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Outlook Water Resource Potential and Irrigation Agriculture Practice in Ethiopia

*Kasye Shitu** *and Adibar Hymiro*

Department of Soil Resource and Watershed Management, Assosa University, Ethiopia

Abstract

In Ethiopia, there has been a general misunderstanding about the water resource potential of the country, irrigation practice, the role of ground water in every aspect in the country especially in irrigation have been lacking. The general objective of this review paper was to receive some information about, the water resource potential and irrigation agriculture practice in Ethiopia from different literatures to provide useful information for decision makers for the planning and management of the water positional of the country for different use. Different literatures which are related with this title have been assessed. In Ethiopia, agriculture is a mainstay of its economy, where around 95% of its output is produced by smallholder farmers. However, with corresponding to the amount and distribution of rainfall crop failure is unavoidable in Ethiopia. Ethiopia has been started traditional irrigation practice since ancient time for the aim of subsistence food production due to unavoidable crop failure. Ethiopia has amble amount of water and irrigation land resource. The surface water potential, groundwater potential and irrigation land of Ethiopia needs update and further detailed investigation. Because there is no consistent and reliable inventory and well-studied and documented with regards this resource of the country. With rash study it has 223.09 BCM water resource potential, 5.3 million hectares of irrigable land. So, as a recommendation it is batter that farther study should be conducted related with the water positional and irrigation practices of Ethiopia in order to get available document for the future time in order to use the resource properly.

Keywords

Agriculture, Ethiopia, Groundwater, Irrigation, Surface water and Water resource

Introduction

In Africa, agriculture forms the backbone of most of the continent's economies, which providing about 60% of all employment [1,2]. For example, in Ethiopia agriculture is a mainstay of its economy, where around 95% of its agricultural output is produced by smallholder farmers [3]. However, in most parts of Ethiopia, production from rain-fed agriculture has been highly fluctuating, corresponding to the amount and distribution of rainfall [4]. When there is too little rainfall with uneven distribution, crop failure is unavoidable. This is, also a common historical event in Ethiopia.

Expansion of small-scale irrigation is one of the mitigation strategies which take under consideration for unavoidable crop failure due to vary little and uneven distribution rainfall, where dry season streamflow is reliable [5-7]. It is known that irrigation is a very old practice, dating back to the earliest civilizations of humankind in Ethiopia. According to Kassie [8], Ethiopia has been started traditional irrigation practice since ancient time for the aim of subsistence food production and since 1950's modern irrigation system was introduced in Awash and Rift Valley basins for production of industrial crops. Irrigation was served as one of the key drivers behind the growth in agricultural productivity, increasing household income and alleviation of rural poverty, thereby highlighting the various ways that irrigation can impact poverty [9-11]. In line with, to meet the food requirements by 2020 in Ethiopian, the Food and Agriculture Organization for United Nations [12], estimated that food production from irrigated areas will need to increase from 35% in 1995 to 45% in 2020.

Although, it needs further detailed investigation, according to Kidanewold, et al. [13], the country has about 124.4 billion cubic meter (BCM) River water, 70 BCM lake water, and 30 BCM groundwater resources. This water has a potential to develop 3.8 million ha of irrigation and 45,000

***Corresponding author:** Kasye Shitu, Department of Soil Resource and Watershed Management, Assosa University, P.O. Box 18, Assosa, Ethiopia

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MW hydropower production. Awulachew, et al. [14] also, has indicated that Ethiopia has a large potential of arable land and great irrigation potential, which is estimated as 5.3 million hectares of land of which 3.7 million hectares can be developed using surface water sources and 1.6 million hectares using ground water and rain water management [15,16].

Groundwater is that part of the hydrologic system that occurs in a geologic environment. It plays an important role in water supply, ecology and maintaining river flow. It comprises 97 percent of the world's readily accessible freshwater and provides the rural, urban, industrial and irrigation water supply needs of 2 billion people around the world [17]. In Ethiopia, the annual groundwater potential is 40 $Gm^3\ a^{-1}$ and the total annual discharge is 122 $Gm^3\ a^{-1}$ [14,18]. However, in the country, groundwater is not adequately used due to higher development and operational cost and lack of understanding of the resource dynamics [19] as compared to surface water of the country. The groundwater in Ethiopia is mainly used for domestic water use. There may be limited cases where the groundwater is used for irrigation and other purposes. Despite, some gross estimates [20], and large-scale assessments of groundwater irrigation potential [21], there is little quantitative study on the groundwater resource potential for irrigation and other nondomestic water uses in Ethiopia.

Hence, for a long time in Ethiopia, there has been a general misunderstanding about the water resource potential of the country, Irrigation practice, the role of ground water in every aspect of the country spatially irrigation has been lacking. In the country, water resource potential and irrigation practice are still poorly assessed, hardly managed, underestimated and under used. So, the general objective of this review paper is, to receive some information about the water resource potential and irrigation agriculture practice in Ethiopia from different literatures to provide useful information to decision makers for the planning and management of water positional of the country for irrigation use.

Water Resource of Ethiopia

Surface water resource

Ethiopia is endowed with a substantial amount of water resources. The surface water resource potential is impressive, but little developed. The country possesses twelve major river basins which form four major drainage systems and twelve

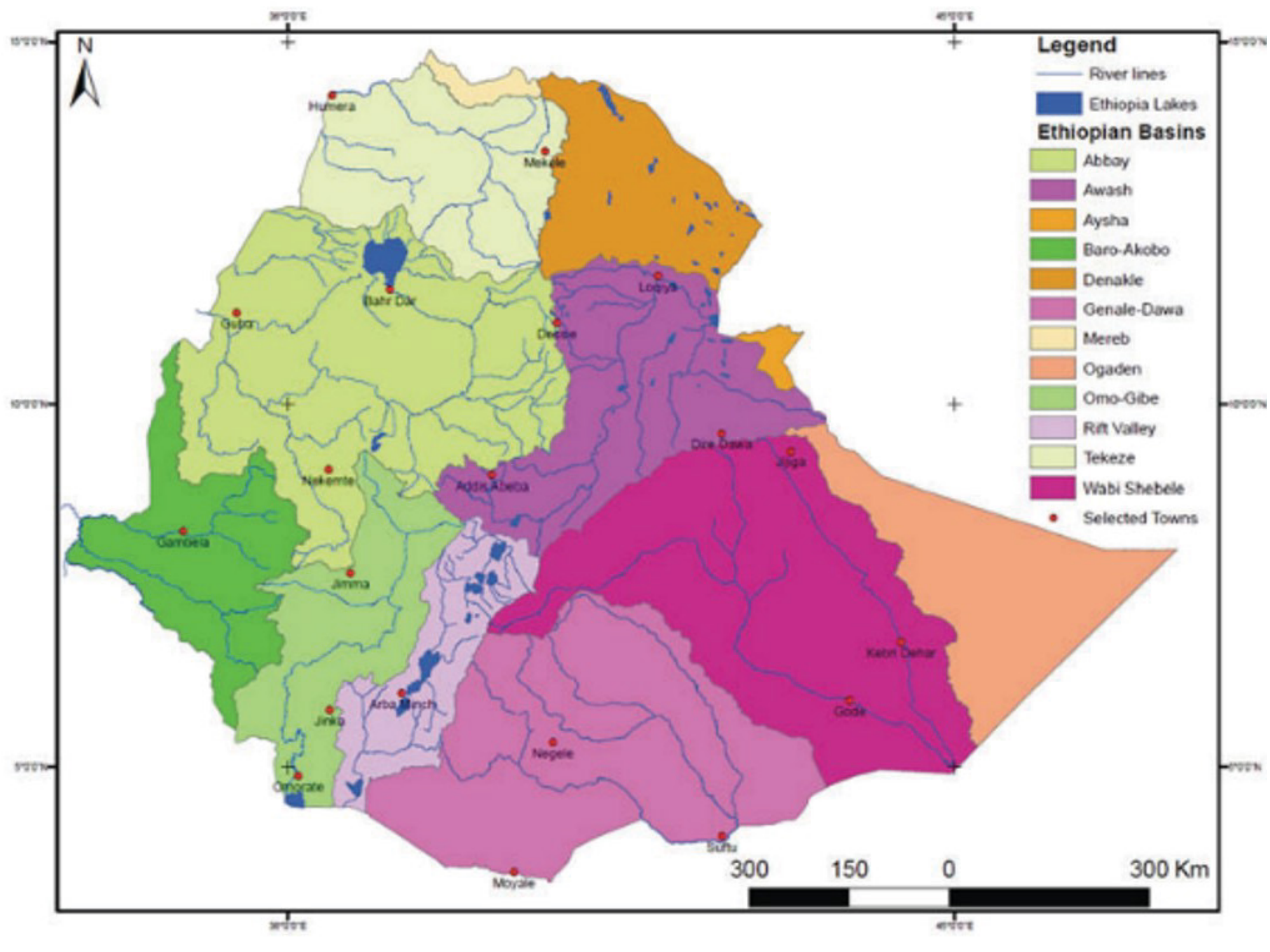

Figure 1: River basin map of Ethiopia.

Source: [13].

large lakes, and differently sized water bodies as indicted in Figure 1.

As, identified and estimated in different integrated river basin master plans, Ethiopia has 123.09 billion cubic meter surface water potential (Table 1). But this figure needs update and further detailed investigation. Because, according to Kidanewold, et al. [13] 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) but, these systems store significant amount of water. For example, the Water Audit Modelling 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 [22]. This is an indicator to change our surface water accounting system to understand the surface water potential of the country in addition to rivers and lakes.

In Ethiopia, most of the rivers are transboundary and 97% of the estimated annual stream flow of the country flows out of Ethiopia into neighbouring countries and only 3% of the estimated amount remains within the country [13]. As indicated, in Table 1 more than 70% of surface water of Ethiopia found in westward flow direction (Abbay, Baro-Akobo, Mereb and Tekeze).

Lakes are surface water resources that are very important components of the earth's hydrological cycle, providing a variety of services for humans and ecosystem functioning [23]. In Ethiopia, like that of rivers, lakes are major surface water source. Ethiopia has 12 major lakes. They cover about 7,300 km^2 area and store about 76.8 BCM of water [13]. As indicated in Figure 1, most Ethiopian lakes are found in central, south, and southwest area of the country. They have different drainage and surface area, water depth and water volumes as indicated in Table 2.

Groundwater resource

The topographic features and general surface gradient,

Table 1: Sum of mean annual flow surface water of each river in the flow direction at outlet of the river basins.

Flow direction	Basins included in the section	Water resource (BCM)	Area coverage share (%)	Surface water share (%)
Westwards	Abbay, Baro-Akobo, Mereb, and Tekeze	86.55	38.75	70.31
East	Genale-Dawa and Wabishebele	9.4	33.34	7.64
South	Omo-Gibe, Rift Valley lake basin	22.24	5.15	18.07
Northeast	Awash	4.9	9.79	3.98
No flow	Aysha, Dinakle, and Ogaden	0.0	12.97	0.0
Total		123.09	100	100

Source: Respective Basin Master Plan Studies compiled by the web Master of Ministry of Water and Energy, MoWE [48].

Table 2: Major lakes of Ethiopia and their physical and water resource features.

Name of Lake	Elevation (masl)	Drainage area (Km^2)	Surface area (Km^2)	Max.depth (m)	Volume (BCM)
Tana	1,788	1,788	3,156	14	28.4
Ziway	1,636	7,380	440	9	1
Langano	1,585	2,000	230	46	3.8
Abijata	1,580	10,740	180	14	1
Shala	1,550	2,300	370	266	37
Awassa	1,680	1,300	129	22	1
Abaya	1,169	16,342	1,140	24.5	9.82
Chamo	1,110	18,575	317	14.2	3.24
Chew Bahir	570	-	1125	-	-
Hayq	1,900	83	23	81.41	1.01
Ashenge	2,440	129	140	25.5	0.25
Beseka	1,900	420	48.5	7	0.28
Total					76.8

Source: Yesuf, et al. [49] Dinka [50] and Awulachew [14] regional structure, porosity, permeability and special geological structure like; sink hole, alluvial fan, dykes, joint, lineaments, buried channel, weak zone and fractures and climatic condition have great role on the occurrence of ground water in Ethiopia [24]. The rainfall that percolates below the ground surface passes through voids of rock, fracture, and joints to reach water table. These voids are generally interconnected permitting the movement of ground water. In the country, the mode of occurrence of ground water largely depends on the topographic formation and geologic structure. 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. However, in the country the occurrence of groundwater is not uniform because it depends on various environmental and geological factors [25].

Geologically, Ethiopia 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 [26]. With the understanding of the nature of the distribution of these rocks, and the recharge classification of the country, Alemayehu, et al. [25] 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 recharge for the entire country is assumed as 200 mm.

Figure 2 indicates the areas which are more potential for intensive groundwater development in Ethiopia. There are several large areas with potential for groundwater development in all regions especially, in Amhara, Oromia, SNNPR and Gambela. However, in some areas such as Afar and South Omo the potential are not so much available and the present ground water also characterized by salinity nature [27].

In Ethiopia, in addition to regional level large amount of groundwater also present in specific watersheds. For example According to Kobo Girana Development Project Office report [28], the Kobo sub-basin groundwater resource safe yield was estimated using analytical method and is found to be around 309,942.00 m^3/day (186,514.00 m^3/day for Hormat Golina well field and 123,428.00 m^3/day for Waja Golesha Well field) and also according to Taye, et al. [29], on the basis of the water balance model, the mean annual rechargeable water in to the Ada'a-Becho plains groundwater aquifers is more than 965 Mm^3 with 67% contributed by upper Abay Basin and groundwater recharge of the Alaidege valley is about 112 MCM.

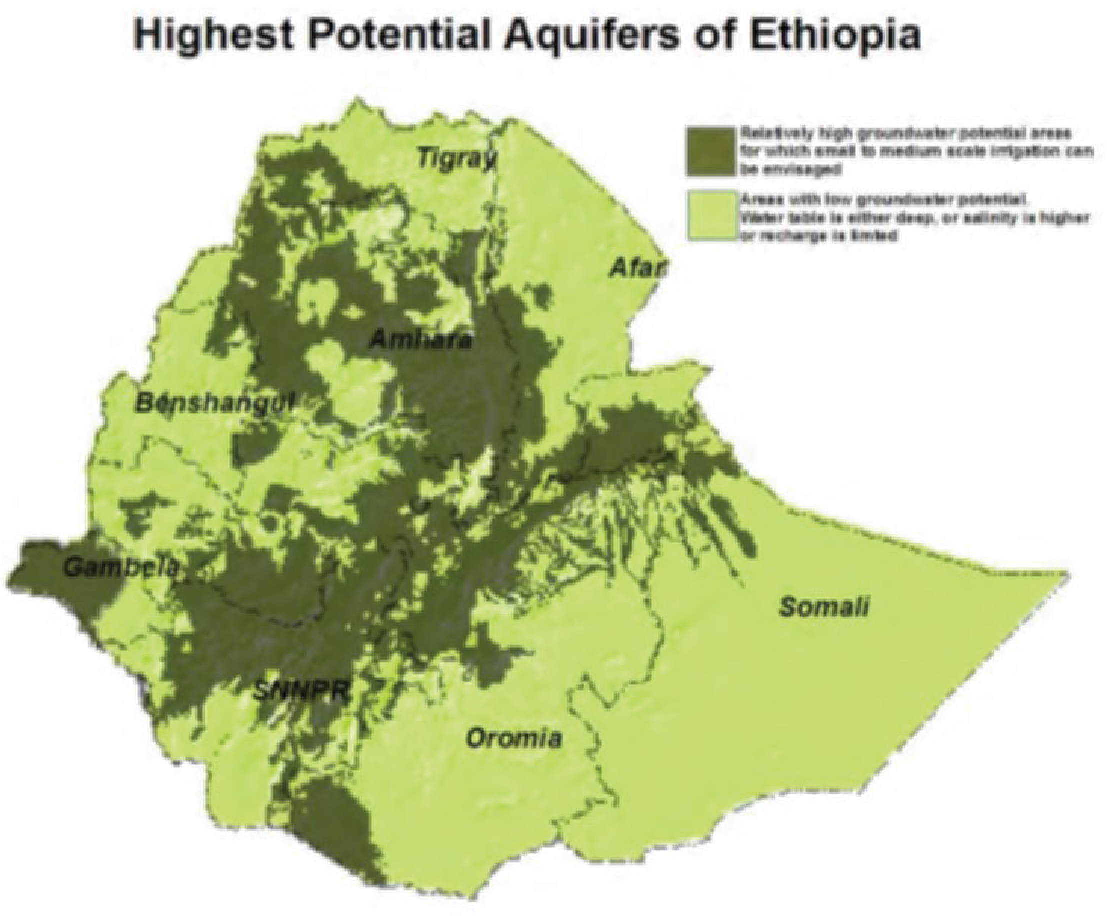

Figure 2: Areas which are more potential for intensive groundwater development in Ethiopia.
Source: (Seifu Kebede as cited in [27]).

The total ground water storage potential in Ethiopia is estimated 1 trillion m^3 [30]. But the amount of yearly groundwater recharge of the country is estimated about 28000 mm^3 [31]. Previous studies, including, Awulachew, et al. [14] and minster of water resource report (2012) showed that, groundwater usage potential of the country was estimated at 2.6 BCm^3 and this figure is still often quoted. Because, following the results of recently completed assessment for parts of the country like kobo Girana, Alaidege and Raya show that, there is consensus that the 2.6 BCm^3 figure is an underestimate and that it needs to be considerably revised upwards. Based on this problem the research, which was conducted by MoWR [32] indicates, the best guess in groundwater potential range between 12-30 Bcm^3 or even more if all aquifers in the lowlands are assessed. In addition to this, MoWIE [33] was estimated the ground Water Resources of the country with a value of 26 Bm^3. After one year even although, it needs further detailed investigation Berhanu, et al. [34] was reported the country groundwater resources with a value of 30 BCM.

Hence, like that of surface water of Ethiopia, there is no consistent and reliable inventory and well-studied and documented with regards to groundwater of Ethiopia. The groundwater potential of the country shows highly different values in different time level study. This may occur due to complex geological formation of the country, location of selected watershed part (initial, middle, and lower part of the water shed) for groundwater potential estimation, lack appropriate expert and others.

Irrigation in Ethiopia

Irrigation practice across the world is vital to successful green revolution all year round to achieving sustainable development goals in food security, socio-economic and rural development [35]. Because irrigation plays an essential role in stabilizing crop production by either supplementing or replacing the need for natural precipitation and it makes agriculture more confidential, stabilizes crop production by protecting against drought [36].

In Ethiopia, it is believed that irrigation practices were long been in use during ancient times with unspecified beginning period [37]. According to Bekele, et al. [38], in Ethiopia, traditional irrigation was practiced before centuries in the highlands of Ethiopia. Awulachew, et al. [14] Bacha, et al. [39] and MoA [40] also states that, irrigation practices have been in use since ancient times for producing subsistence food crops in Ethiopia. These points, simply indicate that, Ethiopian has a long history of irrigation practices; even it is difficult to know when and where it was started.

Depending on the area irrigated, scale of operation and type of control or management, irrigation is categorized as small-scale, medium-scale and large-scale. However, the criteria for this category may vary from country to country. For example, in India the irrigation scheme of 10000 ha is classified as small while in Ghana the largest irrigation scheme is 300 ha. In Ethiopia according to Ministry of Water Resources [41], Bekele and Ayana [42], irrigation development is classified based on the size of the command area, in three types.

- **Small-scale irrigation systems (SSIS):** They are often community-based and traditional methods, covering less than 200 hectares. Examples of SSIs include household- based RWH, hand-dug wells, shallow wells, flooding (spate), individual household-based river diversions and other traditional methods. They are always contracted and managed by the irrigation user and required frequent maintenance spatially after rain season.
- **Medium-scale irrigation systems (MSIS):** which are community based or publicly sponsored, covering 200 to 3,000 hectares. Examples of MSIs include the Sille, Hare and Ziway irrigation schemes.
- **Large-scale irrigation systems (LSIS):** which are covering more than 3,000 hectares, which is typically commercially or publicly sponsored. Examples of LSIs include the Wonji-shoa, Methara, Nura Era, Tehndiho, Omo-Kuraz and Fincha irrigation schemes.

Spate irrigation system has been used for water harvesting from flush floods flooded from larger catchments at upper streams (Table 3). These traditional irrigation systems were developed and managed through forming a water user's association for functions of construction, water allocation, operation and maintenance and were headed by individuals [43]. This, association comprises up to 200 users grouped into 20 to 30 groups of farmers who share a common main canal or its branches [40]. It has been used traditionally in Ethiopia [44] particularly in Northeast Amahara, Southern Tigray and in some semi-arid areas in Oromia region [40].

Table 3: Major sources of water and irrigation typology in Ethiopia.

Source of water	Typology of irrigation		
	SSIS	MSIS	LSIS
Rainwater	✓ (Spate)	✓ (Spate)	
River diversion or pumping	✓	✓	✓
Ground water	✓	✓ (Multiple wells)	
Micro and small dams	✓	✓	
Large dams			✓

Source: [19]

Irrigation Potential in Ethiopia

Ethiopia has vast cultivable land (30 to 70 Mha), but only about a third of this cultivable land is currently cultivated (approximately 15 Mha). From this, cultivable land of the country Awulachew [19] estimates the total irrigable land potential of 5.3 Mha by assuming the use of existing technologies, including 1.6 Mha through RWH and ground water. This is an indicator how much the country has vast amount of cultivable and irrigable land, however a small amount of this quantity is in use now a time. In the country, this may happen due to lake of technology, environmental condition, social condition, political condition, and miss understanding of irrigation advantage.

Irrigation potential of surface water in river basin of Ethiopia

Awulachew, et al. [14] indicated that, as the prevalent rainfed agriculture production system together with the progressive degradation of the natural resources base and climate variability has aggravated the incidence of poverty and food insecurity in Ethiopia. For this, Tadesse [45] argued that, in Ethiopia food shortage can be minimized if farmers have access to irrigation water. Based on this point, the Ministry of Water and Energy (currently, Ministry of Water, Irrigation and Electricity) identified more than 500 irrigation sites with a total of 3.8 million ha irrigable land in different River Basin of Ethiopia.

The details of irrigation potential per Ethiopian major river basin are presented in Table 4. As indicated in the table the potentials of Tekeze, Baro-Akobo, Omo-Ghibe and Rift Valley basins for small and medium scale irrigation project development have not been investigated. This is an

Table 4: Irrigation potential in the river basins of Ethiopia.

Basin	Catchment Area (km²)	Irrigation potentials (ha) (Respective recent master plan studies)			
		Small scale	Medium scale	Large scale	Total
Abay	198,890.7	45,856	130,395	639,330	815,581
Tekeze	83,475.94	N/A	N/A	83,368	83,368
Baro-Akobo	76,203.12	N/A	N/A	1,019,523	1,019,523
Omo-Ghibe	79,000	N/A	10,028	57,900	67,928
Rift Valley	52,739	N/A	4,000	45,700	139,300
Awash	110,439.3	30,556	24,500	79,065	134,121
Genale-Dawa	172,133	1,805	28,415	1,044,500	1,074,720
Wabi-Shebele	202,219.5	10,755	55,950	171,200	237,905
Danakil	63,852.97	2,309	45,656	110,811	158,776
Ogaden	77,121				-
Ayisha	2,000				-
Total	1,118,074.53				3,731,222

Table 5: Irrigation potential by groundwater in the river basins of Ethiopia.

Basin	Groundwater storage (mm)	Aquifer productivity yield (l/s)	Groundwater depth (m)	Potential irrigable land (km²)
Abbay	5,706	3.8	13.7	21,186
Tekeze	4,793	4.1	23.4	1,782
Baro-Akobo	11,070	2.0	13.2	2,603
Omo-Ghibe	7,321	4.4	17.9	10,512
Rift Valley	7,0874	4.6	19.6	1,782
Awash	11,847	5.6	38.8	7,331
Genale-Dawa	15,245	3.2	35.7	208
Wabi-Shebele	16,624	1.6	49.2	4,868
Danakil	7,663	5.7	82.4	523
Ogaden	17,837	1.0	83.0	8,235
Ayisha	12,611	6.6	71.2	-
Total				60,024

Source: Worqlul, et al. [47]

implication point that the irrigation potential of Ethiopia is larger than the estimated irrigation potential by far when these uninvestigated basins are properly studied. The water distribution of river basin in Ethiopia varies place to place. As in dictated in Table 4, the distribution of the surface water potential breakdown by size is five percent SSI, nine percent MSI and 86 percent LSI.

Irrigation potential of groundwater in river basin of Ethiopia

According to Siebert, et al. [46], groundwater accounts for 43% of the global irrigation water use and is more suitable for irrigation purpose as compared to surface water. Ethiopia has large reserves of groundwater that could be used to drive agricultural growth as indicates in Table 5. A large portion of the irrigable land is located in Abbay, Rift Valley, Omo Ghibe and Awash, Wabi-Shebele and Ogaden River Basins. Abbay, Tekeze, Bro-Akobo, Omo-ghibe and Rift Valley River Basin have shallow groundwater less than 25 m and 3.8-4.6 L/s aquifer productivity. According to Worqlul, et al. [47], this makes them favourable for small-scale groundwater irrigation development.

The exponential growth of the urban population and agriculture-led industrial development has resulted in greater attention to groundwater as the potentially cost-effective water supply source. As, growing world focus on the use of groundwater for irrigation, the government of Ethiopian currently implementing irrigation projects by using groundwater. One plan involves nine irrigation projects covering an estimated area of 8,000 ha, being developed on a pilot scale, with 9,000 test wells, 28,000 monitoring wells and 14,657 spring improvements. If this unprecedented Ethiopian groundwater-centered development plan is implemented successfully at such a scale, it is highly likely that its success will persuade other Sub-Saharan developing nations to put in place the necessary policies, regulations and investment for infrastructure and capacity development for exploring, exploiting and managing their groundwater resources.

Conclusion and Recommendation

In Ethiopia, agriculture is a mainstay of its economy. However, in most parts of Ethiopia, production from rain-fed agriculture has been highly fluctuating, corresponding to the amount and distribution of rainfall. Due to this, when there is too little rainfall with uneven distribution, crop failure is unavoidable in the country. Ethiopia has been started traditional irrigation practice since ancient times without specific time and place for the aim of subsistence food production by minimize unavoidable crop failure due to vary little and uneven distribution of rainfall in country.

Ethiopia has amble amount of water and irrigation land resource. It has 224.4 BCM water resource potential (both surface and groundwater) 5.3 million hectares of irrigable land of which 3.7 million hectares can be developed using surface water sources and 1.6 million hectares using ground water and rainwater management. Even Ethiopia, has 1.6 million hectares of land which irrigate by groundwater, but there is no visible document how much of this area irrigated by groundwater.

Most of the river basin master plan (surface water source of Ethiopia) studies do not take into account the surface water resources of the country in open water systems (lakes, wetlands, and flood plains) but, these systems store significant amount of water. So, the surface water potential figure of the country needs update and further detailed investigation. Also, like that of surface water potential of Ethiopia there is no consistent and reliable inventory and well-studied and documented with regards to groundwater potential of Ethiopia and required further investigation.

Hence, as a recommendation, even Ethiopia has a long history of irrigation practices and high amount of water resource potential, but both are under quoted still now. Questions like when and where irrigation state in Ethiopia, why irrigation is not developed based on the irrigation potential of the country and others are raised by different scholars. So, to answer these questions, it is better that further study should be conducted related with the water positional and irrigation practices of Ethiopia in order to get available document for the future time resource use planning.

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Conflicts of interest

The authors of this review have no any conflicts of interest.

Availability of data

All information of this paper is found online published paper.

Code availability

Not applicable.

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