Chapter 6
Surface Water and Groundwater Resources of Ethiopia: Potentials and Challenges of Water Resources Development

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Abstract Ethiopia has a complex topography, diversified climate, and immense water resources. The spatiotemporal variability of the water resources is characterized by multi-weather systems rainfall of the country. Most of the river courses become full and flood their surroundings during the three main rainy months (June–August). West-flowing rivers (Abay, Baro-Akobo, Omo-Gibe, and Tekeze) receive much rainfall unlike the northeast- (Awash) and east-flowing rivers (Wabishebele and Genale-Dawa) which receive normal to low rainfall. Although it needs further detailed investigation, according to the current knowledge, the country has about 124.4 billion cubic meter (BCM) river water, 70 BCM lake water, and 30 BCM groundwater resources. It has a potential to develop 3.8 million ha of irrigation and 45,000 MW hydropower production. This chapter discusses and presents the water resources of Ethiopia and the different challenges faced by the water sector to contribute to the economic development.

Keywords Ethiopia · Surface water · Groundwater · Irrigation · Hydropower

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6.1 Introduction

Ethiopia, with a total area of approximately 1.13 million km^2, is a country that is characterized by a topography that consists of a complex blend of massive highlands, rugged terrain, and low plains. The Great Rift Valley of the eastern Africa divides the country into two plateaus and stretches from north–east to south–west with 40–60 km wide flat-lying plain in the east, south, and west borders of the country that has an elevation of around 600 m above mean sea level (amsl). It creates three major relief regions in the country: the Western Highlands, the Eastern Highlands, and the low-lying Rift Valley and Western Lowlands. The elevation also ranges between two extremes from 125 m below mean sea level at Danakil Depression to 4,620 m amsl at Ras Dejen (Dashen) peak.

Ethiopia has a diversified climate ranging from semi-arid desert type in the lowlands to humid and warm (temperate) type in the southwest (Beyene 2010). Hurni (1982), Osman (2001), and Seleshi and Demaree (1995) also described high inter- and intra-annual rainfall variability in Ethiopia. The mean annual rainfall of Ethiopia ranges from 141 mm in the arid area of eastern and northeastern borders of the country to 2,275 mm in the southwestern highlands (Berhanu et al. 2013). The complex topographical and geographical features of the country have a strong impact on these spatial variations of climate and different rainfall regimes in Ethiopia (National Meteorology Service Agency 1996; Zeleke et al. 2013).

Ethiopia is also endowed with a substantial amount of water resources. The country is divided into 12 basins; 8 of which are river basins; 1 lake basin; and remaining 3 are dry basins, with no or insignificant flow out of the drainage system. Almost all of the basins radiate from the central plateau of the country that separate into two due to the Rift Valley. Basins drained by rivers originating from the mountains west of the Rift Valley flow toward the west into the Nile River basin system, and those originating from the Eastern Highlands flow toward the east into the Republic of Somalia. Rivers draining in the Rift Valley originate from the adjoining highlands and flow north and south of the uplift in the center of the Ethiopian Rift Valley.

Since almost all river basins originate from the highlands and high rainfall areas, they have huge amount of surface water running in the river basin systems and Ethiopia is considered to be the water tower of the Horn of Africa. This potential is not fully utilized and translated into development because of many factors including limited financial resources, technical challenges, and lack of good governance in the water sector. This chapter attempts to review the potential of the surface water and groundwater resources of the country, and the opportunities and challenges of the water sector development.

6.2 Climate of Ethiopia

The climate in Ethiopia is geographically quite diverse, due to its equatorial positioning and varied topography (Block 2008). The climatic condition of the country is traditionally classified into five climatic zones based on the altitude and temperature variation. It ranges from the high cold area named as “wurch” to the highly hot

Table 6.1 Traditional climatic zones of Ethiopia and their physical characteristics. (Source: NRMRD-MoA 1998)

Zones	Altitude (m) (NRMRD-MoA 1998)	Mean annual rainfall (mm) (NRMRD-MoA 1998)	Length of growing periods (days) (NRMRD-MoA 1998)	Mean annual temperature (°C) (NRMRD-MoA 1998)	Area share (%)
Wurich (cold to moist)	> 3,200	900–2,200	211–365	Below 11.5	0.98
Dega (cool to humid)	2,300–3,200	900–1,200	121–210	11.5–17.5	9.94
Weynadega (cool sub humid)	1,500–2300	800–1,200	91–120	17.5–20.0	26.75
Kola (Warm semiarid)	500–1,500	200–800	46–90	20.0–27.5	52.94
Berha (Hot arid)	< 500	Below 200	0–45	Above 27.5	9.39

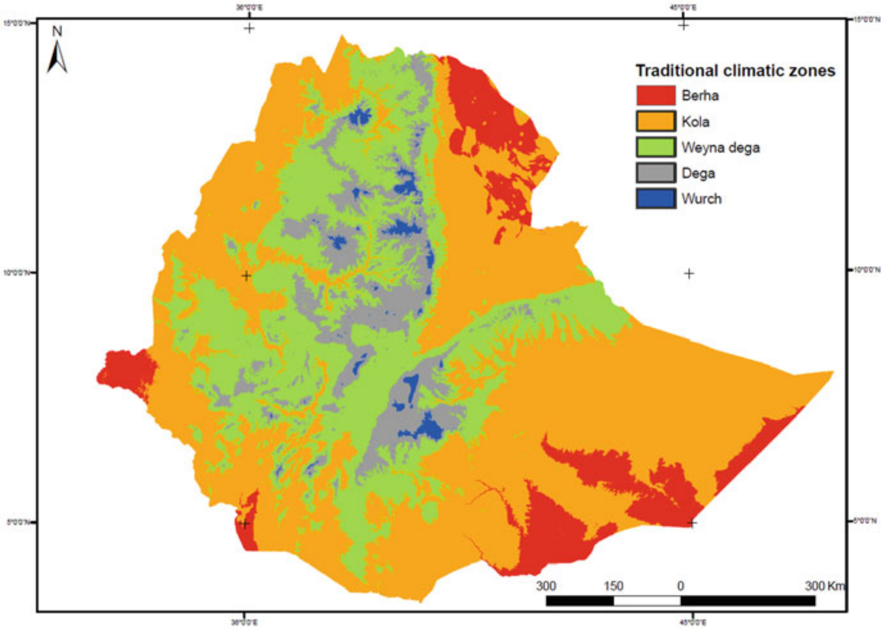

Fig. 6.1 Traditional climatic zones of Ethiopia

climatic condition area known as "Berha." Their physical characteristics and spatial distribution are presented in Table 6.1 and Fig. 6.1.

The climate of the country is described by the statistical interpretation of precipitation and temperature data recorded over a long period of time. As it is described on the

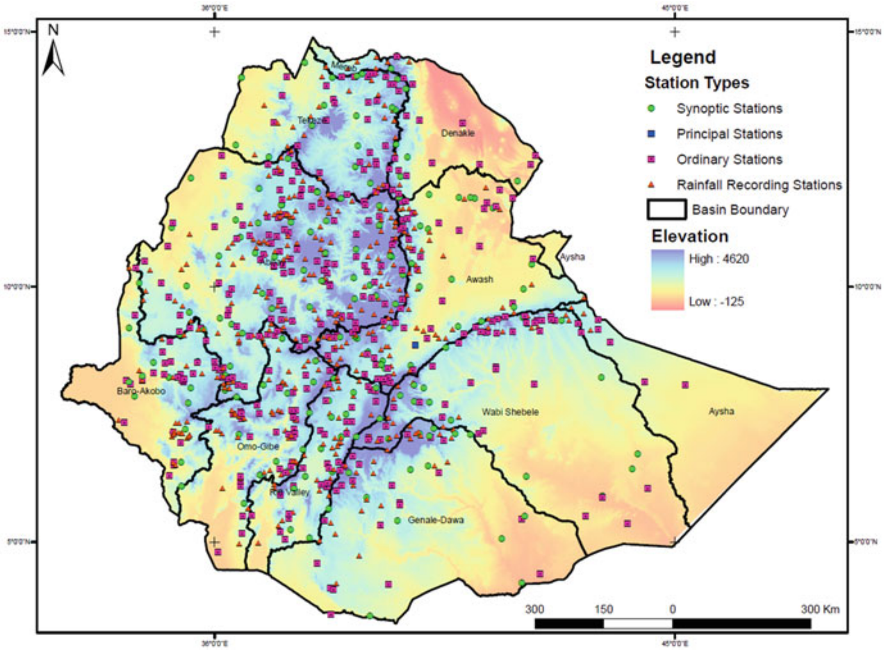

Fig. 6.2 Meteorological station distribution and types per basin and elevation variation in Ethiopia

web site of the National Meteorological Agency of Ethiopia (http://www.ethiomet.gov.et), there are a total of 919 active meteorological stations in the country (NMA 2013). These stations are classified into four classes according to the standard classification of the World Meteorological Organization (WMO). About 171 of them are synoptic and principal stations that have observations for most of the climatic elements, 363 stations are ordinary stations that have precipitation and temperature data only, and the remaining 385 stations only have rain gauge to measure the daily accumulated rainfall. Figure 6.2 shows the meteorological station distribution and types in Ethiopia.

6.3 Rainfall in Ethiopia

Rainfall in Ethiopia is the result of multi-weather systems that include Subtropical Jet (STJ), Intertropical Convergence Zone (ITCZ), Red Sea Convergence Zone (RSCZ), Tropical Easterly Jet (TEJ), and Somali Jet (NMA 1996). The intensity, position, and direction of these weather systems lead the variability of the amount and distribution of rainfall in the country. Thus, the rainfall in the country is characterized by seasonal and interannual variability (Camberlin 1997; Shanko and Camberlin 1998; Conway 2000; Seleshi and Zanke 2004). Moreover, the spatial distribution of rainfall in Ethiopia is significantly influenced by topographical variability of the country (NMA 1996; Camberlin 1997). This makes the rainfall system of the country more complex.

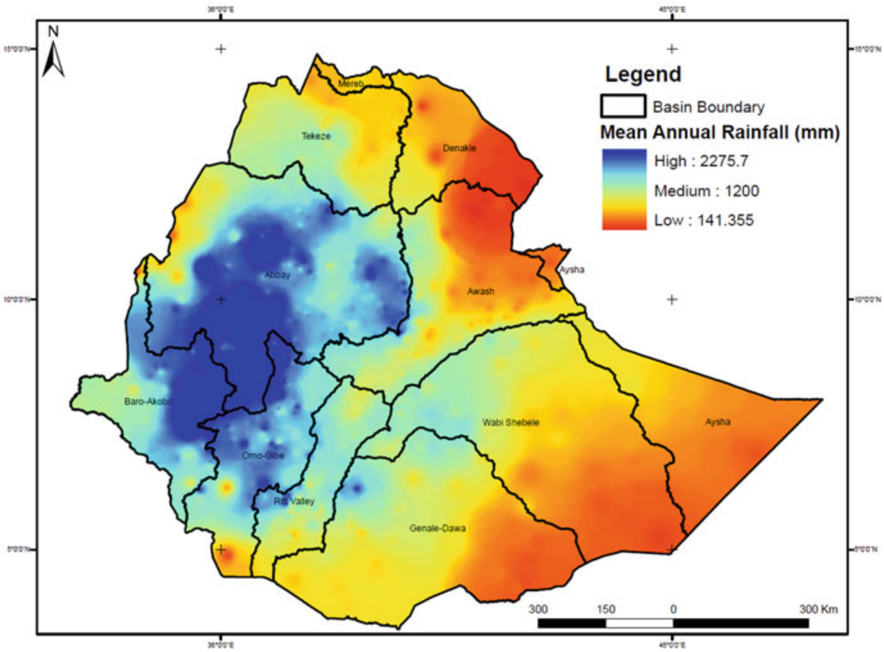

Fig. 6.3 Spatial variability of the mean annual rainfall in Ethiopia

6.3.1 Spatial Variability of Rainfall

The regional and global change of the weather systems and the topographic variation along with the seasonal cycles are responsible for the spatial variability of rainfall in the country. The magnitude of the mean annual rainfall in the southeast, east, and northeast borders of the country is lower by as much as less than 200 mm. The central and western highlands of the country receive an annual mean rainfall of more than 1,200 mm. Looking into the rainfall variability of the country by river basins, the eastern flowing river basins (Wabishebele and Genale-Dawa) receive low to medium rainfall, whereas those that flow to the west (Abay, Baro-Akobo, Omo-Gibe, and Tekeze) receive a mean annual rainfall in the range of medium to high (Fig. 6.3).

6.3.2 Temporal/Seasonal Rainfall Variability

Seasonal rainfall in Ethiopia is driven mainly by the migration of the ITCZ, tropical upper easterlies, and local convergence in the Red Sea coastal region (Conway 2000). The exact position of the ITCZ changes over the course of the year, oscillating across the equator from its northernmost position over northern Ethiopia in July and August, to its southernmost position over southern Kenya in January and February

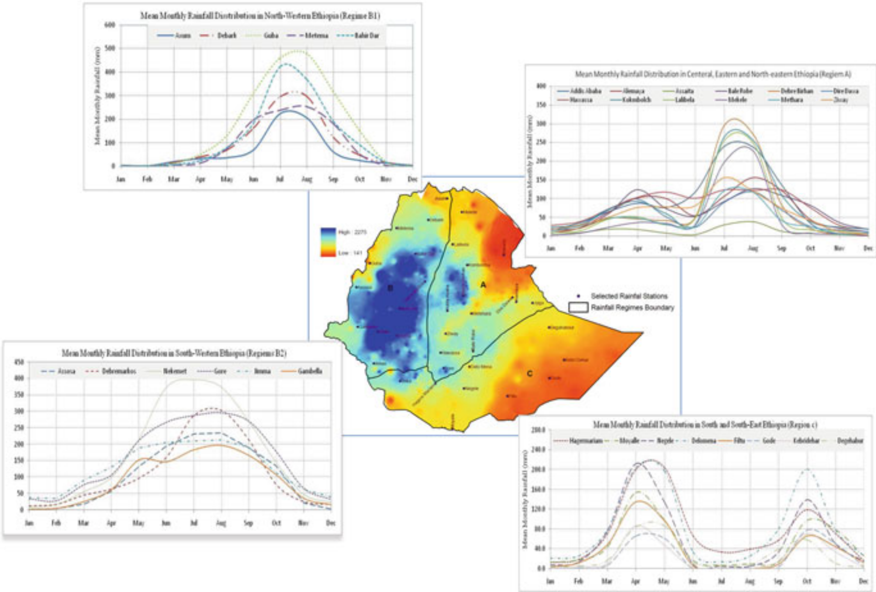

Fig. 6.4 Seasonal rainfall distribution in Ethiopia

lead the interannual variability of rainfall in the country (McSweeney et al. 2012). The complex topographical variations of the country are also responsible for this seasonal variation rainfall in the country (Abebe 2010).

Most of the area in Ethiopia receives one main wet season (called "Kiremt") from mid-June to mid-September (up to 350 mm per month in the wettest regions), when the ITCZ is at its northernmost position (McSweeney et al. 2012). Parts of northern and central Ethiopia also have a secondary wet season of erratic, and considerably lesser, rainfall from February to May (called the "Belg"). The southern regions of Ethiopia experience two distinct wet seasons, which occur as the ITCZ passes through this to its southern position. The March to May "Belg" season is the main rainfall season yielding 100–200 mm of rainfall per month, followed by a lesser rainfall season in October to December called "Bega" (around 100 mm of rainfall per month). The easternmost corner of Ethiopia receives very little rainfall at any time of the year (McSweeney et al. 2012). These unimodal and bimodal rainfall systems are the base for classifying the country into three rainfall regimes (Dawit 2010). Commonly, these rainfall regimes are named as Regime A, Regime B, and Regime C (Fig. 6.4).

Regime A It covers the central and the eastern part of the country, and follows the bimodal rainfall system classified as the long rainy season or locally called "Kiremt" (June–September) and short rains or locally called "Belg" (March–May).

Regime B It is a rainfall region in the western part of the country that covers from southwest to northwest and has a unimodal rainfall pattern (February–November). But the rainy period ranges are varied, if we go through southwest to northwest.

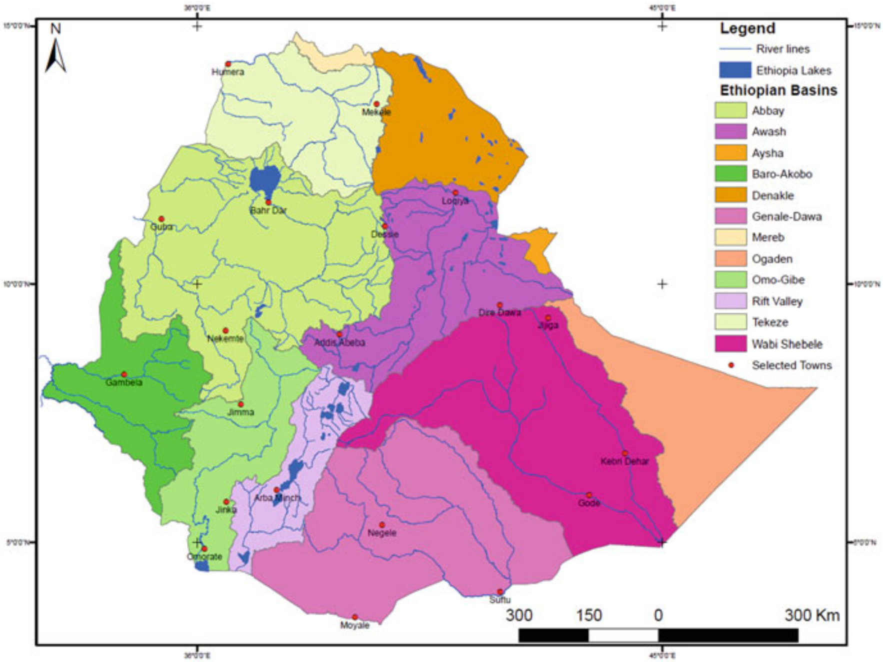

Fig. 6.5 River basin map of Ethiopia

Regime C It comprises the south and southeastern parts of the country and has two distinct wet and dry seasons. The main rainy season is from February to May, and short rains from October to November, and the dry periods are from June to September and December to February.

6.4 Surface Water Resources

Ethiopia constitutes 99.3 % of land area and the remaining 0.7 % is covered with water bodies (MOWE 2013). The country has 12 major basins, 12 large lakes, and differently sized water bodies (Fig. 6.5). However, three of the major basins are dry basins, which do not have any stream flow in these basins. Although it needs update and further detailed investigation, the country's surface water potential as identified and estimated in different integrated river basin master plans is 124.4 billion cubic meter (BCM) (Table 6.2). Since most of the rivers are transboundary, 97 % of this estimated annual stream flow of the country flows out of Ethiopia into neighboring countries and only 3 % of this amount remains within the country.

Similar to the rainfall, the surface water also shows spatiotemporal variability. Spatially, the major rivers in Ethiopia flow into two main directions based on their position from the Great Rift Valley that dissect the country into two major sections:

Table 6.2 Physical characteristics and mean annual flow of surface water at outlet of the river basins. (Source: Respective Basin Master Plan Studies compiled by the web master of Ministry of Water and Energy, MoWE (2013))

NuoO	Basin name	Type	Source	Altitude at source (masl)	Terminal	Altitude at terminal/border (masl)	Flow direction	Area (km^2)	Water Resource	
									Billion m^3	Lt/sec/km^2
1	Abbay	R	Sekela, West Gojam	2,000	Sudan border	500	West (Nile)	199,912	54.40	8.63
2	Awash	R	Ginchi	3,000	Terminal lakes	250	Northeast	110,000	4.90	1.41
3	Aysha	D	–	–	Djibouti border	400	No flow	2,223	0.00	0.00
4	Baro-Akobo	R	Illubabor	3,000	Sudan border	395	West (Nile)	75,912	23.23	9.70
5	Dinakle	D	–	–	Kobar sink	160	No flow	64,380	0.86	0.42
6	Genale-Dawa	R	Bale Mountains	4,300	Somali border	180	East	172,259	6.00	1.10
7	Mereb	R	Zalanbessa	2,500	Eritrean border	900	West (Nile)	77,120	0.72	3.87
8	Ogaden	D	–	–	Somali border	400	No Flow	79,000	0.00	0.00
9	Omo-Gibe	R	Ambo	2,800	Rudolph lake	350	South (Nile)	52,000	16.6	6.66
10	Rift valley lakes	L	Arsi Mountain	4,193	Sudanese border	550	South	5,900	5.64	3.44
11	Tekeze	R	Lasta/Gidan	3,500	Chew Bahir	300	West (Nile)	82,350	8.20	3.16
12	Wabisheble	R	Bale Mountains	4,000	Somali border	200	East	202,220	3.40	0.53

D Dry, *R* River, *L* Lake, *NF* No flow

Table 6.3 Summary of the spatial variability of surface water in Ethiopia

Flow direction	Basins included in the section	Area coverage share (%)	Surface water share (%)
West	Abbay, Baro-Akobo, Mereb, and Tekeze	38.75	69.83
East	Genale-Dawa and Wabishebele	33.34	7.58
South	Omo-Gibe, Rift Valley lake basin	5.15	17.94
Northeast	Awash	9.79	3.95
No flow	Aysha, Dinakle, and Ogaden	12.96	0.69

West and East. The rivers that originate from the western side of central highlands and western plateaus of the country are flowing to the west and joining the Nile system. These include the Abbay, Baro-Akobo, Mereb, and Tekeze basins and cover 39 % of the land mass of the country. This section of the country has the major flow of surface water in the country. It accounts for about 70 % of the estimated surface water flows in this section. The second section includes the basins that originate from the Eastern Highlands and flow toward east. It covers about 33 % of the country land mass but accommodates only 8 % of surface water of the country. The other two sections include the basins along the Great Rift Valley. And they flow to the south and north of the central part of Great Rift Valley around Meki. Awash is the only river basin that flow to the northeast direction and it covers 10 % of the country land mass and 4 % of surface flow in the country. It is the most utilized basin of the country. The south flow section includes two basins, the Rift Valley lake basin and the Omo-Gibe basin. They cover about 5 % of the land mass and 18 % of the surface flow. With regard to the Nile, Ethiopia contributes about 85 % of the Nile water, mainly during the rainy seasons from June to September (Table 6.3).

The temporal variability of the surface water of the country also follows the pattern of the rainfall. The basins that receive two rainfall seasons have two peak flows according to the seasonality of the rainfall. But those basins in the west mostly receive one rainfall season and they have one peak flow months. Although the basins in the west receive a single season rainfall, they receive the largest amount of rainfall and release it in 3–4 months. A summarized description of the seasonality of surface water in Ethiopia is presented in Fig. 6.6 with the help of mean monthly flow of selected hydrological gauging stations and some selected area basin modeling simulations.

Most of the river basin master plan studies do not take into account the surface water resources of the country in open water systems (lakes, wetlands, and flood plains). These systems store significant amount of water. For instance, the Water Audit Modeling Study of the Awash River basin shows that 5.7 BCM water is stored and exposed to evaporation in the lakes, wetlands, and flood plains of the basin (MoWE and FAO 2012). It is an indicator to change our surface water accounting system to understand the surface water potential of the country.

Accordingly, if we assess the major lakes in the country, Ethiopia has 12 major lakes. They cover about 7,300 km^2 area and store about 70 BCM of water (Table 6.4).

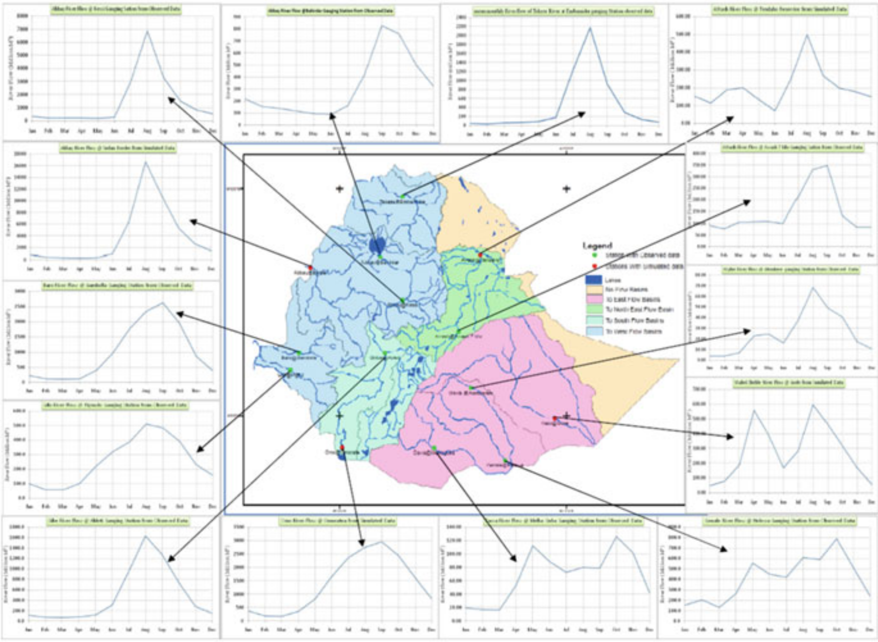

Fig. 6.6 Summarized descriptions of surface water seasonality in Ethiopia

6.5 Groundwater Resource

Always, the occurrence of groundwater is mainly influenced by the geophysical and climatic conditions of the area. The difficulty in obtaining productive aquifers is a peculiar feature of Ethiopia, which is characterized by the wide heterogeneity of geology, topography, and environmental conditions (Alemayheu 2006). Actually, the geology of the country provides usable groundwater and provides good transmission of rainfall to recharge aquifers, which produce springs and feed perennial rivers. In many parts of the country, groundwater is an important source of domestic and industrial water use especially in rural areas and towns. However, the occurrence of groundwater is not uniform because it depends on various environmental and geological factors (Alemayehu 2006). Geologically, the country can be characterized with generalized classifications, such as 18 % of the Precambrian basement, 25 % of the Paleozoic and Mesozoic sedimentary rocks, 40 % of the Tertiary sedimentary and volcanic rocks, and 17 % of the Quaternary sediments and volcanic rocks (MoWR 2009) (Fig. 6.7).

With the understanding of the nature of the distribution of these rocks and the recharge classification of the country, Alemayehu (2006) estimated the total groundwater reserve of the country as 185 BCM, which is distributed in an area of 924,140 km^2 made of Sedimentary, Volcanic, and Quaternary rocks and sediments, including the highlands and the Rift Valley. In this estimation, the mean groundwater

Table 6.4 Morphometric characteristics of lakes in Ethiopia as compiled from different sources. (Sources: Awlachew 2007; Ayenew and Robert 2007; Dinka 2012; Hughes and Hughes 1992; Mohamed et al. 2013; Kebede 2005; Bird Life International 2013)

	Maximum length (km)	Maximum width (km)	Surface area (km^2)	Average depth (m)	Maximum depth (m)	Water volume (BCM)	Surface elevation (amsl)
Lake Abaya (Awlachew (2007))	79.20	27.10	1,140.00	8.61	24.50	9.82	1,169
Lake Abijatta (Ayenew and Robert (2007))	17.00	15.00	180.00	8.00	14.00	1.00	1,578
Lake Ashenge (Bird Life International (2013))	5.00	4.00	140.00	14.00	25.50	0.25	2,409
Lake Awassa (Ayenew and Robert (2007))	16.00	9.00	129.00	11.00	22.00	1.00	1,680
Lake Basaka (Dinka (2012))	–	–	48.50	8.40	–	0.28	950
Lake Chamo (Awlachew (2007))	33.50	12.50	317.00	10.23	14.20	3.24	1,110
Lake Chew Bahir (Hughes and Hughes (1992))	64.00	24.00	1,125.00	–	7.50		570
Lake Hayq (Mohamed et al. (2013))	6.39	4.99	23.00	32.65	81.41	1.01	1,903
Lake Langano (Hughes and Hughes (1992))	23.00	16.00	230.00	20.00	46.00	3.80	1,585
Lake Shala (Ayenew and Robert (2007))	28.00	12.00	370.00	86.00	266.00	37	1,550
Lake Tana (Kebede (2005))	84.00	66.00	3,156.00	9.00	14.00	28.40	1,788
Lake Ziway (Ayenew and Robert (2007))	31.00	20.00	440.00	3.00	9.00	1.00	1,636

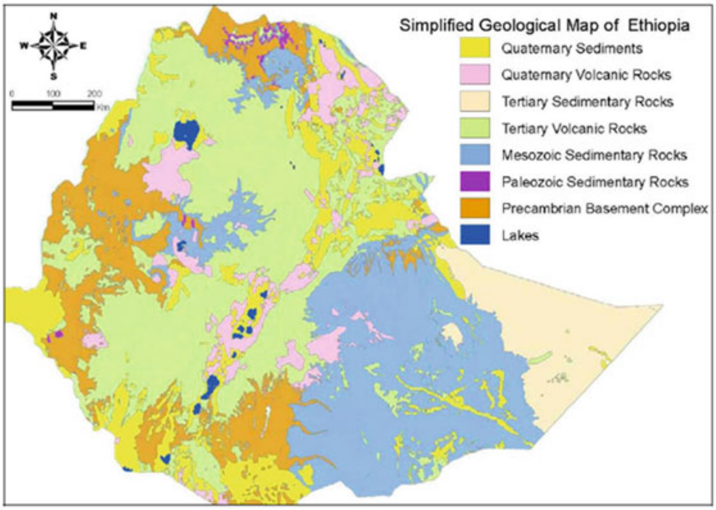

Fig. 6.7 Simplified geological map of Ethiopia. (Adopted from Water Information and Knowledge Management Project (MoWR 2009))

recharge for the entire country is assumed as 200 mm. But it should be confirmed with a detailed hydrogeological investigation to use as a reliable potential. Hydrogeological investigations refer to the study of lithological, stratigraphical, and structural aspects of a territory using basic geologic methods and will be finalized in the understanding of the factors that regulate effective infiltration, groundwater reserve, and circulation and outflow of the groundwater (Alemayehu 2006). The Ethiopia Geological Survey so far covers only 20.4 % of the Ethiopian landmass that has been mapped at 1:250,000 scale, about 36.8 % of the country is mapped at one million scale and the whole country at two million scale (MoWE 2013).

The Ethiopian National Groundwater Database (ENGDA) has been implemented since 2003 jointly by the Ministry of Water Resources, Addis Ababa University, and Geological Survey of Ethiopia. It has a close collaboration with the regional water resources development bureaus, Water Work Enterprises, NGOs, and contractors. ENGDA has large attributes and collections of about 5,000 boreholes in the country. The availability of this groundwater database is playing an important role in understanding the hydrologic cycle and discharge–recharge relation, for assessing and managing water resources within the hydrogeologic environment.

At present, detailed groundwater assessments are ongoing in several areas and these indicate that the previously estimated groundwater usage potential of 2.6 BCM was underestimated. And it needs to be revised. Best guesses in this respect range between 12 and 30 BCM, or even more if all aquifers in the lowlands are assessed (MoWR and GW-MATE 2011). Studies for irrigated agriculture in Kobo, Raya, and Adaa Bechoo suggest that regional aquifers are deep and water movement crosses surface basin boundaries. It is estimated that the groundwater reserve of the Kobo Girana Valley alone is in the order of 2.5 BCM, that of Raya is 7.2 BCM, and Adda Bechoo is 0.96 BMC (AGWATER 2012).

6.6 Water Resources-Based Development Potentials in Ethiopia

- Water resources are the central elements for the development of Ethiopia. One can easily understand that "water-centered development" is the key for growth and transformation of the country. The growth and transforming plan (GTP) also considers and targets to enhance the uses of country's water resources (MoFED 2010). It gives priority for the expansion of small-, medium-, and large-scale irrigation to the extent of possible, hydropower developments to satisfy the energy demand of the upcoming industries and then the water supply and sanitation system for the satisfaction of the inhabitants. Technologies that will enable us to use the water resources will also be used extensively. The GTP recognized to expand watershed management and to carry out effective water- and moisture-retaining works that will help to cope the challenges of climate change.
- Planning should support with information about the resources availability. Thus, to enhance the use of country water resources, we have to understand the potential with spatial and temporal variations of the resource. For the past two to three decades, the government of Ethiopia is exerting efforts to cover all the major river basins with the integrated master plan studies. All the master plan studies were devoted to assess the availability of resources and potentials of the river basins for different developments (MoWR 1996, 1997, 1998a, b; PDRE 1989).
- Some of the master plan studies need to be updated to reflect the current situation on the ground. With this regard, other resources that include the water sector development program (MoWR 2002, 2010), feasibility studies and detailed designs of different development projects (WWDSE 2005; Halcrow and MCE 2007), and other basin-level studies (MoWE and FAO 2011, 2012) are reviewed to estimate and analyze the different water resources development potentials of the country.

As a part of the water-centered development strategy in the country, it is essential to share and to own the water sector vision and principle of the country. As it is clearly described on Ethiopian Water Sector Policy, water is commonly owned economic and social goods that should be accessible to all in sufficient quantity and quality to meet basic human needs. Additionally, the principles emphasize the need for a rural-centered, decentralized, integrated, and participatory water management system as well as the attainment of social equity, economic efficiency, empowerment of water users, and sustainability. Thus, the national water sector vision is to enhance and promote all national efforts towards the efficient, equitable, and optimum utilization of the available water resources of Ethiopia for significant socioeconomic development on a sustainable basis.

6.7 Irrigation Potentials in the River Basins

Tadesse (2002) argued that food shortage can be minimized if farmers have access to irrigation water. Awulachew et al. (2007) also indicated that, as the prevalent rainfed agriculture production system together with the progressive degradation of

Table 6.5 Irrigation potential of the country by basin. (Sources: Awulachew et al. 2007; MoWE and FAO 2012; FAO 1997)

Basin	Irrigation potentials (ha) compiled from respective master plan studies			
	Small scale	Medium scale	Large scale	Total
Abbay (Awulachew et al. (2007))	45,856	130,395	639,330	815,581
Awash (MoWE and FAO (2012))	198,632	–	139,627	198,632
Ayisha	–	–	–	–
Baro-Akobo (Awulachew et al. (2007))			1,019,523	1,019,523
Denakil (Awulachew et al. (2007))	2,309	45,656	110,811	158,776
Genale-Dawa (Awulachew et al. (2007))	1,805	28,415	1,044,500	1,074,720
Mereb (FAO (1997))				5,000
Ogaden	–	–	–	–
Omo-Ghibe (Awulachew et al. (2007))	–	10,028	57,900	67,928
Rift Valley (Awulachew et al. (2007))	–	4,000	45,700	139,300
Tekeze (Awulachew et al. (2007))	–	–	83,368	83,368
Wabishebele (Awulachew et al. (2007))	10,755.00	55,950	171,200	237,905
Total				3,800,733

the natural resources base and climate variability has aggravated the incidence of poverty and food insecurity. Currently, the Ministry of Water and Energy identified more than 500 irrigation sites with a total of 3.8 million ha irrigable land. The details of this irrigation potential per Ethiopian major river basin are presented in Table 6.5.

From this irrigation potential, the GTP is being planned to develop 15.4 % of the potential at the end of 2015. It will boost the irrigable land of the country to 785,582.6 ha. Accordingly, over the past 2 years and 6 months of the GTP, the performance of the ministry indicates that the study and design have been finalized for 473,225 ha, and 148,836 ha of land has been constructed out (MoWE 2013).

Generally, up until the first 6 months of the 2012–2013 fiscal year, 276,078.6 ha of land has been at different levels of studies and design through medium- and large scale-irrigation schemes. On the other hand, several irrigation development projects are under construction, among those to mention few: Kesem-Tendaho, Koga, Rib, Gidabo, Megech-Sereba, Kobo-Girana, Raya-Azebo, and Adea-Betcho. This has increased the overall irrigation coverage growth from 2.4 to 7.34 % (MoWE 2013).

Table 6.6 Hydropower production potential of Ethiopian river basins. (Source: Solomon 1998)

River basin	Number of potential sites				Hydropower potential (GWh/year)	Percentage share of the total (%)
	Small scale < 40 MW	Medium scale 40–60 MW	Large scale < 60 MW	Total		
Abbay	74	11	44	129	78,800	48.9
Awash	33	2	–	35	4,500	2.8
Baro-Akabo	17	3	21	41	18,900	11.7
Genale–Dawa	18	4	9	31	9,300	5.8
Omo–Gibe	4	–	16	20	35,000	22.7
Rift Valley lakes	7	–	1	8	800	0.5
Tekeze–Angereb	11	1	8	20	6,000	4.2
Wabishebelle	9	4	3	16	5,400	3.4
Total	*173*	*25*	*100*	*300*	*159,300*	

6.8 Hydropower Development Potentials in the River Basin

Despite the huge amount potential of the hydropower resources of Ethiopia, the country's energy sector has been highly dependent on the biomass sources. According to Halcrow and MCE (2006), in the year 2000, 73.2 % of energy came from woody biomass, 15.5 % from non-woody biomass (8.4 % cow dung, 6.4 % crop residue, and 0.7 % biogas), 10.3 % petro fuels, and 1 % hydropower. In this period, only 360 MW has been exploited from the hydropower source (Solomon 1998).

Later, the Ethiopian government recognized the power shortage and its role in the economic development of the country (MoFED 2006) and planned on developing a number of hydropower projects. In total, generating capacity is to be increased to about 2,218 MW at the end of the Plan for Accelerated and Sustainable Development to End poverty (PASDEP) period (2009–2010). Thus, the government has highly mobilized its full capacity towards tapping water for the energy purpose. The Grand Ethiopian Renaissance Dam, which has a capacity to generate 6,000 MW electricity, and the Gibe cascading dam's hydropower projects are the parts and parcel of this motivation. All will scale up the access of electricity from 2,000 MW in 2009–2010 to 10,000 MW by the end of GTP, 2015 (MoFED 2010).

So, to have such development plan and commitment, understanding the potential sources is essential. Similar to irrigation developments, integrated master plan studies identified the potential sites for the dam's construction and hydropower developments. Solomon (1998) compiled a total of 300 different-scale hydropower sites in eight river basins of Ethiopia (Table 6.6). With these development sites, Ethiopia has 45,000 MW exploitable hydropower potential (MoFED 2010) which can generate 159,300 GWH energy annually (Table 6.7).

In the 2.5 years of GTP, electric power plants have gone operational.The constructions of Fincha-Amerti-Neshe, Gibe III hydropower, and Grand Ethiopian Renaissance Dam projects are under way and their 90, 72, and 20 %, respectively, construction of work is completed.

Table 6.7 Existing, under construction, and near-planned hydropower projects in Ethiopia

Project/site name	Basin	Installed capacity (MW)	Status
Beles	Abbay (Blue Nile)	460.0	Existing
Fincha	Abbay (Blue Nile)	134.0	Existing
TisAbbay I HPP	Abbay (Blue Nile)	11.5	Existing
TisAbbay II HPP	Abbay (Blue Nile)	67.0	Existing
Awash II HPP	Awash	32.0	Existing
Awash III HPP	Awash	32.0	Existing
Koka HPP	Awash	43.5	Existing
Gilgel Gibe I	Omo Gibe	180.0	Existing
Gilgel Gibe II	Omo-Gibe	420.0	Existing
Tekezé	Tekeze (Atbara)	300.0	Existing
MelkaWakena HPP	Wabishebele	153.0	Existing
Sub Total		*1,833*	
Fincha-Amerti-Neshe (FAN)	Abbay (Blue Nile)	100	Under construction
Great Ethiopian Renaissance Dam	Abbay (Blue Nile)	6,000	Under construction
Gilgel Gibe III	Omo Gibe	1,870	Under construction
Sub Total		*7,970*	
Beko Abo	Abbay (Blue Nile)	2,100	Planned
Chemoga-Yeda	Abbay (Blue Nile)	278	Planned
Karadobi	Abbay (Blue Nile)	1,600	Planned
Mendaia II	Abbay (Blue Nile)	2,800	Planned
Genale-Dawa	Genale-Dawa	256	Planned
Halele Worabese	Omo River	440	Planned
Gilgel Gibe IV	Omo-Gibe	2,000	Planned
Tekeze II	Tekeze (Atbara)	450	Planned
Sub Total		*9,924*	
Total project capacity		*19,727*	

Source MoWR

6.9 Water Supply and Sanitation Development Potential

1. Although an immense surface water and groundwater availability is recorded in the country, Ethiopia has one of Africa's lowest rates of accesses to freshwater supply, sanitation, and hygiene service. Based on the population censes and its growth rate provided by the Central Statistics Authority (CSA 2007), the projected demand for clean water at the end of GTP is about 2.6 BCM.
2. According to the GTP, 29,678,721 people live in rural areas and 3,613,216 people in urban areas are expected to become beneficiaries of safe drinking water by 2015 (MoWE 2013).
3. To achieve the goals set by the GTP, the Ministry of Water and Energy together with other partners has designed, and construction is being made for, different safe water facilities. The water supply development works include:

- Newly constructed water schemes
  - 26,739 hand-dug wells
  - 7,372 medium-deep water wells
  - 7,212 spring developing works
  - 880 deep-dug water wells
  - 335 water harvesting ponds
  - 545 rainwater and surface drinking water tankers
  - 1,968 rural piped water system construction
- Expansion and rehabilitation
  - 11,935 hand-dug wells
  - 2,968 hand pump medium deep water wells
  - 8,032 developed springs
  - 377 deep dug water wells
  - 785 rural piped water systems
  - 153 rain harvesting works
  - 70 old water institutions expansion works

4. Overall, 68,514 water schemes have been built. Moreover, more than 8,896 old rural water service schemes have been maintained and have become operational (MoWE 2013).

6.10 Challenges in Water Resources Developments

Despite the potential, the availability of resources and demand of the water resources and its products in Ethiopia, the water sector development is still at infancy. A number of factors that can group into four main streams as natural, technical, economical, and institutional factors hinder the water sector development. Thus, critical analysis and understanding of these challenges are required to overcome them and to arrive at appropriate mitigating strategies in the water sector.

6.10.1 Natural Challenges

The spatial and temporal variability of climate, topography, soil, and geology of the country induce high variability in the amount and distribution of water resources in Ethiopia. It hinders the water sector development. Rainfall has high seasonal and spatial variability; it also makes water availability seasonal. Since rainfall is erratic and unreliable, unless water harvesting structures (reservoirs, or ponds) are developed for off-season supply and groundwater recharge in some cases, water-based development will be challenged. The occurrence of extreme events, floods and drought is rising in intensity and extent, which hinders the development of water sector. The rugged topography also leads most riverwater flows into gorge, thereby hindering large storage and irrigation development. Also, most of the population, about 80 %, is living in the 30 % of the highlands of the country; thus, the water resource developments that can be done in the lowlands suffer with shortage of labor and focus on potential lowland areas.

6.10.2 Technical Challenges

Due to the variability in the nature of the climatic, topographic, and water resources, the country needs a wide varied knowledge and information. But there is little or no organized knowledge and information about the water resources of the country. Most information is dispersed and detailed studies at a desired scale and depth are scant. About 470 hydrological gauging stations, which cover only 40 % of the country, are operational. This is very little by any standard and lot of hydrologic information of river basins is estimated using models that may not be verified using observed data. To cover the ungauged section of the country, engineers are using rainfall–runoff methods, but there are no reliable rainfall–runoff methods that address the climatic and topographic variability of the country. Again such methods and models need highly skilled professionals. There is no dedicated national research, academic and development institute on water to assess the challenges of water resources with branch office at various climatic regions. Regional water resource bureaus are mainly charged with data gathering and project supervision instead of water resources research and outreach program. Farmers practicing irrigation have limited access to technical support. The existing system also suffers from high staff turnover.

6.10.3 Economic Challenges

The rugged topographic and the nature of the river flow again make the hydraulic structure to be expensive and need much investment. Developing countries such as Ethiopia have many priority areas (education, health, etc.), which demand huge budget and investments; thus, the water resources developments do not get sufficient budget allocation. By their nature, water resources developments are not short payable investments, securing finance for water resources projects from either lenders or private investors are challenging.

6.10.4 Hydropolitics Challenges

Most of the rivers in Ethiopia are transboundary. To date, no formal transboundary water use and management agreements exist between riparian countries. Development of projects on shared rivers, thus, leads to political discussions and sometimes it is challenging to have smooth development; often this will lead to lack of discouragement for the financing institution to lend. The terms of sharing the transboundary water resources have been a very big hindrance for transboundary water management and utilization of the Nile River equitably. This will require realizing the current setting and the needs of all basin countries and seeking for an all-winning scenario where every basin country uses the resources equitably.

6.11 Conclusion

As we see in this review work, Ethiopia has huge surface water and groundwater resources potential that can be harnessed for developments. It is clearly seen that the water centered development thinking is the footstep for the economic development of the country. It is started with self-financed development of 6,000 MW hydropower dam on the Abay River. It is time to further pull national resources to face the challenges and change the potentials to reality.

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