Total water demand for the baseline period (2017) scenario in the Omo-Gibe River Basin (Orkodjo et al., 2022b)

These physical and socio-economic characteristics provide the context for the major development pressures examined in the following sections. Hydropower regulation, agriculture development irrigation expansion and land-cover change do not affect the basin uniformly but their impacts rather vary by elevation, rainfall regime, livelihood system and position within the river network.

3. Hydropower scheme

3.1 Energy sector of Ethiopia

Ethiopia's energy sector has been growing steadily, with energy production, access, and affordability serving as key indicators of socio-economic progress, not just within the country but across Sub-Saharan Africa (Shrome and Abusha 2026; Bahta et al., 2025). Ethiopia possesses an estimated hydropower potential exceeding 45,000 MW, yet less than 10–12% of this potential has been developed, pointing to substantial opportunities for expansion (Shrome and Abusha, 2026). However, this percentage should be read with caution, as load factors vary from one plant to another, and summing individual plant capacities can introduce some error. Other renewable sources, such as wind and solar, remain similarly underexploited, at less than 1% (Getie 2026). With around 80% of the population living in rural areas, biomass remains the dominant energy source (Getie 2026). Biomass still supplied 86.1% of the country's total energy demand in 2022, with implications on indoor air pollution and deforestation (MoWE, 2024; Bahta et al., 2025). In 2021, only 26.7% of rural residents had electricity compared to 96.2% of urban residents ((MoWE, 2024; Shrome and Abusha 2026). As a response, the National Sustainable Energy Development Strategy (N-SEDS) aims to raise rural access to 72.3% by 2030 (MoWE, 2024; Bahta et al., 2025).

Against a global backdrop of reduced fossil fuel reliance and the transition to renewable energy for societal growth, Ethiopia has made significant strides through major large-scale projects such as the Grand Ethiopian Renaissance Dam (GERD) and the Gibe cascade, which have positioned the country as a potential regional energy hub, offering opportunities for economic growth, energy exports, and employment (Shrome and Abusha 2026).

3.2 Gibe hydropower scheme

From the late 1980s, the African Development Bank supported Ethiopia's Preliminary Water Resources Development Master Plan (1990), which identified hydropower and irrigation potential across the country's major river basins (Turton et al., 2018). The Gibe cascade concept emerged in the late 1990s through national energy-planning exercises that highlighted the Omo River's steep gradient and substantial discharge as favourable for hydropower generation. Hydropower development in the Omo-Gibe basin has since evolved over more than two decades, reflecting Ethiopia's broader strategy to promote renewable energy and harness water resources for economic transformation.

The first phase began with Gibe I, a relatively modest 180 MW run-of-river facility located on the Gilgel Gibe River, a tributary of the Omo (Table 2; Simaika et al., 2026, forthcoming). Commissioned in 2004, Gibe I established technical and institutional foundations for subsequent larger projects and signalled Ethiopia's commitment to hydropower-led development.

Gibe II was commissioned in 2010, adding 420 MW of capacity through a power generation facility connected to Gibe I via a 26-kilometre tunnel. However, Gibe II experienced significant technical challenges, including a tunnel collapse that necessitated extensive repairs (Abate et al., 2023).

The Gibe III dam represents the center piece of the Omo-Gibe cascade water infrastructure project (Carr 2017; Turton 2018). Located 464 km southwest of Addis Ababa in a deep gorge of the Omo River, Gibe III is among the world's tallest dams. It lies at a point in the basin where around 67% of the total river inflow can be captured (International Rivers 2013; Carr 2017). The construction of Gibe III began in 2006 under a contract with Italian firm Salini Costruttori, and was completed in 2016 at an official cost of EUR 1.47–1.7 billion (Carr 2017). The dam is designed to generate 1870 MW of electricity 6500 GWh per year from ten turbines, each with 187 MW capacity (Carr 2017). From the beginning, the Gibe III dam was planned for power production geared to both the domestic Ethiopian market and export markets in the eastern Africa region, primarily by direct transmission to Kenya. A 2006 Inter-Governmental Memorandum of Understanding (MOU) formalized this export agreement when it was signed by the ministers of energy of both Kenya and Ethiopia (Carr 2017). Beyond energy generation, Gibe III was also designed to supply water for irrigation, enabling the development of large-scale irrigated plantations for sugarcane, cotton, and palm oil (Lautze et al., 2021). Further, its reservoir (~20,000 ha and 240 m deep) was envisaged to support numerous additional activities like fisheries, recreation and transport that can directly benefit the local communities (Kahssay and Mishra 2013).

The Koysha dam, formerly known as Gibe IV, commenced construction in 2016 and represents the largest component of the cascade, with a planned capacity of 2,160 MW. Located downstream of Gibe III, Koysha is designed to regulate flows for the wider cascade and enable expanded irrigation development. As of October 2025, construction was reported to be approximately 65–70% complete.

Gibe V, a 660 MW, 12-turbine project in South Omo, owned by Ethiopian Electric Power Corporation was proposed alongside Gibe IV in the mid-2010s but its status is unclear. Commercial hydropower trackers such as Global Energy Monitor states the Gibe V to be cancelled while Global Data's Power Intelligence Center lists it as being announced with construction projected to start in 2030 and commercial operation by 2034

Table 2 Hydropower and irrigation plants in the Omo-Gibe basin (based on Simaika et al., 2026, forthcoming)

	Gibe I	Gibe II	Gibe III	Koysha/Gibe IV
Location	Gilgel Gibe tributary, ~7.83°N, 37.32°E	Damless plant; 26 km diversion tunnel from intake at 7.75°N, 37.56°E	Main Omo-Gibe River, ~6.84°N, 37.30°E (max level 892 m asl)	~6.58°N, 36.57°E
River	Gilgel Gibe River (tributary of the Omo River)	Inflow at Gilgel Gibe River; outflow at Omo River	Omo River	Omo River
Installed Capacity (MW)	180	420	1,870	2,160
Power Production (GWh)	722	1635	6500	5917
Reservoir Capacity (Mm3)	839	No reservoir	14,700	6000

Annual water throughput	No explicit value (power intakes designed for 102 m3 s-1)	78.4 m3 s-1	438.2 m3 s-1	540 m3 s-1
Exploitable Net Head (max/avg)	232.3 m / 207.3 m	505 m / 470 m	211 m / 186 m	158 m / 150 m
Dam Height (m)	40	55	243	164-178.5
Status	Commissioned 2004	Commissioned 2010	Commissioned 2016	Under construction, originally scheduled for commissioning in 2025 (~65-70% complete as of October 2025)

The country's Voluntary National Review (VNR) of SDGs indicates that energy development in Ethiopia, alongside other sectoral initiatives, has translated into positive impacts (UNHLPF 2025). Specifically, due to the hydropower expansion, the proportion of the population with access to electricity almost tripled, rising from 21.8% to 63% between 2015/16 to 2023/2024. Similarly, the number of households connected to electricity in Ethiopia rose from 2.50 million in 2015/16 to 8.83 million in 2023/24. This notable expansion highlights the country's strong commitment to energy infrastructure development and inclusive electrification.

Productivity has also increased in the country where nominal GDP per capita rose from USD 815 to USD 1,937 from 2015 to 2023. The headcount poverty ratio has also fallen in both rural and urban areas over the past decades. The poverty headcount ratio declined from 32.6% in 2014/2015 to 27.7% in 2019/20, according to World Bank data as presented by Ejigu (2025). Nevertheless, based on UNDP estimates, 68.7% of Ethiopia's population is multidimensionally poor, while an additional 18.4% is classified as vulnerable to multidimensional poverty. These figures point to a continued need for improvement across health, education, and standard of living, the latter of which encompasses electricity access and use (UNDP 2023).

4. Agriculture

Agriculture is the backbone of the Ethiopia's economy, contributing about 34.9% to national GDP directly (National Bank of Ethiopia 2020). Agricultural production is dominated by small-scale subsistence farmers with more than 19.23 million households engaged in smallholder farming in the 2019/2020 cropping season, a rise of 79.2% (8.51 million households) compared with the 1999/2000 cropping season (ESS 2022).

4.1 Traditional agriculture

Communities across the Omo-Gibe basin, including the lower Omo valley, have practiced diverse forms of agriculture for thousands of years, with farming systems shaped by altitude and rainfall. Given the basin's range of slope and precipitation, agricultural practices differ markedly between the cooler, wetter highlands and the hot, arid lowlands (Mati and Merrey 2021). In the highlands, traditional farming centres on crops such as teff, pulses, enset, and faba bean, cultivated with hoe and oxen and minimal external inputs, largely for home consumption (Matewos, 2019; Mati and Merrey 2021; Orkodjo et al., 2022a) (Fig. 3). In the middle reaches, mixed agricultural systems have developed around cereal crops and oxen cultivation. Further downstream, sorghum, maize, and millet are grown along the banks of the Omo River and its tributaries as the annual flood recedes (Nederveen, 2012; Lautze et al., 2021). In these lowland areas, agro-pastoral communities cultivate riverbanks using traditional hoe farming tied to the flood recession cycle (Yazew et al., 2015), while taro, which favours warm, wet conditions, is grown in the valley bottoms.

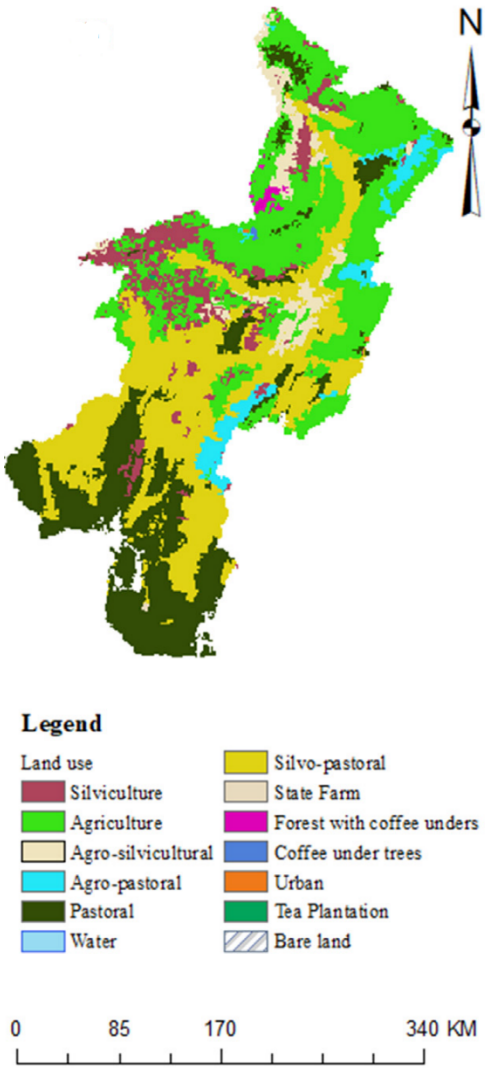


Figure 3 Major land use map types including agricultural areas in the Omo-Gibe basin (extracted from Orkodjo et al., 2022a)

Communities in the river delta combine agro-pastoralism with fishing. This is particularly true of the semi-nomadic groups in the lower Omo and close to Lake Turkana, who traditionally relied on livestock but have increasingly abandoned pastoralism as drought, disease, and cattle rustling have eroded their herds. Many have since settled along the Omo River and the lake shore, adopting agro-pastoralist livelihoods and fishing (Carr, 2017; Mati and Merrey 2021).

4.2 Contemporary rainfed agriculture

Rainfed agriculture dominates the upper zones of the basin, where wetter conditions support a wide range of crops, including teff, wheat, barley, maize, pulses, oilseeds, enset, root crops, fruit, and coffee (Fig. 3). SNNPR ((now consisting of Central Ethiopia, South West Ethiopia and South Ethiopia) is a particularly important maize producer, contributing 556,547 tons annually, or 11.2% of national production (Mati and Merrey). Among commercial cereals nationally, teff generates the highest sales value at 38.1%, followed by maize and wheat at 21.8% and 23.1%, respectively (Lautze et al., 2021). Some root crops, such as Irish potato, are grown for commercial markets, though most tuber crops are consumed domestically. Spices like ginger and red pepper, by contrast, command high market value and represent an important source of income for farmers. To optimize productivity, farmers also practice multiple cropping systems, including double cropping, intercropping, and relay cropping (Mati and Merrey 2021).

In the middle reaches of the basin, farmers grow tuber crops such as taro and sweet potato alongside grains. Erratic rainfall in this zone, however, often causes moisture stress, poor yields, and occasional total crop loss, which is a pattern identified as a key driver of rural poverty (JICA, 2012; Mati and Merrey 2021).

4.3 Irrigated crop production

Flood-based agriculture, including flood recession farming, has been practiced along the banks of the lower Omo valley and its delta for centuries, with riparian areas traditionally irrigated by overbank flow during the rainy season. Increasingly, however, these flood dependent farming systems face growing pressure from erratic droughts and floods (Nederveen, 2012; Mati and Merrey 2021). Compounding these climatic challenges, upstream dam construction, particularly Gibe III, may have altered both the volume and timing of flow, though concrete evidence to confirm this remains limited. Altered flows resulting from climate change and dam construction can affect the livelihoods of communities dependent on flood-based farming, rainfed agriculture, livestock keeping, and fishing, many of whom belong to indigenous ethnic groups (Abbink, 2012; Carr, 2017; Hodbod et al., 2019; Mati and Merrey 2021; Gebeheyu and Abbink 2022). As the extent of flooded area decreases, evapotranspiration losses from flooding will also decline. However, Global Surface Water data for the lower Omo valley indicate that no more than 4,000 ha are susceptible to seasonal flooding (Pekel et al., 2016; Dondeyne et al., 2024), while estimates of the area actually flooded on a recurrent basis are considerably lower, ranging between 500 and 2,000 ha (HWRM-ETHZ 2019; Dondeyne et al., 2024). Thus, questions remain as to how flooded area has changed over time, and whether these changes are driven by climate change, land-use patterns, or dam-related flow alteration.

The irrigation potential of the basin was estimated to be more than 248,000 ha (Belayneh 2024), while the surface and groundwater potentials were estimated to be 16.8 billion and 1.0 billion $m^3\ yr^{-1}$, respectively (Awulachew et al., 2007; Belayneh 2024). Irrigation typology of Ethiopia is classified under three categories consisting of small-scale(<200 hectare), medium scale (200–3000 ha), and large-scale (> 3000 ha) irrigation. It is noted that the total area under irrigation is not well known, as irrigation is implemented by different actors (Federal Government, Regional Governments, Sugar Corporation, Development Partners, Private Investors, and Farmer).

According to an unpublished inventory report by the SNPPR (now consisting of Central Ethiopia, South West Ethiopia and South Ethiopia) in 2022, there are currently more than 186 irrigation schemes of varying sizes in the basin, with different levels of functionality ranging from fully functional to non-functional (Baleyneh 2024). This trend of irrigation expansion is also reflected in country-wide crop yield data for major food crops, including teff, barley, wheat, maize, and sorghum, between 2006/7 and 2021/22 in the Meher season (ESS 2022) (Fig. 4). Meher season crops are defined as any temporary crop harvested between the months of Meskerm (September) and Yekatit (February), in most cases crops planted during the major rainy season. Oromia and former SNNPR regions, both part of the Omo-Gibe basin, are among the top contributors to this production and showed a rise in yield from the previous year, 2020/2021 (ESS 2022) (Table 3). Overall, however, cereals account for the highest percentage distribution of area at 71.65%, while sugar cane accounts for the lowest at 0.14% (Fig. 5).

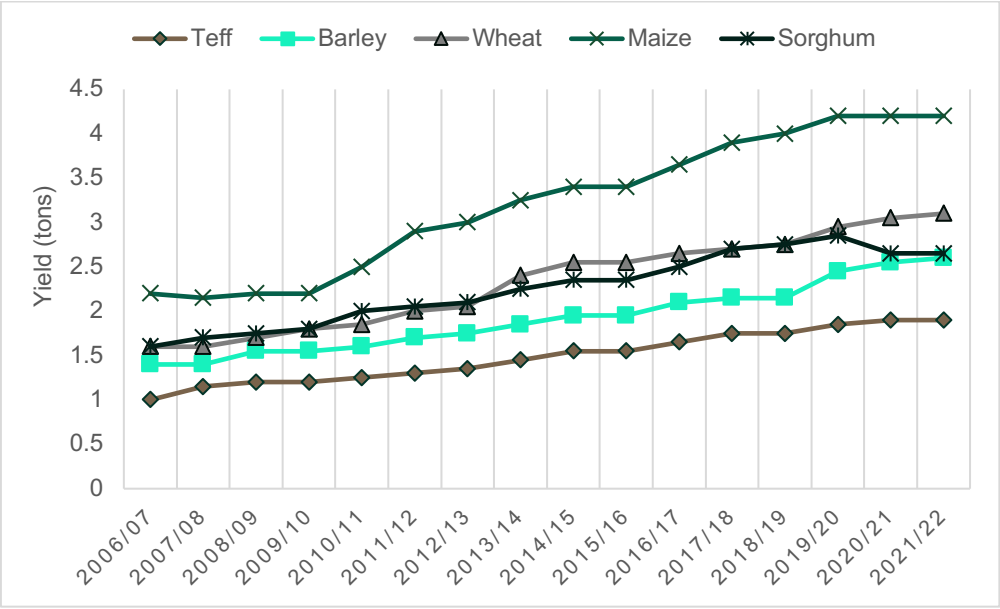


Figure 4 Trends in estimated (approx.) crop yields of major food crops in the country (Source: ESS 2022).

Table 3 Estimate of area and production of major grain crops for 2020/21and 2021/22 meher season – small holders (Source: ESS 2022)

Region	Area 2020/21 (ha)	Area 2021/22 (ha)	Area change (%)	Yield 2020/21 (tons/ha)	Yield 2021/22 (tons/ha)	Production change (%)
Afar	8,744.34	9,943.02	13.71	0.84	0.50	-32.98
Amhara	4,532,477.24	4,586,325.72	1.19	2.45	2.45	1.44
Oromia	5,944,474.67	6,100,987.75	2.63	2.85	2.88	3.65
Somali	103,923.16	30,956.50	-70.21	1.83	0.80	-87.02
Be. Gumuz	255,589.87	255,589.87	0.00	2.78	2.78	0.00
S.N.N.P.	1,077,135.33	1,102,915.09	2.39	2.69	2.65	0.85
Gambella	8,565.02	9,993.15	16.67	1.92	2.92	77.59
Harari	11,485.61	10,131.54	-11.79	1.91	2.18	0.77
Dire dawa	11,882.22	10,180.34	-14.32	1.03	1.08	-10.49
Sidama	79,501.49	79,525.70	0.03	3.16	3.32	5.31
All regions	12,033,778.95	12,196,548.67	1.35	2.67	2.69	2.05

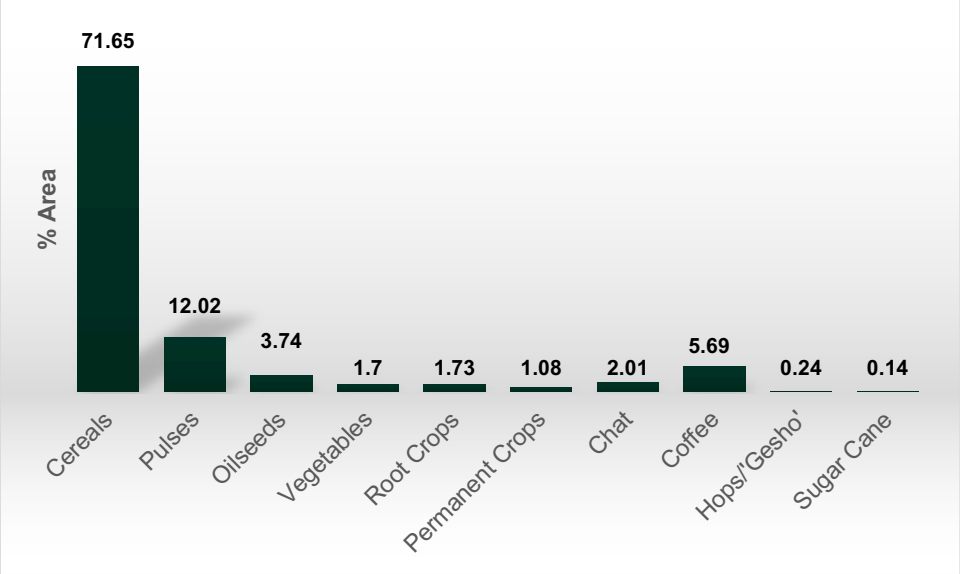


Figure 5 Percentage distribution of area under varied crops in 2021/2022 (Source: ESS 2022)

Kuraz Sugar Development Project (KSDP) announced in 2011 forms part of Ethiopia's broader state-led development strategy aimed at supporting the country's transition toward middle-income status, with the government envisioning bringing socio-economic development to the lower Omo area (Kamski and Yitbarek 2023). According to Kamski (2016), the project was initially envisaged to cover 175,000 ha of floodplains downstream of Koysha (also known as Gibe IV) and the author attributes the subsequent scaling back of the planned irrigated area to 100,000 ha to the cancellation of Gibe V. However, Gibe V's status could not be independently confirmed for this report. At full development, the scheme is expected to abstract approximately 1.1-1.9 km³ of water per year, equivalent to 4-12% of Gibe III's total annual discharge. Its long-term viability is therefore closely tied to the reliable availability of regulated water from Gibe III and the still-under-construction Koysha/Gibe IV project (Yitbarek & Kamski, 2023; Dondeyne et al., 2021). According to Gebul (2021), the Ethiopian Sugar Corporation nationally operates some 300,000 ha of irrigation command area, accounting for more than 50% of the total irrigated area under medium- and large-scale projects in the country but the exact spread across Omo-Gibe basin is unclear. Beyond boosting production for domestic use and export, these sugar cane irrigation schemes are reported to have generated thousands of permanent and temporary employment opportunities, with employees granted access to free housing, water, electricity, schools, clinics, and other facilities (Eshete et al., 2020). Nevertheless, questions remain as to whether the irrigable land's potential has been fully realised and whether current processes associated with sugar production are optimal.

Next to sugar producers, the smallholder farming community is known to be the largest beneficiary of medium- and large-scale irrigation development implemented and managed by the government (Gebul 2021). These projects serve hundreds of thousands of smallholder farmers and are jointly managed with the Irrigation Development Commission (IDC), which is responsible for water allocation and distribution through operation of the headwork and main system (Gebul 2021). This helps relieve reliance on rain-fed agriculture, which, combined with high rainfall variability, is a primary driver of food insecurity (Gebul 2021). Field surveys have shown that relative to households depending on rain-fed agriculture, households using traditional irrigation achieved higher crop yields on average and were able to grow a more diverse range of crops (Garbero and Songsermsawas 2018; Eshete et al., 2020). The effects are not significant on intermediate outcomes such as investments in farm inputs (improved seeds, fertilizer and pesticides), but in terms of final outcomes, small-scale irrigation systems have been reported to increase production, income, and dietary diversification, particularly in the Oromia and South regions (Garbero and Songsermsawas 2018). Irrigation schemes are further reported to have had a positive effect on education levels, use of improved inputs, per capita aggregate income, living standards, and marketing and distribution (Eshete et al., 2020).

Despite documented positive outcomes from irrigation expansion, irrigation management and optimisation in the country remain under speculation. Several studies indicate that the performance of irrigation schemes, measured against various applicable indicators, is poor and has vast potential to be improved (Gebul, 2021; Baleyneh, 2024). Baleyneh (2024) examined 186 irrigation schemes across the basin and the wider (former) SNNPR region in 2022, finding that 143 (77%) were functional, either fully or partially, while the remaining 23% were completely non-functional after commissioning. Among the functional schemes, only 45% were fully operational, with the rest either partially or largely non-functional. Similarly, of the total area covered by these schemes, only 61% was actually under cultivation, leaving 39% unutilised. The study identified a range of social and structural factors behind this underperformance: the most common social factors were limited community participation in scheme development and weak institutional management, including insufficient funding for operation and maintenance, while common structural factors included damage from upstream flooding, canal leakage, sedimentation and siltation, and obstructed sluice gates (Baleyneh, 2024). Improving irrigation infrastructure performance and management could therefore yield multiple benefits for food and nutritional security, household income, and land and water management.

4.4 Livestock

Ethiopia is believed to hold the largest livestock population in Africa with the sector already contributing to a considerable share of the national economy. Livestock products and by-products, including meat, milk, honey, eggs, cheese, and butter, supply the animal protein needed to improve the nutritional status of the population. Dairy production specifically underpins the livelihoods of millions of smallholder farmers in both rural and urban settings, as well as pastoralist and agro-pastoralist communities (Legese et al., 2023). Cattle, sheep, and goats are the dominant livestock species, while poultry is also an important category, and donkeys, horses, camels, and mules are reared to varying degrees across the country.

The latest livestock statistics record approximately 65.7 million cattle, 38.0 million sheep and 45.7 million goats across the listed Ethiopian regions (ESS 2022). Oromia has the largest cattle population (26.3 million), while SNNPR (now consisting of Central Ethiopia, South West Ethiopia and South Ethiopia has the third-largest (10.6 million), after Oromia and Amhara (Fig. 6). Poultry is also important, with more than 40 million animals across the country, while donkeys, horses, camels and mules are reared at varying scales. Because the Omo-Gibe basin covers only parts of Oromia (about 6%) and SNNPR (about 53%), these regional livestock figures cannot be attributed to the basin in full, but they nonetheless indicate the likely importance of livestock rearing to rural food security and livelihoods within the basin area itself.

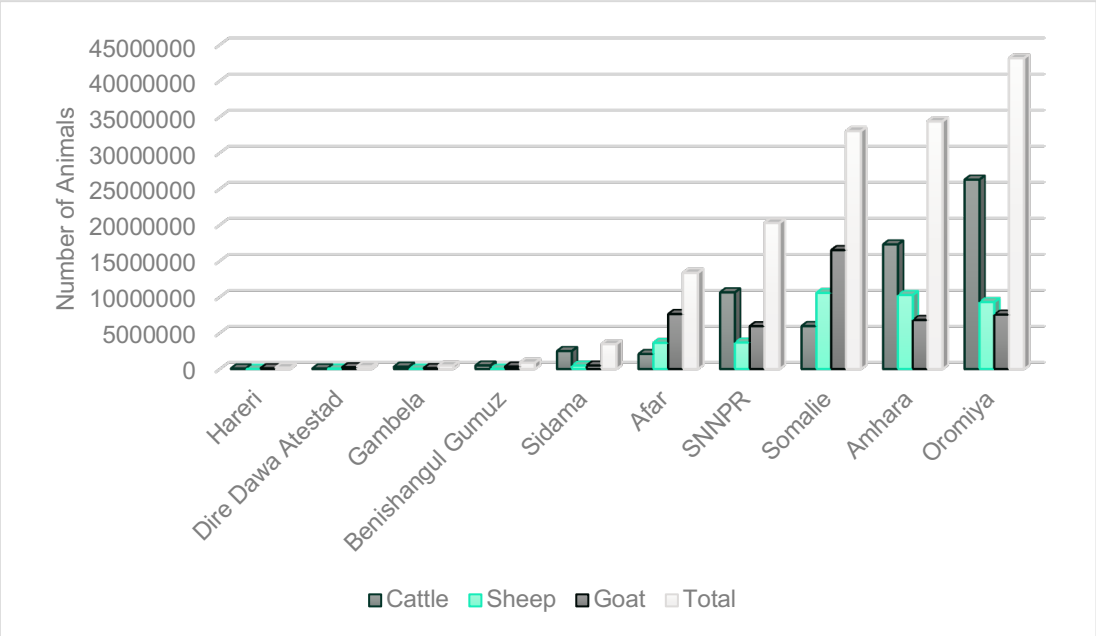


Figure 6 Cattle, sheep and goat distribution by region (Source: ESS 2022)

Mati and Merrey (2021) outlines in depth the role of livestock rearing in local livelihoods and food security across the basin, with rural communities integrating pastoralism, agro-pastoralism, and mixed crop-livestock systems. The mode of pastoralism varies but generally involves some form of mobility and transhumance. In the lower Omo, in hot, arid environments, many indigenous communities practice pastoralism, though this is inadequately supported by effective marketing or value chains, despite its contribution to the local economy and livelihoods. Agro-pastoralism combines elements of pastoralism with sedentary rainfed and flood-based crop cultivation along the banks of the Omo River and its tributaries. In the cooler highlands, where crop cultivation dominates, agro-pastoralism remains important. At mid and high altitudes in particular, livestock keeping within mixed crop-livestock systems is mostly geared toward dairy production, while crop farming remains the main livelihood activity. The two sectors complement each other as crop cultivation provides animal feed, while livestock supply draught power for tilling the land, along with by-products such as cow dung, used both as fuel for cooking and as manure (Lautze et al., 2021). Country-wide statistics indicate that around one third of the farmers (34% equaling ~12.5 million) use crop residue as animal feed while majority (39% equaling ~14.3 million) rely on green fodder or grazing areas, while others rely on improved feed, hay and other by-products (ESS 2022).

Agro-pastoral livestock production systems are found in the lower zones of the basin and are also valued as a socio-cultural practice (Lautze et al., 2021). Cattle are the primary livestock kept, with herd sizes typically ranging from 10 to 20 individuals, reared mainly for milk that is largely consumed at home, with any surplus dairy or dairy products sold in nearby towns. However, erratic rainfall patterns have affected the availability of feed and drinking water for livestock. Further, it is also noted that the expansion of irrigated plantations following the construction of Gibe III has also negatively impacted agro-pastoral livelihoods, as grazing areas have been converted to irrigated fields, which in turn also affect game animals and wild foods relied upon by local communities (Stevenson, 2018; Lautze et al., 2021). Communal dry grazing lands and wetlands are identified as the major source of grazing pastures for smallholder cattle herders (Assefa and Eneyew 2025). Given that a large proportion of farmers nationwide rely on green fodder or grazing land for animal feed, the conversion of such land to irrigated cropland is likely to carry broader impacts, though these remain scarcely documented.

Beekeeping, or apiculture, for the production of honey and beeswax is also a traditional enterprise practiced across much of the Omo-Gibe basin and Turkana area (Lautze et al., 2021). Ethiopia produces around 52 million kilograms of honey annually, most of it harvested from traditional hives (ESS 2022). Oromia and former SNNPR both hold large numbers of beehives, 3,373,583 and 963,290 respectively, out of a national total of 5,982,336 (ESS 2021). As a non-timber forest product, honey production depends directly on the extent and condition of natural forest and woodland cover, since bee colonies rely on forage from indigenous flowering trees and shrubs across the annual cycle. This links apiculture closely to the wider ecosystem service benefits provided by natural vegetation in the basin.

4.5 Fisheries

As a land-locked country, Ethiopia's fisheries depend exclusively on inland water bodies, including lakes, rivers, streams, reservoirs and wetlands (Tesfaye and Wolff 2014). Both aquatic habitats in the Omo-Gibe basin and Lake Turkana provide important fishing grounds, though inland fisheries in the system remain understudied (Obiero et al., 2023; Getahun et al., 2020). The indigenous Daasanech community, also known as Merille, is the primary inhabitant of the area stretching from the lower Omo River to the delta and along the northern and northeastern Ethiopian shore of Lake Turkana. While communities along the Omo River are semi-pastoralists who depend on recession farming (Carr 2017; Getahun et al., 2020; Amos et al., 2021), communities on the northeastern shore of the lake depend entirely on Lake Turkana fishing, with no alternative means of livelihood (USAID 2006; Getahun et al., 2020). Based on personal observations, Getahun et al. (2020) report that fisheries at the junction of the Omo River Delta and Lake Turkana are an important source of livelihood and income for the local community, particularly for youth. A preliminary assessment by Wakjira (2016) similarly indicated that fisheries potential is high in the Lower Omo River and the Ethiopian part of Lake Turkana, with considerable scope for socio-economic returns, though this potential remains largely untapped on the Ethiopian side (Getahun et al., 2020).

The Omo-Gibe basin is stated to have the second-highest fish diversity in Ethiopia, after the Baro-Akobo Basin (Getahun, 2017; Wakjira and Getahun, 2017; Getahun et al., 2020). Of the 79 native fish species recorded across the entire Omo-Turkana system, 65 occur within the Ethiopian portion of the basin (Wakjira and Getahun, 2017). Despite this high diversity, only 22 fish species are actually targeted by fisheries in the Lower Omo River and the Ethiopian side of Lake Turkana, with fishing effort concentrated on larger species (e.g Nile perch) rather than smaller, more abundant species (e.g. pebbly fish and catfish) (Getahun et al., 2020). The fisheries industry overall has seen an expansion in Ethiopia between 2013 and 2022 (Lakew 2025 based on data from Ministry of Agriculture) (Fig. 7). In recent years, the demand for fish in the country has increased significantly primarily due to population growth and increased awareness of the nutritional and health benefits associated with fish consumption (Lakew 2025). Currently, capture fisheries dominate with the catch doubling from 50 metric tons in 2013 to 101 metric tons in 2022. Aquaculture has observed an outstanding growth with 41 tons in 2013, 126 tons in 2017 and reached 1070 tons in 2022.

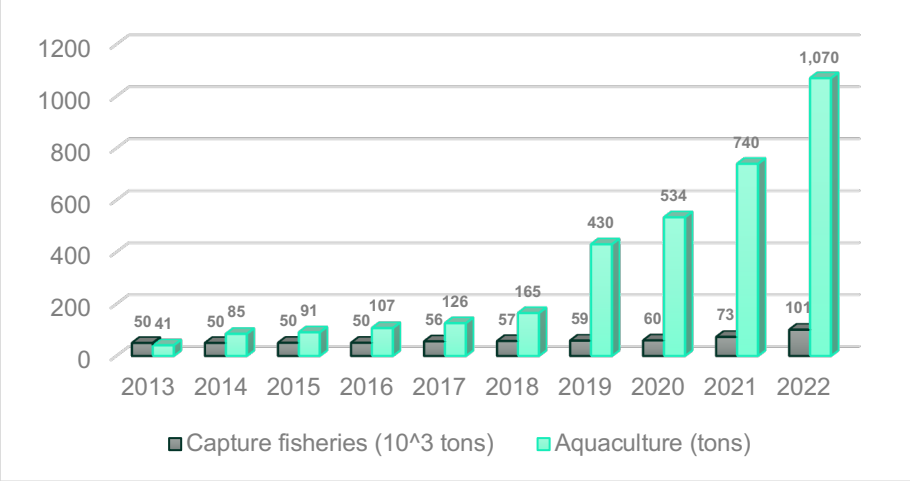


Figure 7 Fisheries production from capture fisheries and aquaculture in Ethiopia between 2013-2022 (Lakew 2025 based on Ministry of Agriculture data). Note the difference in units in y-axis

A ten-year Fishery and Aquaculture Master Plan (FAMP), spanning 2024/25 to 2033/34, has been developed by the Ministry of Agriculture to enhance fish production in Ethiopia, particularly by leveraging aquaculture potential. The plan estimates that, if fully utilised, total inland fisheries production could reach as high as 127,969 t/yr, with about 104,015 t/yr from lentic water bodies (lakes and reservoirs) and 23,954 tons from lotic water bodies (rivers and streams). This is broadly consistent with earlier projections by Tesfaye and Wolff (2014), who estimated that optimal utilisation of fisheries potential could yield up to 94,500 t/yr nationally, comprising approximately 73,100 t/yr from lentic systems (lakes, reservoirs and small water bodies) and around 21,400 t/yr from lotic systems (riverine fisheries). Within this, the Omo River and the Ethiopian portion of Lake Turkana were estimated to hold a potential fish yield of up to 2,500 tons (valued at US$842 per ton, equivalent to about US$2.1 million), while the Gibe I and Gibe III reservoirs together offer a potential combined yield of around 1,508 tons (~US$1.27 million) (Tesfaye and Wolff, 2014). The FAMP also envisages aquaculture production potential of 200,000 tons by 2030 and 402,000 tons by 2034, although over 60% of this potential is expected to come from commercial intensive aquaculture (Lakew 2025), which could carry unintended negative impacts if not conducted sustainably.

Fisheries productivity in the Turkana basin depends significantly on the Omo-Gibe system, which supplies 80-90% of inflows, with the remaining 6-10% coming from the seasonal Turkwel and Kerio rivers together with other littoral

rivers (Avery and Tebbs, 2018; Dondeyne et al., 2024). Lake Turkana is known for both inter- and intra-annual fluctuations, with lake level varying annually by an amplitude of about 1-1.5 m, alongside considerable long-term variation compared to other Rift Valley lakes in Africa (Velpuri and Senay 2012). While modelling studies have shown that Gibe III's construction reduced lake levels by 1-2 m, particularly during the 2015-2016 filling period (Velpuri and Senay, 2012; Avery and Tebbs, 2018), more recent observations point to an overall rise in lake levels between 1992 and 2021. Dondeyne et al. (2024) report that Lake Turkana's level dropped by about 1.5 m while the Gibe III reservoir was being filled, between January 2015 and January 2017, but note that this fall sits within the range of the lake's natural variability and may equally reflect other factors, such as highly variable rainfall and other, less studied drivers (e.g. land-based runoff). More recent NASA satellite imagery further indicates that the lake is now at its highest recorded level since 1992 (https://earth.gsfc.nasa.gov/gwm/lake/93) indicating that previous modelled predictions may not be fully accurate. While the flood pulse itself remains comparatively understudied, the earlier projected changes in flow volume and timing suggested future reductions in lake productivity. Previous modelling work found a roughly 30% decline in chlorophyll a associated with changes in the flood pulse, driven in turn by reduced downstream sediment transport and its effect on primary productivity (Tebbs et al., 2019). Other scenario-based studies suggest that loss of the flood pulse alone could reduce fisheries yields by more than two-thirds regardless of lake level, while an extreme drop in absolute lake level (around 25 m) would result in total collapse of the lake fishery (Gownaris et al., 2017).

However, fish catch records from Ethiopia's major lakes show fluctuating trends, with Lake Turkana and Lake Abaya standing out for their increases, especially in the recent years (Fig. 8). Lake Tana dominates overall yield but has shown a sharp decline since 2014, attributed mainly to the use of fine-mesh monofilament gill nets. Records from Kenya Fisheries Service also show fish production on Lake Turkana rising from less than 12,000 metric tons in 2015 to more than 16,000 metric tons in 2022, before falling to around 15,899 metric tons in 2023 and 15,618 metric tons in 2024 (Fig. 9). The 2021/2022 increase has been attributed to improved recruitment linked to raised water levels and the flooding of Ferguson Gulf and other critical fish habitats, which also aligns with Dondeyne et al.'s (2024) observations of rising Lake Turkana water levels over this period. The subsequent 2023/2024 decline has been attributed to sustained high water levels through much of the year, which restricted traditional fishers' access to fishing grounds. Some reports suggest that the number of fishers on the Kenyan side of Lake Turkana has increased over the past 15 years, with rising fishing effort contributing to overfishing and declining fish stocks (Obiero et al., 2023). This shift is also reportedly linked to prolonged drought across northern Kenya and southern Ethiopia in recent years, which has devastated pastoralist livelihoods and pushed many herders toward fishing as an alternative means of survival.

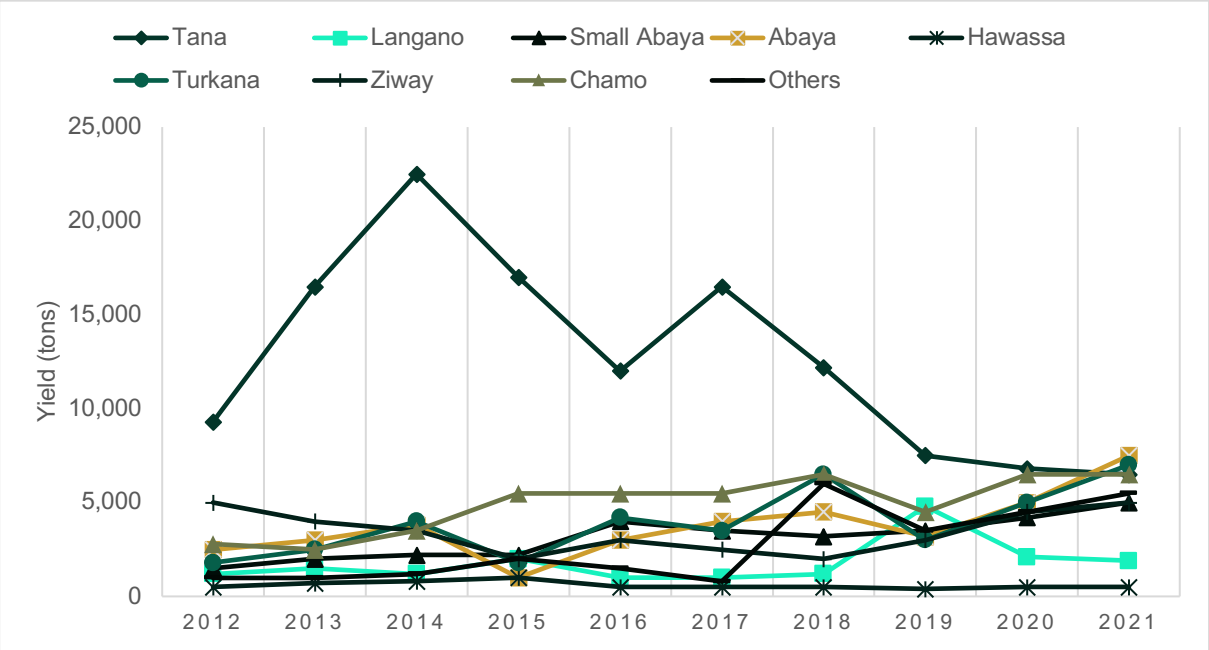


Figure 8 Trends in (approx.) fish catch from major lakes, including Turkana, in Ethiopia between 2012 and 2021 (Source: FAMP 2024/25-2033/2034)

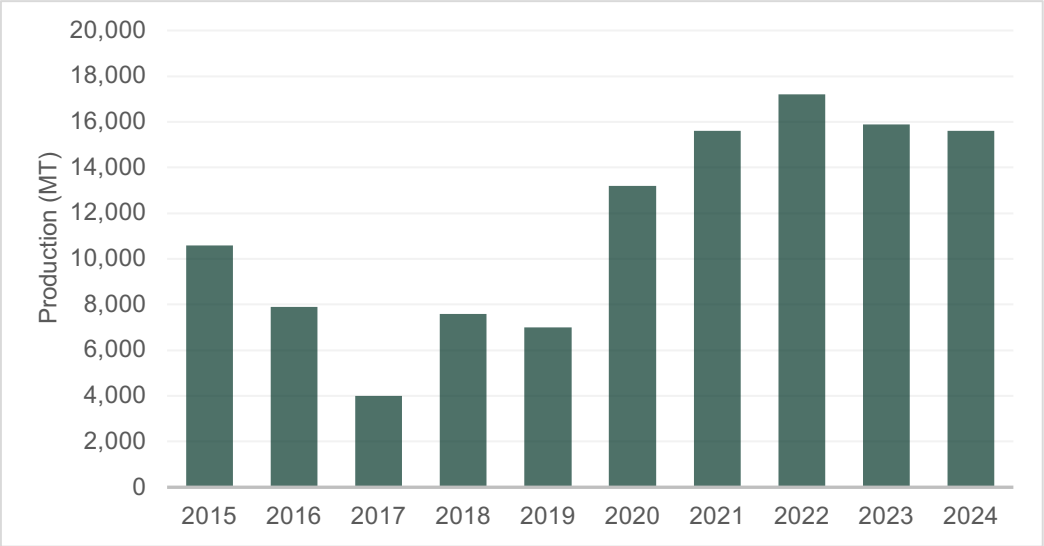


Figure 9 Trends in (approx.) annual fish landings from Lake Turkana fishery in Kenya 2015 – 2024 (Source: Kenya Fisheries Service 2025)

The preceding sections show that hydropower, agriculture, livestock and fisheries are connected through the same river system and are increasingly shaped by managed flows, changing flood pulses and competition for land and water. The environmental sections therefore focus not only on biodiversity in isolation, but also on the ecosystem services that sustain livelihoods and mediate the impacts of development across the basin.

5. Environment

5.1 Habitats and biodiversity

The Omo-Gibe basin is an ecologically important area with diverse ecosystems spanning across the basin shaped by varying climate, altitude, topography and socio-cultural characteristics. A diverse range of ecosystems ranging from mountain forests, wetlands, riparian forests and a delta at the northern end of the lake support a wide range of highly specialized livelihoods (Lautze et al,. 2021). Ecosystems in the basin consist of upper northern part dominated by forests and croplands (agriculture) and the arid southern part with open grasslands and woodlands (Fig. 10) (Chaemiso et al., 2021). Omo-Gibe also has the third-highest share of wetland cover among the basins, at 12.4% (2,584 km²), behind the Baro-Akobo (53%) and Denakile river basins (15%) (Assefa and Eneyew, 2025).

The Omo River originates in the Ethiopian highlands, with its main tributaries being the Gibe, Gilgel Gibe, and Wabe rivers. In the upper catchment, streams are deeply incised into the landscape, and the steep topography combined with variable rainfall creates diverse habitats, including waterfalls, gorges, wetlands, and old-growth forests that contribute to the Eastern Afromontane Biodiversity Hotspot. Further downstream, the lower Omo is characterised by slow-flowing, turbid water that meanders through broad floodplains, with seasonal variation in vegetation growth (Lautze et al., 2020).

Drawing on Joka (2024) and Asfaw et al. (2025), the Omo Valley in southwest Ethiopia is recognised as one of the country's most biodiversity-rich regions, with diverse habitats supporting some of the largest concentrations of wildlife and serving as a migration corridor for wildlife populations moving between Eastern and Central Africa. Four protected areas fall within the Omo-Gibe basin: Omo National Park (ONP) which is the largest in the country (4068 km^2), Tama Community Conservation Area (TCCA) (1,968 km^2), Chebera Churchura National Park (CCNP) (1250 km^2) and Maze National Park (MNP) (202 km^2). Each park has a distinct landscape with CCNP sitting amid steep slopes, hills, and rugged mountain escarpments, ranging in altitude from 500 to 2,000 m. ONP and TCCA, by contrast, are dominated by expansive savanna grassland, hills, and riverine forest along the Omo River, at lower altitudes of 450 to 1,183 m. MNP consists of undulating plains and gentle slopes, with the Maze River and its tributaries draining into the Omo and creating patches of riverine forest along the way, at altitudes between 998 and 1,200 m.

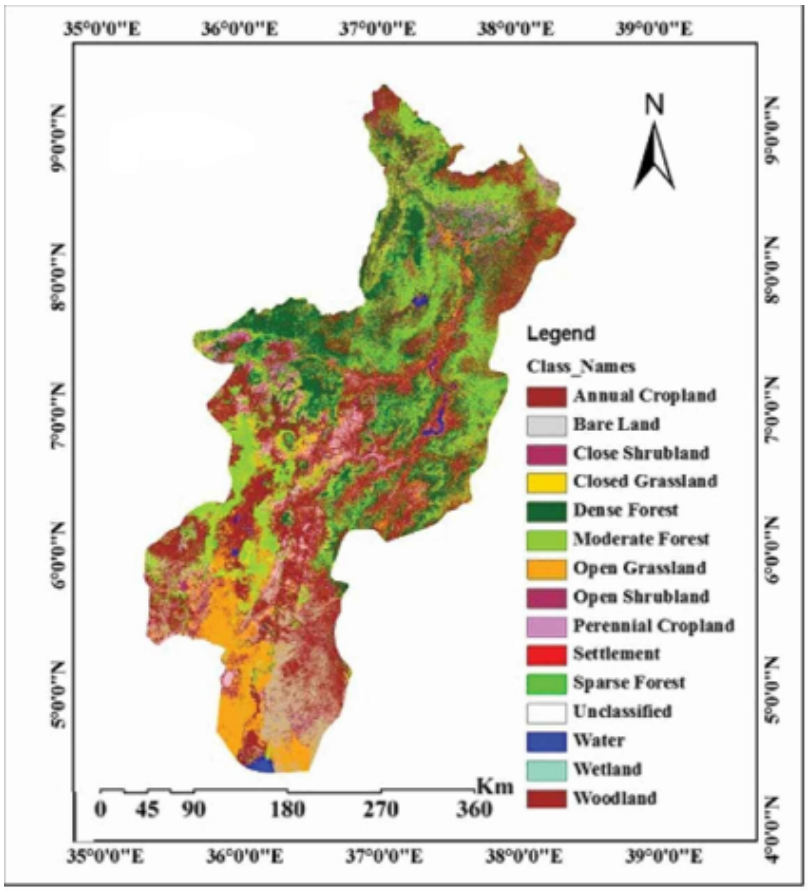


Figure 10 LULC map of Ethiopian portion of the basin in 2017 (Chaemiso et al., 2021)

Recent camera trap surveys by Asfaw et al. (2025) detected 52 mammalian species from nine orders and eighteen families across the four protected areas in the Omo Valley, of which 29.4% are listed as globally threatened by the IUCN. Earlier records show the ONP holding 75 mammal species, 325 bird species, 13 fish species, and 11 amphibian species (Debebe 2018). The most notable among these are the exceptional herds of eland and tiang, with the park hosting the only protected eland population in the country (Debebe 2018; Joka 2024).

The Lower Omo Valley additionally holds UNESCO World Heritage status for its exceptional paleontological and archaeological record, including some of the world's most important discoveries relating to early human evolution, adding a further, globally significant dimension to the basin's natural and cultural heritage (WLRC, n.d.; International Parks, n.d.).

This terrerstrial ecological richness extends into the basin's aquatic systems. As mentioned previously, the Omo-Turkana basin is recognised as harbouring the second-highest fish diversity in Ethiopia, after the Baro-Akobo basin (Getahun et al., 2020). Lake Turkana itself, the largest permanent desert lake in the world, sits at the heart of this system and forms part of the Lake Turkana National Parks UNESCO World Heritage Site, valued globally both for its aquatic biodiversity and as one of the world's most important fossil sites. Together, this combination of habitat diversity, high flora and fauna richness, and globally recognised natural and cultural heritage underpins the basin's considerable tourism potential.

5.2 Ecosystem services

Habitats across the Omo-Gibe basin generate a wide range of provisioning, regulating and cultural services on which local livelihoods depend. Perennial rivers supply most domestic water in the basin; Jimma town, for instance, relies on the Gilgel Gibe River for its water needs (Sahle et al., 2019). Access to safe drinking water remains uneven, with only around 45% of the Ethiopian portion and 28% of Turkana County households reached by safe drinking water (Abebe and Hawassa, 2008; Wandera et al., 2008; USAID, 2016). River water also underpins irrigated agriculture (EEPCO 2009), the large-scale Kuraz Sugar Development Project (Kamski 2016), alongside flood-recession cropping along the Omo Delta and Lower Omo Valley (EEPCO 2009). As discussed previously, the

ecosystem services provided by habitats across the basin offer vital support for hydropower and agriculture, including livestock, as well as fisheries and apiculture.

Forests, woodlands and wetlands moderate the hydrological cycle by influencing infiltration, evapotranspiration and flow regulation, though the underlying evidence base remains limited (McCartney and Dickens, 2020). Restoration of upper-catchment forests is often promoted for erosion control and sediment retention, protecting downstream water infrastructure (Devi et al., 2008; Choto and Fetene 2019; Lautze et al., 2021), while soils and biomass across the basin also contribute to carbon storage, including through REDD+-linked initiatives (Bekele et al., 2015). The basin's ecosystems sustain spiritual, aesthetic and educational values closely tied to the seasonal rhythms of the Omo River (Carr, 2017; Turton, 1977, 2011; Hodbod et al., 2019a), and support emerging ecotourism opportunities within existing protected areas as well as around the recently declared Kafa Biosphere Reserve (Schormann, 2011).

6. Impacts of changing climate and land use

6.1 Climate change impacts on temperature, precipitation and streamflow in the Omo-Gibe Basin

A number of peer-reviewed hydrological modelling studies published between 2020 and 2026 have examined how projected climate change is likely to affect temperature, precipitation and streamflow across the Omo-Gibe Basin. Selected studies are summarised below to provide a broad picture.

Using an ensemble of regional climate models under RCP4.5 and RCP8.5 scenarios, Orkodjo et al. (2022a) projected temperature increases ranging from 2.40–3.34°C under RCP4.5 and 2.6–4.54°C under RCP8.5. Annual average precipitation was projected to decrease by 10.77–13.11% under RCP4.5, while under RCP8.5 the decrease ranged from 11.10–13.86% during the rainy summer season (June–August) and the irregular rain season (March–May). Projected annual average streamflow decreased by 7.08–10.99% under RCP4.5 and 10.98–12.88% under RCP8.5. Their subsequent study (Orkodjo et al., 2022b) modelled the consequences for water availability for various sectors (Fig. 2), finding that, as a result of rising temperatures and reduced precipitation and streamflow, water available for irrigation could decrease by 15.5–25.4% and for hydropower by 10.5–20.2% over the 2073–2100 study period under both pathways.

Anose et al. (2021) used minimum and maximum temperature and rainfall data (1981–2016) from the National Meteorological Agency (NMA), together with CHIRPS satellite precipitation data (Funk et al., 2015) over the same period. Surface runoff and river flow data (1981–2014) were collected from the Ministry of Water, Irrigation and Electricity of Ethiopia (MWEE), selecting only eight stations with complete records for the study period. NMA data showed a significant increasing trend in seasonal rainfall in summer and autumn in the central and northern basin, alongside a decreasing trend in summer and winter in the same areas, while CHIRPS data indicated significant increases in seasonal rainfall in the central and southern basin. Mean temperature increased significantly across the basin in both space and time, confirming a recent acceleration in warming. Mean seasonal runoff showed an insignificant increasing trend (0.013–0.238 mm/year), while mean seasonal river flow increased significantly by 0.069, 0.014 and 0.197 m^3/s/year in summer, spring and autumn respectively, with runoff and river flow both showing an increasing trend overall, particularly over the most recent two decades.

Feyissa et al. (2024), using CMIP6 and SWAT models projected impacts of climate change on hydrological processes in the Omo River Basin was evaluated under two Shared Socioeconomic Pathways (SSP245 and SSP585) scenarios, observing that stream flow will increase annually and monthly in June, July, August, and September (JJAS) under both scenarios except decrease in the months of March, April, and May (MAM) under the SSP245 scenario. The basin mean annual and seasonal (JJAS and MAM) surface runoff will increase under the SSP585 scenarios while it is observed to decrease under the SSP245 scenario.

Similar to Anose et al. (2021), a recent study by Mekuria et al. (2025) focusing on Upper Omo Gibe, also used field data consisting of daily rainfall, maximum temperature, and minimum temperature obtained from the National Meteorological Institute of Ethiopia from 1981 to 2022. Streamflow data were collected from the MWEE for ten gauging stations across the Upper Omo Gibe Basin from 1985 to 2018, with imputations conducted to fill missing data. Statistically significant trends in the examined variables differed both seasonally and from one station to another. Upper Omo Gibe basin-wide, the study observed a generally increasing trend in maximum temperature and decreasing trends in precipitation. Streamflow trends, by contrast, were spatially and temporally heterogeneous, where significant increases were observed at the Gibe and Gilgel Gibe at Assendabo gauging

stations during the summer season, while significant decreases were observed at the Bulbul gauging station in spring and at the Megecha gauging station in summer, alongside a decreasing annual trend overall.

A further study by Anose et al. (2022) analysed drought indices, the Standardised Precipitation Index (SPI) and the Standardised Precipitation Evapotranspiration Index (SPEI), using both satellite and station data from 1981 to 2016. Their results indicate an increasing trend of seasonal and annual drought events was observed in all basin parts with the longest drought durations and most severe drought intensities recorded in the southern part of the basin, decreasing towards the north. However, a considerable degree of drought frequency, magnitude, and intensity was also observed in the central and northern parts of the basin, areas with no prior record of drought. This emergence of drought conditions in the upper reaches (central and northern parts) has implications for agricultural and hydropower production, as well as irrigation activities further downstream in the basin's pastoral lowlands.

Nevertheless, taken together, the literature consistently projects continued warming across the basin under all emission scenarios considered, while projected changes in precipitation and streamflow remain less consistent across models, periods and sub-basins. This uncertainty is itself important for planning: hydropower expansion, irrigation development, and industrial and urban growth should be designed around a wider range of rainfall and discharge conditions rather than a single expected future. The consequences of this variability are likely to be most severe for communities with limited livelihood diversification and high dependence on seasonal river flows.

6.2 Land Use Land Cover Change

The work of Chaemiso et al. (2021) shows that, between 1987 and 2017, land cover in the basin shifted diversely: water bodies, perennial cropland, settlement and wetland increased by 20.19%, 21.08%, 5.02% and 5.73% respectively, while woodland, closed grassland and annual cropland increased more modestly, by 3.26%, 2.25% and 2.34% (see Fig. 10 for the LULC distribution). Sparse forest and open grassland changed only slightly (0.76% and −0.19%), while dense forest, moderate forest, closed shrubland, open shrubland and bare land all declined, by 11.9%, 21.8%, 21.7%, 1.76% and 22.4% respectively. This is broadly consistent with Dondeyne et al. (2024), who found that 1,140 km² of forest (0.8% of total basin area) was lost between 2000 and 2020 across the basin. Global Forest Change data (Hansen et al., 2013, v1.7, updated 2019) similarly shows deforestation to be fragmented and particularly active in highland forest areas above 1,200 msl in both the Omo-Gibe and Turkwel-Kerio-Turkana subbasins. Further confirmation on changes to aquatic habitat comes from Assefa and Eneyew (2025), who found that open-water extent increased by 20% between 2000 and 2020, even as overall wetland coverage declined by 9% over the same period.

The expansion in open-water bodies is attributed to the growth of hydropower schemes, while the marked reduction in dense forest across the basin is attributed to agricultural expansion and urbanisation (Assefa and Eneyew 2025; Chaemiso et al., 2021). These land-use changes carry a range of downstream implications, notably higher erosion and increased sediment yield. The Gibe I reservoir has been affected by siltation, with an initial sediment load of 4.5×10^7 Mg/year entering the reservoir resulting in a capacity loss of 3.8×10^7 m³/year (Devi et al., 2008; Dondeyne et al., 2024). A recent study by Kuma et al. (2024) found that the Gibe-Gojeb sub-catchment produced an average annual sediment loading of 62.5 tons ha^{-1} yr^{-1} between 2002 and 2016, ranging from 0.2 to 108.4 tons ha^{-1} yr^{-1}, with 58,802 tons of sediment transferred from the catchment and deposited in the Gibe I reservoir, reducing its capacity by 5.7%. Using the InVEST model, Aneseyee et al. (2021) estimated that total soil loss across the Omo-Gibe basin rose from 774.86 to 951.21 thousand tons between 1988 and 2018, with a corresponding increase in sediment export of 3.85 thousand tons over the same period. Cultivated fields generated the highest erosion rates of any land-use type, rising from 10.02 to 43.48 t/ha/year over the study period, compared with grazing land, shrubland, forest, woodland and bare land (Aneseyee et al., 2021).

LULC also changes the hydrology and runoff patterns with modelled studies showing increased runoff in wet periods but a decrease in groundwater yield and a dry average monthly flow indicating changes to flow timing and seasonal water availability (Chaemiso et al., 2021). Mekuria et al. (2026)'s work that combined LULC with climate change projections, showed that surface runoff is projected to increase from 368.46 to 512.42 mm, while evapotranspiration decreases from 567.80 to 544.50 mm, while lateral flow and groundwater recharge decline markedly, from 81.96 to 62.36 mm and 365.04 to 264.29 mm, respectively.

However, there are notable efforts to improve land cover in the country, with the Government of Ethiopia planning to plant 50 billion seedlings by 2030, with a strong focus on native species, fruit trees, and ornamental trees for urban greening (UNHLPF 2025). Further, according to the country's VNR, Ethiopia's forest cover has increased over the past decade, from 15.5% of total land area in 2015/16 to 17.2% in 2021/22, rising again to 23.6% in 2023/24. Additionally, multiple studies from Ethiopia provide ample evidence that climate-smart agriculture practices can offer cost-effective opportunities to increase productivity and household income while reducing erosion, sometimes by 23–86% (Asefa et al., 2025; Admassu et al., 2023).

7. Hydropower-agriculture-environment tradeoffs and challenges

The most substantial trade-off analysis undertaken for the basin was produced under DAFNE (Decision-Analytic Framework to explore the water-energy-food Nexus), a four-year Horizon 2020 project (2016–2020) led by Politecnico di Milano together with ETH Zurich, Osnabrück University, KU Leuven among other partners (including IWMI), applied in parallel to the Omo-Turkana and Zambezi basins. The project combined hydro-economic modelling with a series of stakeholder Negotiation Simulation Labs to jointly identify and test development pathways for the basin. The main peer-reviewed output, Giuliani et al. (2022), modelled the operation of the planned dam cascade and irrigation expansion across five competing sectors: hydropower production, environmental protection, indigenous recession agriculture, fish yield in Lake Turkana, and large-scale commercial irrigated agriculture. Key findings include:

- The analysis identified more than 800 alternative operating strategies for the system, each striking a different balance among the competing water demands.
- Hydropower and irrigation were found not to be strongly conflicting, suggesting the dams and irrigation schemes are reasonably well aligned from the perspective of these two uses alone, a pattern the authors note is consistent with other African basin systems (e.g. Zambezi river basin).
- The sharpest trade-off emerged between irrigation supply and fish production in Lake Turkana, reflecting the basin's transboundary structure: irrigation expansion is concentrated in Ethiopia, while the majority of Lake Turkana, and its fishery, lies in Kenya. However, records of fish catch from Lake Turkana in both Kenyan and Ethiopian sides show that in recent years there has been an increase in fish, albeit not showing a consistent trend.
- The stakeholder-negotiated pathway from the Negotiation Simulation Labs showed a slight preference for protecting fish yields over irrigation output, indicating some willingness among stakeholders to trade economic return for ecological protection. The stakeholder-negotiated pathway achieved performance in the top 20% of the solution set for 'Environment, Recession agriculture, and Fish', but this came primarily at the cost of an irrigation deficit close to 45% of the best feasible solution, alongside a 70 GWh/year reduction in hydropower production. This is said to result in a streamflow regime close to natural conditions in the lower Omo, achievable mainly by limiting water diversion, particularly to the Kuraz sugar plantation. In reality, this would mean reducing the extent of the irrigation district or increasing the share of land left fallow within it, a recommendation consistent with others (e.g. Hodbod et al., 2019).
- Planned infrastructure performance was projected to decline over time under future climate and irrigation-demand scenarios, though the authors found this could be mitigated through robust operating rules triggered by streamflow changes in the northern part of the basin.

In May 2026, IWMI conducted a workshop on environmental flows (e-flows), with the aim of assessing the quantity, quality and timing of the flows in the Omo-Gibe Basin for enhanced ecosystem service provisions, including those related to energy and agriculture sectors. It was convened under the CGIAR Multifunctional Landscapes programme, which brought together 27 stakeholders from government, academia, and civil society and confirmed several priorities directly relevant to this work plan (Simaika and Haile, 2026). Key messages from these discussions include:

- Cross-cutting priorities such as flow variations, water quality degradation, environmental flow policy gaps, data scarcity, and flood-drought vulnerability were identified as interlinked, reinforcing the case for an integrated trade-off approach rather than single-sector analysis.
- Water quality is an underexamined gap, with pollution, sedimentation, and nutrient loading emerging as a stronger stakeholder concern than anticipated.
- Persistent structural constraints remain, including sparse hydrological/meteorological monitoring, weak institutional coordination on dam operation and water allocation, and the absence of a basin-specific e-flow policy or framework.
- A foundation has already been laid, with the workshop setting the stage for a follow-up co-design process and planned digital-twin development for the basin.
- An established partner network exists, with IWMI, the Ministry of Water and Energy, Arba Minch University, and Addis Ababa University already engaged for continued collaboration on trade-off and e-flow questions.

8. Next steps – work plan outline (June 2026 – December 2028)

Thus, this work plan translates the trade-off evidence synthesised above into a structured, 31-month programme (June 2026–December 2028) to develop an updated, jointly owned trade-off assessment for the Omo-Gibe Basin.

It builds directly on previous work, including the DAFNE/Giuliani et al. (2022) trade-off analysis and the findings of the May 2026 IWMI e- flows workshop (Simaika and Haile, 2026), updating the evidence base against current climate, land-use, and sediment trends. The programme is structured in five phases, moving from diagnostic stakeholder engagement, through data acquisition and assessment set-up, to trade-off scenario analysis, policy dialogue, and consolidation into an agreed monitoring and adoption framework.

The proposed work plan has two aims.

1) To widen the basin's ecosystem service evidence base to include services that remain largely overlooked, such as honey production, tourism, and aquaculture, alongside the more established focus on water, hydropower, and fisheries
2) To reassess the basin's trade-offs, last analysed under DAFNE in 2018–2020, against this new evidence, evolving stakeholder priorities, and this untapped ecosystem service potential. Several of the original analysis's core assumptions no longer hold: Lake Turkana's water level was projected to decline under upstream damming and irrigation expansion but has instead risen sharply in recent years, and climate projections for the basin have shifted from a consistent drying signal to a more mixed picture of wetter conditions with altered seasonality. With the basin's hydrology, land use, ecosystem service potential, and stakeholder priorities all having moved since the original analysis, this work is needed to re-examine whether the negotiated trade-off pathway still holds and to ground future decisions in a fuller, more current picture of the basin.

The following section outlines the planned phases of this work plan, along with the key questions each phase seeks to address, the associated activities, and their intended outcomes

1. Diagnostic and Framing – Inception Workshop (June–September 2026, 4 months)

This phase opens the programme with an inception workshop bringing together the range of basin stakeholders to jointly review the evidence base compiled in this report and establish a shared point of departure. Findings are presented as a shared starting point rather than settled conclusions, so the workshop can surface where stakeholders agree, disagree, or consider the evidence outdated, and establish whether priorities have shifted materially since the 2018–2020 DAFNE process.

- Revisit the evidence base: present findings from existing hydro-climate, LULC, ecosystem service, and past trade-off studies as shared starting material, not settled conclusions.
- Surface uncertainty and disagreement: facilitated discussion on which findings stakeholders find credible, contested, or outdated, including the previous negotiated pathway's 45% irrigation deficit/70 GWh/y hydropower cost, and the divergence between CMIP5 (drying) and CMIP6 (wetter, seasonally shifted) projections.
- Test for priority shift: has the balance of interests changed since 2018–2020 (new infrastructure, new plantations, changed government priorities)?
- Identify grey areas and gaps: technical (sediment/erosion trends, e-flow standards, monitoring data continuity), operational (institutional mandates, transboundary coordination), and evidentiary.
- Stakeholder mapping and problem framing: map who was involved in previous efforts versus who should be at the table now (national ministries, basin authorities, county/regional government, hydropower operators, plantation operators, communities – fisher and pastoralist representatives, civil society, researchers) and co-draft a shared problem statement.

2. Co-Developing the Work Plan (October 2026–January 2027, 4 months)

Building on the diagnostic phase, this stage translates shared understanding into a concrete, agreed work plan for the technical work ahead. It defines the specific questions the trade-off analysis is meant to answer, the tools and scenarios to be used, and the institutional arrangements needed to carry the work forward.

- Agree trade-off questions: what decisions is this analysis meant to inform and which socio-economic-environmental benefits should be maximised?
- Screen candidate assessment approaches against the agreed trade-off questions and available data, without committing in advance to a specific tool: options range from lighter scoring and multi-criteria approaches to fuller quantitative modelling, drawing on methods developed within CGIAR and elsewhere, with the final choice depending on data availability, timeline, and stakeholder needs.
- Define scenarios: bracket plausible futures using both drying and wetting climate branches, plus development scenarios (current plans versus constrained irrigation, hydropower, etc.).
- Map data needs to responsible institutions: what is available, what is missing, and questions of ownership and sharing.

- Agree the modelling framework and indicator set (hydropower output, irrigation deficit, e-flow compliance, fish/ecosystem proxy, sediment yield, livelihood indicators).
- Set the engagement schedule: sequence of technical working sessions, validation workshops, and a policy dialogue specifically on environmental flows and reservoir operation.

3. Data Acquisition and Assessment Set-Up (February–September 2027, 8 months)

With trade-off questions and scope agreed, this phase assembles the data and assessment infrastructure needed to generate updated scenarios. The specific method, whether a quantitative hydrological model, a scoring-based multi-criteria approach, or a mix depending on where good data exists, is finalised as part of the tool-screening step in Phase 2, so this phase is structured to accommodate any of these. Throughout, the upper, middle and lower basin reaches are considered explicitly, given the differing pressures across the basin: deforestation and sedimentation upstream, irrigation and hydropower operation midstream, and ecosystem and fishery outcomes downstream.

- Remote-sensing data acquisition: precipitation (CHIRPS), land use/land cover (Landsat/Sentinel via Google Earth Engine), and evapotranspiration/water use (WaPOR), to update and extend existing LULC and hydro-climate datasets beyond 2020.
- Institutional data acquisition: hydrometric and meteorological records from the National Meteorological Institute and Ministry of Water and Energy, reservoir operation and sediment records from dam operators, and fisheries and livelihood statistics from relevant county and zonal offices.
- Data-gap assessment: identify where records are missing, discontinuous, or held by different institutions without shared access, and agree interim proxies or imputation approaches where gaps cannot be closed within the programme timeline.
- Assessment set-up: configure the selected approach, whether a basin water balance/sediment model or a scoring-based framework, establishing a baseline against current conditions before layering updated climate and development scenarios.
- Operationalise the agreed indicator framework (hydropower output, irrigation deficit, e-flow compliance, fish/ecosystem proxies, sediment yield, livelihood indicators) within the selected assessment structure.
- Share an interim conceptual model and data-gap assessment with stakeholders for validation before committing to full scenario runs.

4. Trade-off Pathway Analysis (October 2027–March 2028, 6 months)

This phase applies the selected assessment approach across the agreed climate and development scenarios to generate an updated set of trade-off pathways, drawing on the multi-objective logic used or a comparable scoring-based ranking of options. Because current climate projections diverge in direction as well as magnitude, scenarios are run across both drying (CMIP5/RCP) and wetting (CMIP6/SSP) branches, and results are presented with explicit uncertainty ranges rather than as single central estimates.

- Generate a ranked or trade-off set of alternative operating and development pathways across the agreed indicators, updating the past trade-off frontier with current data, using whichever method (quantitative or scoring-based) was selected in Phase 2.
- Conduct uncertainty analysis across the climate scenario branches, and flag where trade-off conclusions are robust versus scenario-dependent.
- Translate model output into stakeholder-facing formats: scenario scorecards, and basin trade-off storylines.
- Present results back to stakeholders and test them against local and institutional knowledge, particularly on distributional questions – which pathways shift risk onto downstream and dryland communities with fewer alternative livelihood options.
- Map results against current policy and investment plans to identify where trade-offs are likely to be politically or operationally contentious.

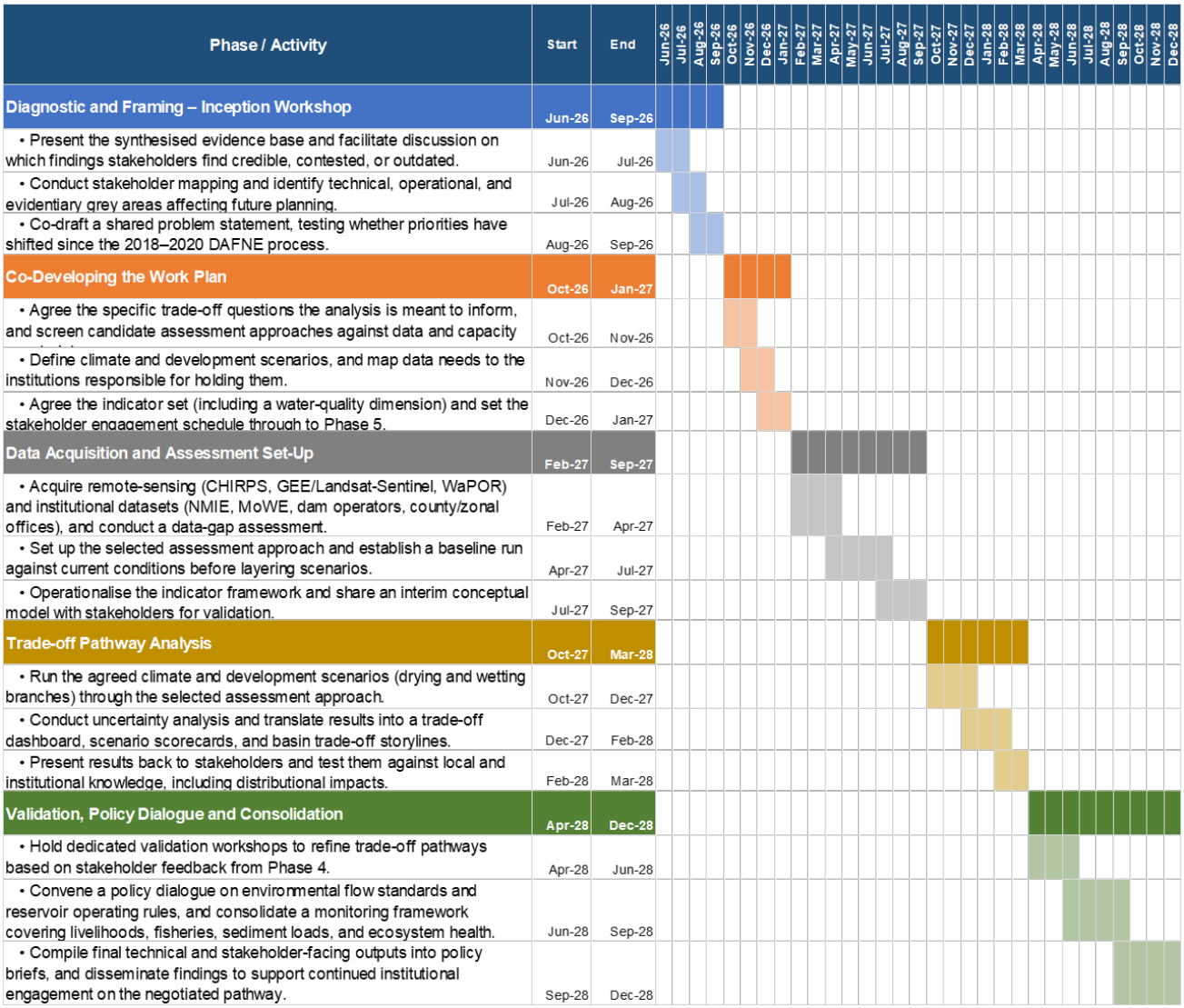
5. Validation, Policy Dialogue and Pathway Deliberations (April–December 2028, 9 months)

The final technical phase moves from analysis towards identifying opportunities for compromise, addressing directly the extent to which the past negotiated pathway was, or was not, taken up, and what would need to differ this time for results to translate into practice.

- Hold dedicated validation workshops to refine trade-off pathways in light of stakeholder feedback from Phase 4.
- Convene a policy dialogue specifically on e- flow standards and reservoir operating rules, building on the negotiated pathway precedent.
- Work toward agreed principles for e-flows/ reservoir operation/irrigation and fisheries development, explicit about the trade-offs each principle implies.
- Identify the institutional and operational changes (mandates, coordination mechanisms, data-sharing arrangements) needed for adoption, drawing on any identified gaps between previous agreed pathways and implementation
- Compile and disseminate final technical outputs (e.g. conceptual model/scenario model/indicator matrix, trade-off dashboard/data-gap assessment/uncertainty analysis) and stakeholder-facing outputs (e.g storylines, risk/opportunity maps, scorecards, summary of priorities).

Gantt Chart

Phase / Activity	Start	End
Diagnostic and Framing – Inception Workshop	**Jun-26**	**Sep-26**
• Present the synthesised evidence base and facilitate discussion on which findings stakeholders find credible, contested, or outdated.	Jun-26	Jul-26
• Conduct stakeholder mapping and identify technical, operational, and evidentiary grey areas affecting future planning.	Jul-26	Aug-26
• Co-draft a shared problem statement, testing whether priorities have shifted since the 2018–2020 DAFNE process.	Aug-26	Sep-26
Co-Developing the Work Plan	**Oct-26**	**Jan-27**
• Agree the specific trade-off questions the analysis is meant to inform, and screen candidate assessment approaches against data and capacity	Oct-26	Nov-26
• Define climate and development scenarios, and map data needs to the institutions responsible for holding them.	Nov-26	Dec-26
• Agree the indicator set (including a water-quality dimension) and set the stakeholder engagement schedule through to Phase 5.	Dec-26	Jan-27
Data Acquisition and Assessment Set-Up	**Feb-27**	**Sep-27**
• Acquire remote-sensing (CHIRPS, GEE/Landsat-Sentinel, WaPOR) and institutional datasets (NMIE, MoWE, dam operators, county/zonal offices), and conduct a data-gap assessment.	Feb-27	Apr-27
• Set up the selected assessment approach and establish a baseline run against current conditions before layering scenarios.	Apr-27	Jul-27
• Operationalise the indicator framework and share an interim conceptual model with stakeholders for validation.	Jul-27	Sep-27
Trade-off Pathway Analysis	**Oct-27**	**Mar-28**
• Run the agreed climate and development scenarios (drying and wetting branches) through the selected assessment approach.	Oct-27	Dec-27
• Conduct uncertainty analysis and translate results into a trade-off dashboard, scenario scorecards, and basin trade-off storylines.	Dec-27	Feb-28
• Present results back to stakeholders and test them against local and institutional knowledge, including distributional impacts.	Feb-28	Mar-28
Validation, Policy Dialogue and Consolidation	**Apr-28**	**Dec-28**
• Hold dedicated validation workshops to refine trade-off pathways based on stakeholder feedback from Phase 4.	Apr-28	Jun-28
• Convene a policy dialogue on environmental flow standards and reservoir operating rules, and consolidate a monitoring framework covering livelihoods, fisheries, sediment loads, and ecosystem health.	Jun-28	Sep-28
• Compile final technical and stakeholder-facing outputs into policy briefs, and disseminate findings to support continued institutional engagement on the negotiated pathway.	Sep-28	Dec-28



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