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An overview of the role of irrigation in the attainment of sustainable development goals through hunger and poverty alleviation in Ethiopia

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Abstract

A potential irrigation area of 3,088,395 hectares exists on the 74.3 million hectares of arable land in Ethiopia. The country has not received many benefits despite its enormous irrigation potential. A sizable section of Ethiopia's population today experiences food insecurity and lives below the poverty line. A comprehensive analysis has been conducted to determine the impact and potential of irrigation farming in Ethiopia. Studies have confirmed the role of irrigation in alleviating poverty and promoting food security. Irrigation plays an important role in poverty reduction in Ethiopia. It can alleviate poverty by improving crop productivity, boosting farmer incomes, providing more employment and a better pay rate and contributing to the national GDP in the long run. Irrigation also promotes food security by contributing to all dimensions such as food availability, access to food, food utilization and stability. The development of the sector is thought to significantly contribute to the achievement of the Sustainable Development Goals (SDG) given the significance of irrigation in reducing poverty and hunger. Hence, this study emphasizes the necessity of using the irrigation potential and developing the irrigation sector in order to alleviate the misery of hunger and poverty in the country.

Keywords: Agriculture, Ethiopia, Food security, Irrigation, Poverty, SDG.

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1. Introduction

The Sustainable Development Goals (SDGs) were adopted by United Nation (UN) members including Ethiopia in general assembly resolution A/RES/70/1 on September 25, 2015 [1]. The resolution sets 17 interlinked goals to be achieved by 2030. The first and second goals of the SDGs were described as no poverty and no hunger. The former aims at the alleviation of poverty in all of its manifestations worldwide and the latter intend to end hunger, achieve food security and

improve nutrition through sustainable agriculture. Although all the SDGs are very important worldwide, these two goals are especially important in the context of Ethiopia where ten million people lack access to food and a significant percentage of its citizens live below the national poverty line [2, 3].

Ethiopia is suitable for cultivating more than 100 different types of crops due to its approximately 74.3 million hectares of fertile land that are distributed over 18 different agro-ecological zones [4]. The country is also blessed with 12 river basins with an annual runoff volume of 122 billion m3 of water [5]. Despite all this and being an agricultural-based economy, the country has faced significant challenges in achieving food security and reducing poverty levels.

According to several studies, using sustainable irrigated farming techniques is essential for raising farm households' earnings [6], maintaining food security [7] and reducing poverty [8, 9]. Irrigation increases agricultural productivity, reduces dependence on rainfall and protects crops from drought.[10-12] results in increased agricultural incomes and better community food security. It encourages a healthy diet and access to treatment, irrigation also significantly contributes indirectly to enhancing human health [13]. Irrigation can also boost economic growth, open up new job opportunities and improve market accessibility [14]. Irrigation in Ethiopia faces various challenges such as an insufficient infrastructure, poor mechanization and a lack of technical expertise. Recently, the Ethiopian government has been working hard to modernize the irrigation industry and overcome these challenges. Some of these efforts include the construction of dams, canals and other water infrastructure as well as the training of farmers in efficient irrigation techniques. The impact of these efforts can be seen in the significant growth of the country's agricultural sector and the improvement of food security for communities.

This study aims to shed light on the major pathways through which irrigation contributes to food security and economic improvement both at the local and national level in Ethiopia and manipulate the pathway so that the sector becomes an even better contributor to the country's fight to feed and prosper its population, thereby realizing the SDGs.

2. Irrigation Potential of Ethiopia

Irrigation potential is the total land area that is technically feasible, economically profitable, socially viable and environmentally acceptable that is irrigated or capable of being irrigated based on water and land availability [15]. The estimation of the irrigation potential of a region may vary a lot from study to study or from time to time. For instance, some consider land resources only, others consider water availability and the rest may take into consideration the environmental and economic conditions of the country etc. Knaome [16]. You, et al. [17] considered factors such as production geography, the potential performance of irrigated agriculture, potential runoff, irrigable area and associated water delivery costs in the assessment of the potential for irrigation investment. Researchers now prefer models, remote sensing and GIS technology when assessing a region's potential for irrigation. Yimere and Assefa [18] used the "mike hydro model" to assess and map irrigation potential in the Abbey river basin of Ethiopia. Remote sensing and GIS have been used to assess the irrigation potential of a canal system in India [19]. Such deviations in assessment and estimation strategies lead to ambiguous and inconsistent reports on the irrigation potential of countries.

The renowned Engineer Awulachew, et al. [20] research and his colleagues at the International Water Management Institute (IWMI [5, 20-22]) are mainly responsible for the traditional irrigation-related survey studies that were carried out in Ethiopia. Engineer Awulachew is well-known for serving as the chief negotiator in the trilateral negotiations between Ethiopia, Sudan and Egypt over the massive Ethiopian Renaissance Dam. According to Awulachew, et al. [20], about 5,300,000 hectares of land in Ethiopia have the potential to be irrigated. The country's irrigable land has increased by approximately 28.3% from the Awulachew, et al. [5] estimate of 3,798,782 hectares. The different results from the inclusion of groundwater and captured rainfall by Awulachew, et al. [20] have the capacity to irrigate an extra 1,600,000 hectares of land. According to Nakawuka, et al. [23], Ethiopia has a potential for irrigation of 2,700,000 hectares. The Food and Agricultural Organization (FAO) estimated Ethiopia's irrigation potential at about 2.7 million hectares in 2016 based on the availability of water and land resources, technology and funding [24]. In the same report, FAO included details on the area and percentage contributions of each drainage and river basin. This is a typical example of how different estimates of a country's irrigation potential can be made depending on factors taken into account during the study or survey. According to current estimates [4], Ethiopia's total groundwater reserve is expected to be 27.27 billion m3, a 76.2% increase over the highest estimate of 6.5 billion m3 [5]. The variation in the estimation of groundwater resources has increased from time to time and currently sits at 234,772 km2 [4]. The Ethiopian agricultural transformation agency (ATA), in its latest (2020/21) annual report stated that the country has an irrigation potential of 3,088,395 hectares which can support 6,176,898 farm households. However, the irrigation potential of Ethiopia estimated by Awulachew, et al. [5] and Awulachew, et al. [20], a decade or more ago is superior by 23% and 71.6% respectively to the current estimation by ATA (Agricultural Transformation Agency) [4].This gets difficult to accept especially when realizing the currently estimated groundwater resource of the country has increased dramatically (quadrupled) compared to the estimation in earlier times (2.6–6.5 billion m3) [5]. This discrepancy may be related to the differences in the assessment strategies and criteria considered in the studies. In this paper, we will make our arguments and discuss them based on the latest report on the country's irrigation potential by the ATA Agricultural Transformation Agency (ATA) [4].

3. Total Irrigated Land in Ethiopia

Ethiopia has the largest irrigation potential in East Africa followed by Tanzania and Kenya but it uses only a small portion of it Nakawuka, et al. [23]. In its latest annual report, ESS estimated the total irrigated land for 2020-21 by private peasants to be only 181,395 hectares practiced by around 1.4 million households [25]. This represents only 5.9% and 22.7% of the total land area and the number of farmers the country's irrigation potential could support respectively [4].

However, the majority of authors only include land irrigated by private peasant holdings when reporting the country's percentage of irrigated land with irrigation potential. They ignore commercial farms and sugar plantations [13]. Though the ESS releases survey reports on different aspects of private commercial farms, they do not include the areas irrigated by those farms. Hence, it is difficult to obtain data on trends in irrigated land areas on commercial farms. However, by considering at least the recent report on the area irrigated by the sugar estates of the country, we might get some more insights into the percentage of the irrigation potential used. According to the Ethiopian Sugar Corporation (ESC), there are eight sugar estates involved in irrigated sugarcane production on an area of 145,030 hectares [26]. If we sum up the total irrigated land by private peasant holdings and the sugar estates, the total estimated irrigated land area would be 306,425 hectares which again makes up only 10% of the country's irrigation potential. Dr. Abiy Ahmed, prime minister of Ethiopia in his welcoming speech at the opening of the 35th ordinary session of the African Union (AU) on February 5, 2022 said:

Nationally, we have attained production of 20 million quintals of irrigated wheat farmed over 500,000 hectares. This has generated nearly 60 billion birr in income for our farmers."

One of the main points to take from this speech is the claim by the prime minister that nationally a total of 500,000 hectares of land are under irrigated wheat production. The claim seems strange as the Ethiopian Statistical Service (ESS) [25] estimated only 181,395 hectares of irrigated crops in the 2020-21 cropping season. Thus, the Prime Minister's claim may be based on the work done during the ' Meher' season of 2022 when the Ethiopian Statistical Service releases its upcoming report the correct figure might be reflected. Even, if the total area currently under irrigation (806,425 hectares) as estimated by the ESS on land irrigated by private peasants, the ESC report on the area irrigated by sugar estates and the claim by the prime minister were taken into account, this would still represent only 26.1% of the country's irrigation potential. This is a clear indicator of how long the country has left to go in improving the irrigation sector when realizing that an estimated 5.7 million people live in the misery of hunger [27] and around 22 million people live below the national poverty line [28].

4. Importance of Irrigation to Food Security in Ethiopia

During the 1996 World Food Summit, food security was described as "a state in which all people, at all times have physical, economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life". This definition outlines four requirements that must be fulfilled for a country or a household to be considered food secure: food availability, access to food, food utilization and a stable supply of food [29]. The degree to which these four aspects are met largely depends on the level of agricultural production and the financial capacity of households or nations to produce, purchase and import food [30-32]. Ethiopia has experienced a significant increase in food insecurity in recent years due to droughts, floods and other natural and man-made disasters [33-35]. This has put immense pressure on the government and local communities to find solutions to the challenges posed by these changing environmental conditions. Currently, there are approximately 15 million people who are food insecure and in need of immediate humanitarian food assistance [36]. According to the 2022 Global Hunger Index (GHI), Ethiopia has a GHI score of 27.6 which puts the country 104th out of the 121 countries with sufficient data to calculate GHI scores [37]. This is very concerning as a significant percentage (nearly 15%) of the population is facing hunger and the country has a very poor GHI score which indicates a very serious hunger level.

Irrigation has been identified as one of the most effective ways of addressing these challenges and ensuring food security in Ethiopia. Irrigation systems allow for the controlled and efficient use of water for agriculture which leads to an increase in crop yields and an improvement in food production. Irrigation is also witnessed to contribute to food security in the country by reducing the risk of crop failure and generating higher and year-round farm and nonfarm incomes [38] which leads to more stable food supplies and improved food security for the population. Irrigation has been shown to contribute to all dimensions of food security through various direct and indirect pathways (see Figure 1).

4.1. The Contribution of Irrigation to Food Availability in Ethiopia

The food availability dimension of food security is mostly related to the general food supply status of an area which is dependent on the totality of domestically produced and imported food products [29].According to studies, irrigation can boost crop yield [39, 40] and provide crop production throughout the year [41, 42] which are the two main factors affecting a community's access to food. Increased agricultural yield and yearly output assure a sufficient supply of food on the market while other elements are kept under control.

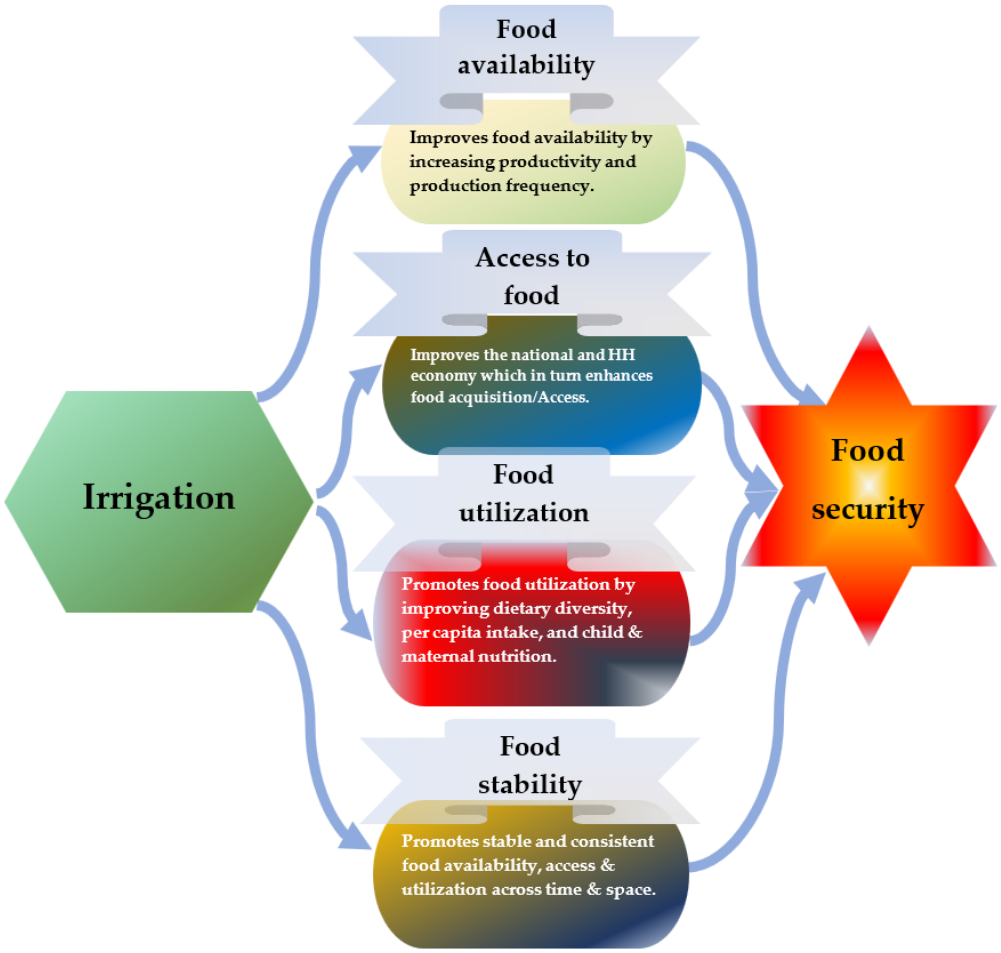

Figure 1.
Contribution of irrigation to the different dimensions of food security in Ethiopia.

The major way in which irrigation promotes food availability is by boosting crop productivity through yield increment [43, 44]. A higher onion yield (46.7t/ha) was obtained when the crop was fully irrigated throughout its different growth phases compared to when it faced water shortage at some point in its growth [45]. In the north eastern, Amhara region of Ethiopia, it was demonstrated that supplemental irrigation greatly increased grain production and other yield-related parameters of sorghum [46]. Irrigation increases the yield teff (Eragrostis tef (Zucc.) Trotter) by 16% under different soil fertility regimes and sowing periods in the Tigray region [47]. Due to the basic economic principle that higher output equals higher supply, increasing crop yields are one of the factors influencing the local food supply. Additionally, greater production in one nation results in a surplus that is eventually exported to nations with less access to food, improving food availability in the nation that is importing.

The other important way in which irrigation promotes food availability is by encouraging multiple productions per year. In northern Wollo, a sizable percentage of irrigation users (32.1%) reported that irrigation had improved the frequency of their agricultural production[48]. According to reports, farmers in the Haramaya district of eastern Ethiopia produce more than twice per year using irrigation which has enabled them to become self-sufficient in food [49].

Irrigation does not promote food security only through an increment in crop productivity or production frequency. Irrigation may also directly or indirectly contribute by exposing farmers to other sources of food. For instance, irrigation users in the Arsi zone of Ethiopia were in a better position when it came to livestock possession (7.58 to 4.38 total livestock units (TLU)) and oxen ownership (1.78 to 1.12 TLU) compared to rainfall dependent farmers [50]. Livestock and poultry possession makes other types of foods such as dairy products, meat products and eggs available to the households. Furthermore, irrigation is also an important factor in preventing potential future food shortage. Supplemental irrigation was modeled to improve food security in the rift valley drylands of Ethiopia by increasing the yield of maize under different climate change scenarios [51]. Therefore, it is important to focus on increasing food productivity and strengthening crop output through irrigation in order to prevent problems with the current food supply and any potential future food scarcity in the entire country.

4.2. The Role of Irrigation in Promoting Access to Food in Ethiopia

Food security is not always ensured by the market's or area's supply of food. This propensity to buy food is largely reliant on the nation's ability to import goods from abroad or the ability of households to buy goods locally. Irrigation increases food access by increasing crop yield at the farm which the farmer may then use for immediate consumption or sell to make money to buy other foods [39, 52]. Irrigation has been reported to improve household food consumption and

expenditure in different parts of the country. Food consumption expenditure is an important aspect of household socioeconomic conditions that reflects food acquisition and consumption or purchasing power. The household food consumption expenditure of irrigation users in western Oromia was Ethiopian birr (ETB) 1631(USD 71) higher than those households not practicing irrigated crop production [1]. The mean annual consumption expenditure for irrigation users in northern Ethiopia was 114% higher than that of irrigation non-users [53]. Similarly, households in eastern Ethiopia were reported to enjoy 16% higher per capita consumption expenditure compared to their counterfactual group [6].

The possibility of receiving loans is the other key method by which irrigation improves the ability to purchase food. Irrigation users in Ethiopia are 23% to 52% more likely to get a credit compared to those not practicing it Tefera and Cho [50]. Households had access to credits in the far region were shown to be more food secure (by a factor of 6.52) than those that did not get access to credits [54]. This can be explained by the idea that credits give households purchasing power, allowing them to purchase high-quality, diversified and nutritious food in market shortage.

Access to the available food may also depend on the overall political and civil stability of the region or country. A typical example of people not getting access to food regardless of its availability in Ethiopia is the recent cruel war in the northern part of the country. Numerous international aid organization reported that they were unable to provide food to the war affected community despite having food stocks in their depots [55, 56] due to the extreme risk to their aid workers [57] and the permit restriction by the government that accused the aid organization of intervening in its internal affairs [58].

The problem of food access in Ethiopia can be addressed in three possible ways [59].

i) With direct food aid (food transfers) to affected households.
ii) By incapacitating poor households economically.
iii) By reducing food prices in the market and boosting productivity across the food system.

However, the first route (food aid) is dubbed outdated or inefficient unless in cases of emergency food access issues, as it creates a sense of dependency and reluctance to work towards food self-sufficiency [60, 61]. Therefore, increasing household incomes and reining in the food market should always be priorities. Irrigation plays an important role in both respects as it improves household incomes and stabilizes the food market with increased production outputs, thereby promoting access to food.

4.3. Irrigation and Food Utilization in Ethiopia

Utilization is a component of food security that frequently refers to how likely it is for people or households to eat the full variety of wholesome foods that contribute to a healthy way of life. This could refer to people consuming enough calories and nutrients as a result of having access to and being able to eat food.

In many regions of Ethiopia, irrigation has been demonstrated to enhance the daily per capita intake of households. Research in the Oromia region found that farmers who use small-scale irrigation tend to consume 643.76 Kcal more daily calories than farmers who only use rain-fed crops [62]. Only 26.25% of irrigation users in the Arsi zone consume fewer than 1500 Kcal of calories per day compared to 49.2% of non-irrigation users [50]. It has been asserted that access to irrigation in western Ethiopia increased food intake for communities that had previously experienced food insecurity [63].

Irrigation improves the variety of foods taken at home. Irrigating households in Ethiopia were observed to have higher productivity and a more diverse diet due to their propensity to produce more fruits, vegetables and cash crops than non-irrigating homes. According to Passarelli, et al. [64], access to irrigation was one of the most significant drivers of household dietary diversity. Their research showed that households with access to irrigation had a food diversity that was 5.824 times greater than households without such access. The average household dietary diversity score for the seven food groups consumed in Kobo Town was found to be 3.84 for irrigation participants and 3.21 for irrigation non-participants respectively [66]. In the same town, the computed food consumption value was 44.89 for irrigation users and 41.64 for non-users respectively.

Irrigation also improves the maternal dietary and nutritional status of children. In the Amhara region's Robit and Dangila districts, women who lived in families that used irrigation had more variety in their diets and greater intakes of calcium and vitamin C than women who lived in households that did not use irrigation [67]. Irrigation also improved the dietary diversity of women from households that allegedly encountered drought by around 9% in Ethiopia [68]. The same study also revealed that the weight and height z-scores of Ethiopian children under five improved by 0.87 SDs indicating that irrigation had a positive impact on their nutritional health. This phenomenon is crucial to achieving the SDGs because it keeps mothers and their children well-fed and healthy by giving them access to nourishing meals.

4.4. The Role of Irrigation in Creating Stabilized Food Security in Ethiopia

The 'stability' dimension of food security refers to the consistent availability, accessibility and utilization of food by an individual, household or society across time and space. Hence, stable food security is a factor in the prevalence of all the factors contributing to food availability, accessibility and utilization. The factors of economic strength, production capability, peace and stability as well as personal or social knowledge, culture and food utilization practices are referred to as stable food security.

Irrigation improves the overall food security status of households practicing it. About 70% of farmers deployed in small-scale irrigated crop production in the Ada-liben district tend to be food secure whereas the food security status of rain fed producers is only 20% [7]. A study in the Sibu-sire district found that food insecurity was 27% to 56% among small-scale irrigation users and non-users respectively [69]. Households with larger irrigated crop production areas were also reported to be more food secure and to have a better response to food insecurity factors [54].

Irrigation was found to be among the major determinants of food security in different parts of Ethiopia. The distance of households from irrigation water sources in the central highlands of Ethiopia affects the tendency to use irrigation [70]. Furthermore, the future of agricultural development and food security in Ethiopia is to a great extent a factor of how the country intensifies irrigated crop production [71]. These studies indicate the importance of irrigation for the attainment of stable food security, hence the realization of the SDGs in Ethiopia.

5. Importance of Irrigation in the Ethiopian Economy

Agriculture is the backbone of the Ethiopian economy because it accounts for about 32.5% of the country's gross domestic product (GDP) and 85% of its employment [72, 73]. It is essential to consider irrigation seriously because agriculture is so important to both the national economy and the livelihoods of Ethiopian households. This applies not only to Ethiopia but to all developing countries whose economies are heavily reliant on agriculture.

Rainfed agriculture draws a relatively lesser income from the same plot of land compared to irrigated agriculture. Millions of smallholder farmers in Ethiopia have reduced crop yield and productivity due to the agriculture sector's reliance on rainfall and its unpredictability. Rain-fed agriculture is less efficient both in terms of water use and profitability compared to irrigated agriculture [40] attributed to the decline in crop productivity resulting from the provision of inappropriate doses of water (water deficit and water-logging) from rainfall variability in rain fed agriculture [74]. Such a decline in agricultural productivity leads to a drastic reduction in income from the sale of agricultural products at the household level and in foreign currency earnings from exports at the national level.

Irrigation contributes to the development of export-oriented crops such as fruits and vegetables which can generate foreign exchange earnings for the country. The economic impact of improved agricultural productivity due to irrigation is more pronounced in developing countries like Ethiopia which depend largely on agriculture for their livelihood, foreign earnings and GDP. There are so many direct and indirect pathways through which irrigation may contribute to the Ethiopian economy (see Figure 2). Some of which are discussed in the sections to follow.

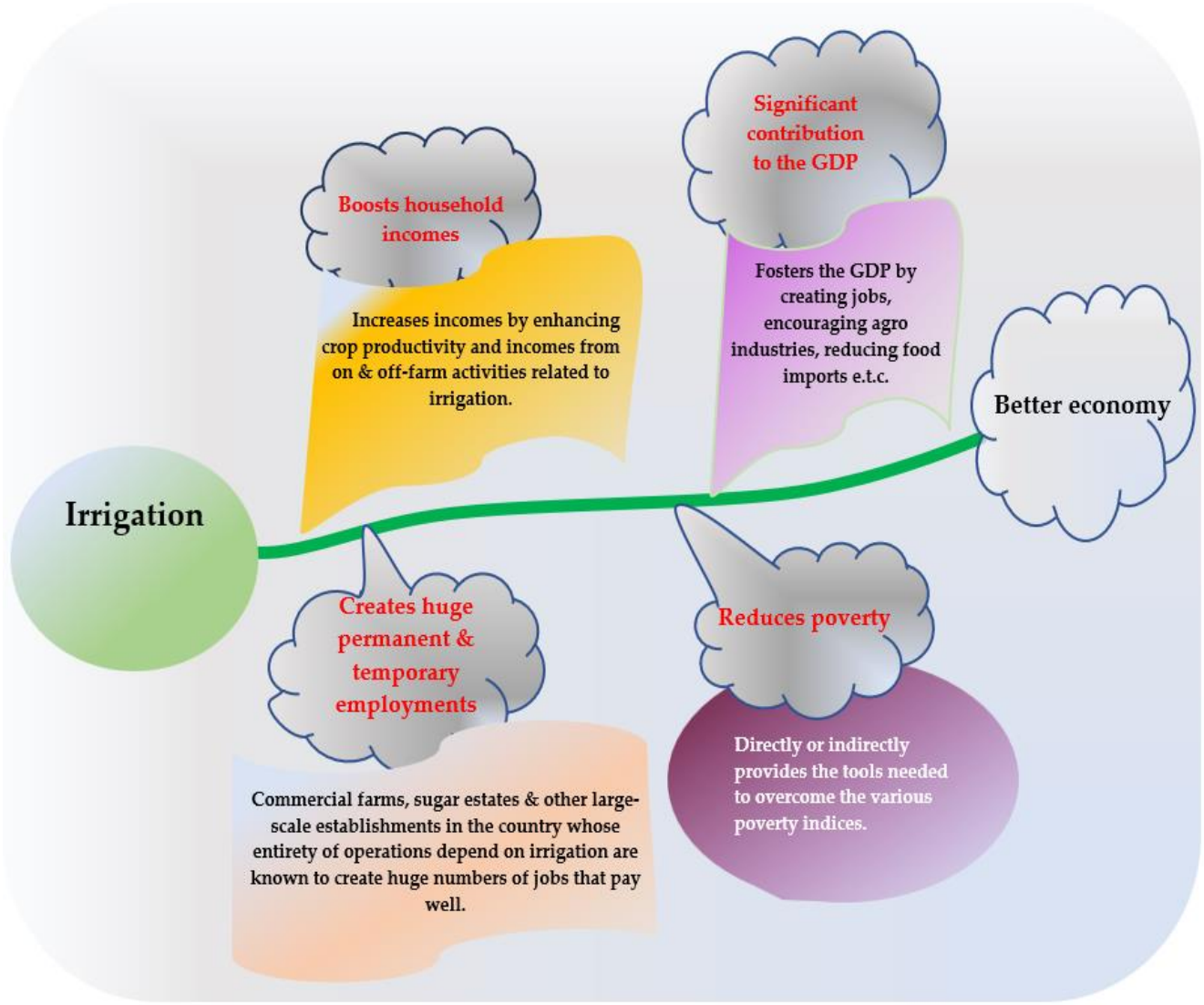

Figure 2.
Contribution of irrigation to poverty reduction in Ethiopia.

5.1. The Role of Irrigation in Boosting Farmer Income

The introduction of high-value products including fruits, vegetables and spices has resulted from the diversification of Ethiopia's agricultural industry brought about by irrigation. For Ethiopian farmers, the cultivation of these products opens up new markets, increasing their income and promoting the economic development of the nation.

According to research, farmers in Ethiopia who use rainfed agriculture make an average of just USD 147 per hectare per year which is significantly less than the USD 323 per hectare per year that farmers who use irrigated agriculture make [75]. This demonstrates a 54.5% revenue gap between farmers who just use rainfed agriculture and those who also use smallholder-managed irrigation systems. Contrary to non-participants, participation in Tigray's irrigated crop production increased household incomes and asset accumulations by about 9% and 186% respectively [76]. Irrigation users in northern Ethiopia had mean annual income and asset accumulation that were 97% and 103% higher than those who did not [53]. Households in eastern Ethiopia reportedly earn 35% more per person than their counterfactual counterparts [6]. Similar results were found in north-eastern Ethiopia where households with access to irrigation had an estimated ETB 7829/USD 200 (8.5%) higher income than their non-irrigating counterparts [77]. In some places, irrigation contributes the largest annual income compared to any other income source for farm households. For instance, irrigation contributed around 71.5%, 74.4% and 76 % of the total annual income for three consecutive years (2011-13) in the Gum- Salesa district of southeastern Tigray [78]. Similarly, the contribution of irrigated crop production to the total annual income of households in Shilena district of the same part of the country was around 70.2% 74.73% and 78% as compared to other sources of income.

Research in the rift valley lake basin, a huge area covering 52,739 km2 and possessing an irrigation potential of 45,700 hectares has also shown farmers deployed in irrigated crop production earn an annual mean income of ETB 10161.5 (USD 188.17) per household which is 33.6% higher than that of farmers relying on rainfall [79]. These figures would have made a visible impact on the national economy in aggregate as 12 million smallholder farming households are currently involved in agriculture. They account for estimated 95% of agricultural production in the country [25, 72]. The following Table 1 shows the income difference between irrigation users and non-users observed across some time and space at different administrative levels in Ethiopia.

Table 1.
Variation in the annual income of households as affected by irrigation.

Location	Administrative level	Region	Total annual income		Exchange rate (USD to ETB)	Reference
			Irrigation users	Non-users		
Shara	Kebele	SNNPR	9166	3413	22.46	Abebe [80]
Elgo	Kebele	SNNPR	15520	7995	22.46	Abebe [80]
Dorga	Kebele	SNNPR	15733	5381	22.46	Abebe [80]
Bahir Dar zuria	District	Amhara	50,681	22,474	20.68	Astatike [81]
Numerous	-	Afar, Oromia, Somali	41,282	16,276	20.0	Nigussie, et al. [82]
Gubalafto	District	Amhara	10,099	3146.75	20.0	Mengistie and Kidane [48]

Note: SNNPR- Southern nations, nationalities, and peoples' region.

However, the degree of contribution of irrigated crop production as a tool to alleviate poverty and create equity depends on the type of irrigation technology used. A comprehensive study assessing the role of agricultural water management (AWM) technologies in poverty alleviation showed that the poverty incidence among non-users was 15% higher than among technology users [83]. The same study revealed the poverty gap and severity were 0.28 and 0.17 respectively for non-users, whereas they were only 0.19 and 0.11 for users. The degree of poverty reduction also depends on the AWM technologies used with 37, 26 and 11%, respectively for deep wells, river diversions, and micro dams [83]. Households possessing motorized water pumps in Tigray were reported to have higher agricultural productivity leading to significantly higher income compared to those not using mechanized irrigation [84]. This underscores the importance of adopting better irrigation management technologies for better and faster poverty reduction in the country.

5.2. The Role of Irrigation in Providing Employment

It has been shown that irrigated crop production generates more employment opportunities and higher wages than rain-dependent farming because irrigated crop production is labor-intensive and requires more work force for its construction, maintenance and operation compared to rain fed agriculture [85]. In addition, the increased agricultural production due to irrigation leads to the creation of jobs in the processing, storage, transportation and marketing of agricultural products. Therefore, irrigation creates temporary and permanent employment opportunities which generate good pay checks.

The hours spent and the pay rates for the operation of irrigated farming are better than those of rain fed farming. Mean hours invested in the irrigated farm operation and the associated labor cost in Wolaita were significantly higher than the rain fed farms for all activities including, ploughing (71%), weeding (70.8%), harvesting (67.6%) and trashing (65.86%) [86]. The labor cost per hectare for irrigated farms in the same area was also relatively higher (535.94 ETB~10.72 USD) compared to the rain fed (305.92~6.1), the former creating 42.9% more pay than the latter. Similarly, irrigation was shown to create a total of 30-210 days of employment and generate 2035–8635 total wages per laborer during irrigated crop

production activities in four irrigation schemes in north Wollo, Ethiopia [48]. This indicates the potential of irrigated crop production in generating more employment and a better pay rate per task compared to rain fed farming. Hence, agriculture provides a large chunk of the country's employment, expanding irrigated farming would create sustainable jobs and better income for employees, thus aiding in the attainment of the SDG through poverty alleviation.

Table 2.
Jobs opportunities are created by the irrigate farms of major sugar estates in Ethiopia.

Sugar estates	Location/ Region	Irrigated plantation area (Ha)	Individual jobs created	Jobs created in terms of OGA	
				Number of OGA	Members
Metehara	Oromia	10.230			
Omo-kuraz (2&3)	SNNPR	40.000	110.000	4	2205
Welkait	Northern Ethiopia	39.500	84.659		
Tendaho	Afar	25.000	77.035	16	1667
Tana Beles	Amhara	40.000	91.493		
Wonji shoa	Oromia	12.800		31	9.319
Arjo-Dedesa	Oromia	16.000	17.547		
Kesem	Afar	20.000	42.773		399
Fincha	Oromia	21.000			
Total		224.530	+423.507	+51	+13.590

Source: Ethiopian sugar corporation report ESC [87].

Another interesting area in which irrigation creates various jobs is through the large sugar estates and commercial farms whose existence and operation are entirely dependent on irrigation [88]. There are already nine sugar states and other big commercial farms that use irrigation which have created tens of thousands of jobs both temporary and permanent (see Table 2).

5.3. The Contribution of Irrigation to the National GDP

One of the major contributors to a country GDP is its exports to Ethiopia. The majority of Ethiopia's export goods and foreign exchange revenues come from agriculture as the government pursues an economic growth strategy that places an emphasis on agriculture-led industrialization. Agricultural commodities accounts for 67% of all exports of goods. This also implies that agriculture account for 67% of the total foreign currency earnings.

Such high export and foreign currency earnings greatly uplift the country's GDP. Irrigation is used to grow the majority of the high-value crops that account for the greatest export shares and generate massive quantities of foreign currency. For instance, flowers make up 13% of the total annual export merchandize of the country and obviously the total of water required for flower production comes from irrigation. The same goes for other crops such as pulses and oilseeds, as it is difficult to generate the desired export earnings with just once year rain fed farming but with year-round production using irrigation.

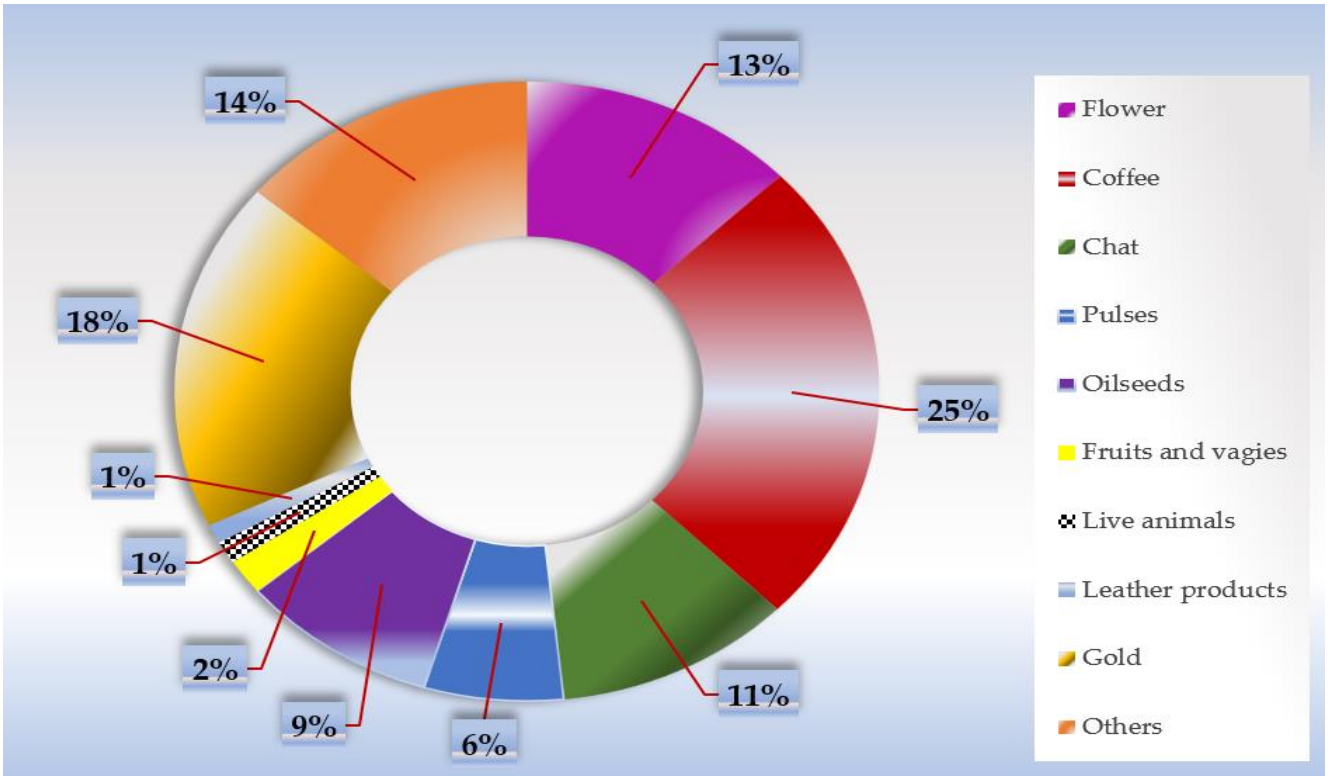

Figure 3.
The share of different merchandizes in the total export commodities of Ethiopia.

The only study linking the contribution of irrigated agriculture to the GDP of Ethiopia came from Hagos, et al. [75]. The authors estimated the contribution of irrigated crop production to be approximately 5.8 and 2.5% respectively to the agricultural GDP and the overall national GDP during the 2005-2006 cropping season (see Table 3).

Table 3.
Contribution of irrigated farming to the agricultural and national GDP.

Typology	2005/2006		2009/2010	
	Agricultural GDP (%)	National GDP (%)	Agricultural GDP (%)	National GDP (%)
Smallholder-managed	4.5	2	5.5	2.3
Large-scale sugar plantations	1.26	0.5	2.9	1.2
Other large-scale plantations	-	-	0.4	0.2
Over all (%)	5.76	2.5	8.8	3.7

Source: Hagos, et al. [75].

The same authors predicted that during the 2009–10 growing season, irrigation would contribute 3.7% to overall GDP and 8.8% to the agriculture sector. These improvements were about 36.6% and 28.6% respectively compared to the previous estimation in the 2005- 2006 cropping season [75]. However, it was difficult to confirm whether the prediction for the 2009-10 production seasons was held or not.

Moreover, it is necessary to develop research designs that help determine or quantify the contribution of irrigated crops to foreign earnings and the GDP at least on an annual basis. This would help to get updated insight into the performance of the irrigation sector which can be used to improve and sustain the sector.

6. Opportunities to Improve Irrigation Development in Ethiopia

The main opportunity is the more than 3-million hectares irrigation potential which could support well over 6 million farmers and move millions out of poverty and hunger. Furthermore, ATA is leading various projects with the aim of exploring and mapping the country's groundwater resources to further expand the country's irrigation potential. It is necessary to mechanize the irrigation system, increase the irrigated area and boost the number of farmers engaged in the production of irrigated crops.

Ethiopian governments have always been highly eager to develop the irrigation sector regardless of gaps in the implementation of proposed strategies. This was true from the imperial regime to the Dergue government through the Ethiopian People's Revolutionary Democratic Front (EPDRF) and the current ruling government propensity. The Ethiopian government has been working to use irrigation as a tool to achieve food self-sufficiency and economic improvement both at the household and national levels. The PIF allocated about 38% of its 10-years (2010–2020) financial plan or USD 18 billion to irrigation development to achieve an 8% annual increase in arable irrigated land. On the other hand, a 15-year, USD 47.97 billion small-scale irrigation (SSI) capacity-building strategy was also introduced by the ministry of agriculture in 2012 [89].

Prime Minister Abiy Ahmed has advocated for the development of the irrigation industry on several platforms from the African Union Hall to his own social media accounts. At the inauguration of the Meki-Ziway irrigation project in May 2020, he said, "The irrigation project is our top priority in the agriculture sector". This indicates the commitment of the government to improve the productivity of smallholder farmers with an emphasis on the expansion of irrigated crop production. The government has a significant role in both the overall growth of the nation and the development of the irrigation system.

The government is currently undergoing a series of reforms to improve irrigation and mechanization. Recently, a historic tax reform bill that removed almost all duty taxes on irrigation mechanization technologies was signed by the Ethiopian Ministry of Finance (MoF) in May of 2019 [90, 91]. This is a huge opportunity to improve the largely traditional, inefficient and non-equipped irrigation system of the country as irrigation machinery would become reasonably cheap and accessible to farmers. However, farmers still struggle to buy irrigation apparatus despite the tax reform measure eliminating all taxes on it. Thus, the government should provide a long-term, interest-free loan to farmers to help ease access to machinery and mechanize the irrigation system gradually.

Various international organizations, non-governmental organizations (NGOs) and other interested funders are actively engaged in funding irrigation development programs in the country. The World Bank is providing funds to help improve irrigation usage and increase the supply of resources to benefit 1.6 million smallholder farmers in Ethiopia through the agricultural growth program II (AGPII) [92]. A Bill and Melinda Gates Foundation-funded project prioritizing on climate-smart water management practices is currently being undertaken by IWMI in Ethiopia. The project aims at identifying improved water management decision support tools and enhancing climate change adaptation practices for shared socio-economic pathways (SSP) through improved AWM technologies. Other funding entities are currently in the country providing funds for the development of the country's agriculture in general and the improvement of the irrigation sectors. In this era of rapid climate change, these funding organizations provide opportunities because they are forces for good driving the country's irrigation system towards mechanization and the adoption of climate-smart water management technologies.

7. Challenges to Irrigation Development in Ethiopia

The main challenges to irrigation development in Ethiopia are the expensive setup and operating costs of irrigation facilities. The prolonged time spent on the management of irrigated crop farms is reported to be double compared to the less management-demanding and less costly rain-fed farming [79]. This scenario is known to create employment and generate higher pay rates for laborers but it tends to make the operational costs unaffordable for the farmers [92].The farmers' limited financial resources prevent them from acquiring better irrigation technologies and covering the higher operating costs. Moreover, the country's largely traditional irrigation system cannot be modernized due to insufficient extension services and a lack of relevant information on agricultural water management systems [89].

The other challenge hindering the development of irrigation and often leading to the profligate use of water is the absence of strong irrigation water management institutions at various levels. There are only two types of irrigation institutions in the country, irrigation water user's associations (IWUA) and irrigation cooperatives or committees. These two govern only 70% of the irrigation schemes leaving the remaining 30% of the schemes unmanaged [93]. It was also revealed that the average membership of semi-modern and modern scheme irrigation users in the irrigation water association is 70% lower than that of smallholder irrigation users. This is a colossal problem as it hinders the applicability of irrigation water use rules and paves the way for free usage of irrigation water by non-members. This creates a sense of inequity among members usually leading to frequent conflicts. In some regions of Ethiopia, up to 46% of farmers reported routine water-related disputes brought on primarily by irrigation water theft and irrigation turn misuse in their irrigation systems [94]. Therefore, effective water management strategies are important as water is a very scarce resource and should be conserved. This gets even more alarming when realizing that crop water demand is going to drastically increase for most of the crop plants and precipitation will follow a trend of decline or high variability in most parts of the world in this era of rapid climate change [95, 96].

The ongoing civil war and unrest have had a substantial impact on the country's agriculture since their outbreak in 2020 despite the fact that conditions are gradually improving. This has left a great deal of land uncultivated and led million to acute starvation especially in the northern parts of Ethiopia. According to FAO, the war has severely disrupted agricultural operations in Tigray and neighboring areas of the Amhara and Afar regions [97]. The Tigray agricultural bureau revealed that an estimated 1.3 million hectares of crops were damaged in the Tigray regional state due to the destruction of land and plundering as a result of the war [97, 98]. Agricultural research activities have also almost ceased in the region as the Tigray agricultural research institute sustained massive damage.

A lot of damage to crop produce has also been faced in north Shewa of the Amhara region as many farmers could not harvest their crops due to the interruption by the civil war [100]. Therefore, the prevalence of peace and stability would be vital for agricultural activity to return to normal and feed the millions of people starving in the northern parts of Ethiopia, Tigray, Afar and Amhara as well as the rest of the country.

Additionally, there has been widespread civil instability throughout the country, especially in Oromia, Benishangul, and the southern nations, nationalities and regional states which has deteriorated the state of agricultural productivity. Hence, it's not uncommon to observe a decline in the irrigated production area or the number of farmers involved in irrigation in the past few years. However, neither food insecurity nor poverty care about war. It's not like food insecurity and poverty are going to offer people a pass on hunger and malnourishment with the sentiment that they are affected by war or any other excuse for that matter. The SDG can only be achieved by sustainably growing production and revenue and surfing against all obstacles in order to achieve food security and prosperity.

8. Conclusion and Prospects

Ethiopia is blessed with huge irrigation potential and a varying agro-ecology suitable to produce almost every type of food crop. A great deal of the population of the country suffers from acute hunger and severe poverty as result of failure to exploit this great irrigation potential. There is still more work to be done in developing and implementing irrigation development initiatives despite the government's recent strong attention to the irrigation sector. Therefore, a strong commitment is needed to take advantage of the various benefits of irrigation ranging from ensuring food security to fostering the house hold and the national economy.

When the Ethiopian government plans to use irrigation as a tool for famine alleviations, it should focus on dealing with each of the components of food security. This would be very important as it helps identify which dimension of food security the country or the community under consideration lacks. Finding the precise weak point in the food security chain would allow policymakers to immediately devise short- and long-term measures to address it and ensure food security. Otherwise, the government might attempt to increase food availability when the real cause of food insecurity in the nation is a lack of access to or insufficient use of the food that is already available.

The government should first assess the major possible ways irrigation could help improve the economy and deal with them individually. Therefore, the focus should be on how to use the irrigation sector to create better paying jobs, boost household incomes, overcome the various poverty indices, improve the GDP and make all this work for the good of the overall national economy.

It is important to continue conducting systematic studies to determine the precise and direct role irrigation plays in reducing poverty, ensuring food security and achieving the SDGs as well as the overall performance of the national economic strategies.

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