Review

Trends in Irrigated Crop Production in Ethiopia During the Period of Sustainable Development Goals

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Abstract: Ethiopia has 51.3 million hectares of arable land and irrigation potential of 3,088,395 hectares. Despite the country's vast irrigation potential, it hasn't benefited much. Studies have confirmed the role of irrigation in increasing crop production, alleviating poverty, and promoting food security. Given such importance of irrigation in poverty and hunger alleviation, it's believed that the development of the sector contributes to the realization of sustainable development goals (SDGs). Therefore, this review looked into the progress of the irrigation sector over the past seven years, between 2015 (the launch of the SDGs) and 2021 (the midterm of the SDGs period). During this period the number of smallholder irrigators increased by 15.21% and the total increase in irrigated land was only 1.4%. Vegetables, root crops, fruits and stimulant crops showed an increase of 153.8%, 66 %,16.6% and 1% in the irrigated production area, respectively. On the other hand, irrigated production areas of cereal, pulse and oil crops declined by 8.0%, 44.6% and 90.5%, respectively. Among cereals, only Teff showed a slight 4.3% overall increase in the irrigated production area, whereas Barley, Wheat, Maize and Sorghum decreased by 12.5%, 3.3%. 11.3%, 12.9%, respectively. This shows that the irrigation sector is characterized by a decline or underachievement during this period. Hence, there is a need for studies into why the sector experienced such a disappointing performance, in order to come up with strategies to improve the sector in the remaining periods of the SDGs.

Keywords: Irrigation; Food security; Poverty; SDGs

1. Introduction

Member states of the United Nations, including Ethiopia, adopted the Sustainable Development Goals (SDGs) by General Assembly resolution A/RES/70/1 of 25 September 2015[1]. The resolution set 17 interlinked goals to be achieved by 2030. The first and second goals of the SDGs were described as 'No Poverty' and 'No Hunger' in short. The former aims at alleviation of poverty in all its forms everywhere, and the latter intends to end hunger, achieve food security, and improve nutrition through sustainable agriculture. Although all the SDGs are very important across the globe, these two goals are even more important in the context of Ethiopia, where more than 5% of the population are food insecure[2] and nearly 22% of its citizens live below the national poverty line[3].

The UN guidelines on sustainable development goals stress the need for global targets and indicators to assess the achievement of the SDGs for the goals to be action-oriented and easy to communicate. However, most of the indicators for the operationalization of SDGs are considered ambiguous[4]. Hence, it's hard to quantify or approximate the contribution of some development measures, such as irrigation development in a country, to the SDGs. However, it is believed that any sustainable action which will help to end hunger and poverty can contribute to the realization of the SDGs.

Ethiopia has around 51.3 million hectares of arable land, spreading well over 18 agro-ecological zones, making the country suitable for growing over 100 types of

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crops[5]. The country is also blessed with 12 river basins with an annual runoff volume of 122 billion m^3 of water[6]. This potential is less utilized as the current irrigated crop covers only a fraction of the irrigation potential. Several studies have revealed that practicing sustainable irrigated farming is a crucial tool in improving the incomes of farm households[7], ensuring food security[8,9], and alleviating poverty in general[10,11]. Similarly,[12] emphasized the role of irrigation in enhancing agricultural production, increasing household income and asset ownership, improving human health due to a balanced diet and access to medication, and preventing soil and ecological degradation. Thus, playing a huge role in the realization of the SDGs either directly or indirectly. In countries like Ethiopia, where agriculture accounts for about 40% of the country's gross domestic product (GDP) and 85% of its employment, the role of irrigated agriculture is becoming very vital [13,14].

That is why the Ethiopian Ministry of Agriculture (MOA) has been working with the notion that the achievement of food self-sufficiency and food security both at the national and household level requires raising production and productivity through the development of the irrigation system, particularly in the smallholder sub-sector[15]. The Agriculture Sector Policy and Investment Framework (PIF) proposed a major irrigation development investment which was approved in 2010. The PIF allocated about 38% of its 10-year (2010–2020) financial plan, USD 18 Billion, to irrigation development to achieve an 8% annual increase in arable irrigated land. On top of that, MOA also launched a USD 47.97 billion worth of 15 years, small scale irrigation (SSI) capacity-building strategy action plan which was commenced on January 01, 2012, and is expected to be effective until 2025 [15]. All these focus on the irrigation sector from the government reflects the role of irrigation development in Ethiopia's economy and food security, which in turn plays an important role in achieving the sustainable development goals.

In light of the importance of irrigated crop production to alleviate poverty and improve food security in Ethiopia, it's imperative to review its trends during the past seven-year period of the SDGs. In this regard, we collected a seven-year survey data from the Ethiopian Central Statistics Agency (CSA) on private peasant landholdings on irrigated land and irrigated production of major crops and evaluated the progress made in irrigation development. Thus, this paper aims at reviewing the trends in the irrigation sector of Ethiopia during the SDGs period, with an emphasis on the number of irrigators and the total area under irrigated production of major crops.

2. Irrigation Potential in Ethiopia

Irrigation potential can be defined as the total land area which is technically feasible, economically profitable, socially viable, and environmentally acceptable that is irrigated or capable of being irrigated based on water and land availability[16]. The estimation of the irrigation potential of a region may vary a lot from study to study or from time to time. Country or regional studies estimate irrigation potential based on a variety of criteria. For instance, some take into account land resources only, others consider water availability, and the rest may take into consideration the environmental and economic conditions of the country, etc.[17]. [18] considered factors like production geography, the potential performance of irrigated agriculture, potential runoff, irrigable area, associated water delivery costs, etc., in their assessment of the potential for irrigation investment. Recently, models, remote sensing, and GIS technologies are becoming researchers' favorites in determining the irrigation potential of a region. [19] used model to assess and map the irrigation potential of the Abbay (Nile) river basin in Ethiopia. On the other hand, remote sensing and GIS have been used to assess the irrigation potential of a Canal system in India[20]. Such deviations in assessment and estimation strategies lead to ambiguous and inconsistent reports on the irrigation potential of countries, the same is true for Ethiopia.

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Most of the classic irrigation related survey studies in Ethiopia came from the work of the iconic Engineer Seleshi Bekele Awulachew (well known for his role as the Minister of Water Irrigation and Energy of Ethiopia (WIEE) and chief negotiator in the trilateral negotiations in regards to the Grand Ethiopian Renaissance Dam (GERD)) and his colleagues during his days at IWMI [21-23]. According to [24], about 5,300,000 hectares of land in Ethiopia can be potentially irrigated. This has shown an advance of about 28.3% over the estimation by [25], in which they reported the country's irrigable land to be 3,798,782 ha. The variation arises from the fact that [24] included harvested rainwater and groundwater, which has the potential of irrigating an additional 1,600,000 ha of land. On the other hand, in 2016, FAO estimated the irrigation potential of Ethiopia at about 2.7 million ha, based on the availability of water and land resources, technology, and finance, and even outlined the hectarage and percentage contribution of each drainage and river basin [26]. This is a typical manifestation of variation in the estimation of a country's irrigation potential, even by a similar author, based on things taken into consideration during reporting or survey.

According to the Agricultural Transformation Agency (ATA), the current total groundwater resource of Ethiopia is estimated to be 27.27 billion m^3 [27], which has a 76.2% increase compared to the highest estimation, 6.5 billion m^3, by [25]. This variation in the estimation of groundwater resources makes sense as the total groundwater resources mapping area has increased from time to time and currently sits at 234,772 km^2 [27]. ATA in its latest 2020/21 annual report, also revealed that the country has an irrigation potential of 3,088,395 ha which can support 6,176,898 farm households. However, one can realize that the irrigation potential of Ethiopia estimated by [25] and [24] a decade or more ago is superior by 23% and 71.6% respectively, to the current estimation by ATA. This gets difficult to accept, especially when realizing the currently estimated groundwater resource of the country by ATA has increased dramatically (quadrupled) compared to the 2.6–6.5 billion m^3 estimation in earlier years[25]. Well, again, this discrepancy maybe is related to the differences in the assessment strategies and criteria considered during the evaluations. With all this in mind, for the sake of this paper, we will make our arguments and discussion based on the latest report on the country's irrigation potential by ATA (3,088,395 ha).

3. Total Land under Irrigation

Although Ethiopia has the largest irrigation potential in East Africa, followed by Tanzania and Kenya, it uses only a small portion of it[28]. In its latest annual report, CSA estimated the total irrigated land for 2020/21 by private peasants to be only 181,395 ha, practiced by around 1.4 million households. Sadly, this is only 5.9% and 22.7% of the total land area and the number of farmers respectively, the country's irrigation potential can support.

However, most authors report the percentage of irrigated land to irrigation potential of the country based only on land area irrigated by private peasant holdings, without considering those by commercial farms and sugar estates. This is because though the CSA releases survey reports on different aspects of the private commercial farms, it does not include the areas irrigated by those farms. Hence, it is difficult to obtain data on trends in irrigated land area by 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), currently, there are eight sugar estates involved in irrigated sugarcane production on an area of 145,030 ha [29]. So, 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 ha, and this again makes up only 10% of the country's irrigation potential. His Excellency, Dr. Abiy Ahmed, Prime Minister of Ethiopia, in his welcoming

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speech at the opening of the 35th ordinary session of the African Union (AU) on the 5th February 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 birrs in income to our farmers".

One of the main points to take hold of this speech is the claim by the Prime Minister that nationally a total of 500,000 ha of land is under irrigated wheat production. It seems strange that the Ethiopian central statistics agency (CSA) 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, which in any case requires confirmation when the CSA 2022 report is issued. Regardless, even if the estimate by the CSA on irrigated land by private peasants, the report on the area irrigated by sugar estates from ESC, and the claim by the prime minister are considered (806,425 ha) as the total area currently under irrigation, it would still be only 26.1% of the irrigation potential of the country. This is a clear indicator of how long the country has left to go in its irrigation development, to put its estimated 5.7 million people out of the misery of hunger and put its estimated 22 million people living below the national poverty line above it first [30] and even export crops then.

4. Importance of Irrigation to the Ethiopian Economy

The dependence of Ethiopian agriculture on rainfall, and its variability, hamper the production and productivity of millions of smallholder farmers[31]. Rain-fed agriculture is less efficient both in terms of water use and profitability compared to irrigated agriculture [32]. In developing countries, like Ethiopia, rainfed grain yields average 1.5 t ha^{-1}, compared with 3.1 t ha^{-1} in irrigated agriculture [33]. This is 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.

A study found that the average income of farmers practicing rain-fed agriculture in Ethiopia, USD 147 ha^{-1}, is much lower compared to the average income of approximately USD 323 ha^{-1} generated by farmers practicing smallholder irrigated farming [34]. This shows a 54.5% income difference between the farmers practicing rain-fed agriculture only and the income of smallholder-managed irrigation systems. According to [35] the mean annual income, consumption expenditure, and asset accumulation for irrigators in northern Ethiopia were respectively 97%, 114%, and 103% higher than that of the non-irrigators. Research in the rift valley lake basin, a huge area covering 52,739 km^2 and possessing an irrigation potential of 45,700 ha, has also showed farmers deployed in irrigated crop production earn an annual mean income of 10161.5 Ethiopian birr/ETB/ (USD 198) per household, which is 33.6% higher than that of farmers relying merely on rainfall [36]. These figures would have made a visible impact on the national economy in aggregate, as currently 12 million smallholder farming households are involved in agriculture, and they account for 85% of overall employment and an estimated 95% of agricultural production in the country [14,37].

Irrigated crop production is also witnessed to create more employment and better pay rate than rain-dependent farming. [36] revealed mean hours invested in the irrigated farm operation and the associated labor cost are significantly higher than the rain-fed only for all farm activities including, plowing (71%), weeding (70.8%), harvesting (67.6%) and trashing (65.86%). The labor cost per hectare for irrigated farms is also relatively higher, ETB 535.94(USD 10.5) compared to the rain-fed ETB 305.92 (USD 5.96), the former creating 42.9% more pay than the latter. 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, given agriculture provides the greater chunk of the country's labor, expanding irrigated farming would create sustainable jobs and better

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income for employees, thus aiding the attainment of the SDG through poverty alleviation.

The degree to which irrigated crop production contributes to alleviating poverty and creating equity tends to differ among the irrigation technology used. A comprehensive study assessing the role of Agricultural Water Management [AWM] technologies in poverty alleviation showed that the poverty incidence among nonusers was 15% higher than the technology users, and the poverty gap and severity were 0.28 and 0.17 respectively for nonusers, whereas it was only 0.19 and 0.11 respectively for users [38]. The study also found that the degree of poverty reduction depends on the AWM technologies used, with 37%, 26%, and 11%, respectively for micro dams, river diversions, and deep wells. This underscores the importance of adopting better irrigation management technologies or methods for better and faster poverty reduction in the country.

To the best of our knowledge, the only study linking the contribution of irrigated agriculture to the GDP of Ethiopia came from [34]. 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 (Table 1).

Table 1. 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
Overall (%)	5.76	2.5	8.8	3.7

Adopted from [34]

The authors also predicted the contribution of irrigation to the agricultural (8.8%) and overall GDP (3.7%) during the 2009/10 cropping season. This was an improvement of about 36.6% and 28.6% in its contribution to the agricultural and national GDP respectively, compared to the previous estimation in 2005/2006. However, it was difficult to confirm whether the prediction for the 2009/10 production season held or not.

5. Importance of Irrigation to Food Security in Ethiopia

The 1996 world food summit (WFS) defined food security as a state in which all people, at all times, have physical, and economic access to sufficient, safe, and nutritious food which meets their dietary needs and food preferences for an active and healthy life. This definition lays down four preconditions to be fulfilled for a country or a household to be considered food secure; food availability, access to food, food utilization, and stable supply of food [39]. Fulfillment of these four dimensions is mostly related to agricultural production status and the economic or financial capabilities of households or countries to acquire/import food [40-42].

Globally, irrigation has been shown to contribute to all the components of food security. Irrigation was reported to promote food security by increasing crop productivity (food availability)[43], boosting farmer incomes (access to food) [44] encouraging dietary diversity (food utilization) [45], and ensuring year-round crop production (stable food supply)[46,47]. This holds for Ethiopia too, where irrigation was witnessed to contribute to food security by increasing crop production, reducing the risk of crop failure, and generating higher and year-round farm and nonfarm employment [48]. Moreover, the contribution of irrigation to food security in Ethiopia may take different pathways, some direct and others indirect. Upon studying the role of small-scale irrigation in food securi-

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ty in northern Ethiopia,[35] developed a conceptual framework (Figure 1) to illustrate the many forms through which irrigation contributes to household food security in the country.

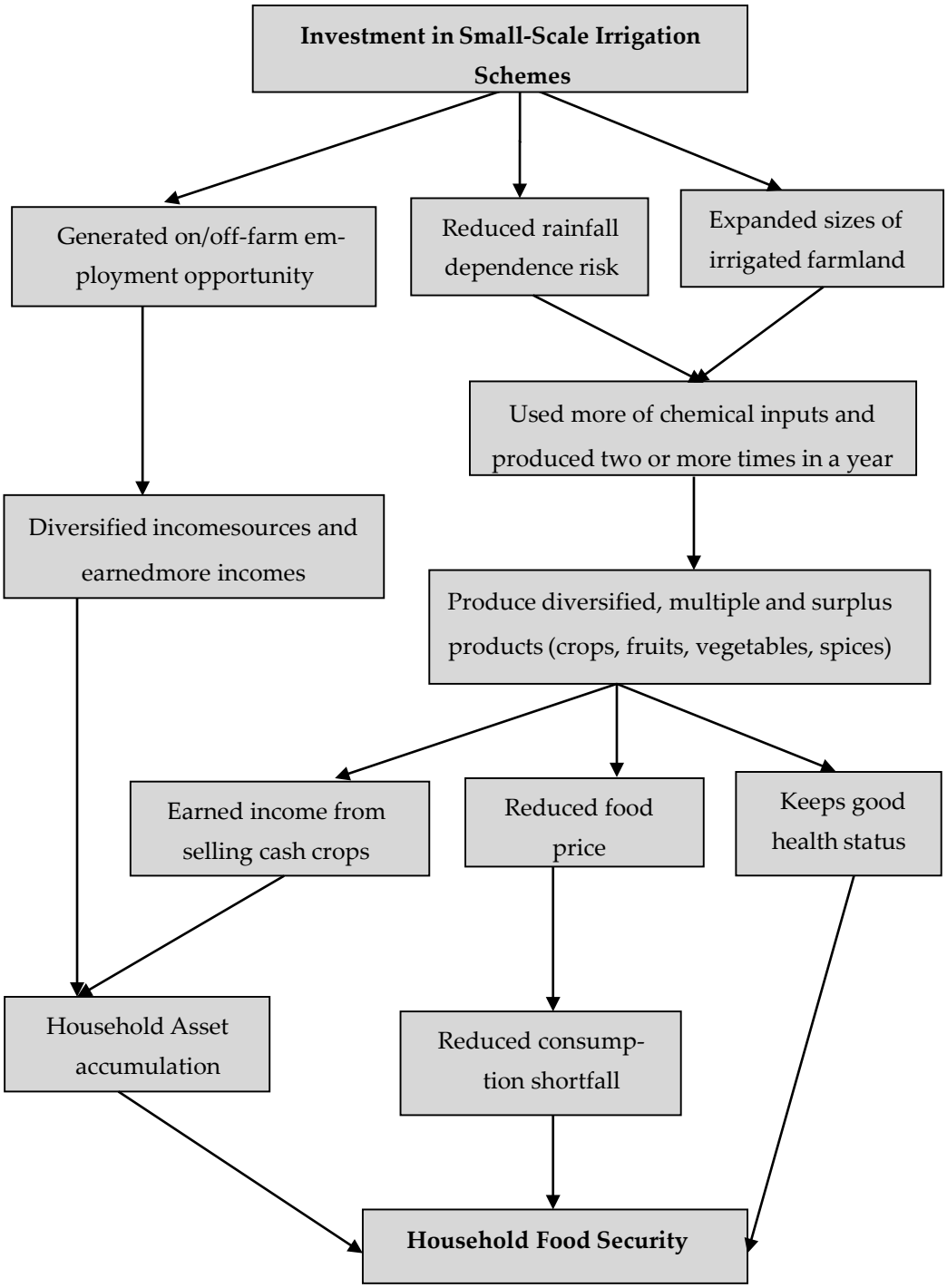

Figure 1. The schematic framework of the linkage between small-scale irrigation to food security [35].

Irrigation was shown to increase the daily per capita intake of households in different parts of Ethiopia. According to a study in a district of Oromia, farmers participating in small-scale irrigation tend to intake 643.76 Kcal more daily calories compared to farmers dependent only on rainfed agriculture [49]. In a study in the Arsi zone, only 26.25% of the irrigation users intake a daily calo-

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rie less than 1500 Kcal while on the other hand, the percentage was almost double, 49.2%, for non-irrigators [50].

Irrigation has also been shown to provide better household dietary diversity. It does so through its role in supporting more diversified production of crops including vegetables, fruits, and cash crops, compared to non-irrigating households[51]. [52] found that access to irrigation was among the most important determinants of household dietary diversity. This was supported by their finding in which dietary diversity of households with access to irrigation was higher by a factor of 5.824 than those households with no access to irrigation. Irrigation also reduced seasonal variation in maternal dietary diversity in a study conducted in watersheds of Robit and Dangila districts of the Amhara region. Women from households that practiced irrigation had a higher dietary diversity coupled with higher vitamin C and calcium intakes compared to women in non-irrigating households of these districts [53]. This helps in the realization of the SDGs as it provides women with nutritious food, keeping mothers as well as their babies healthy. This has its implication in empowering women and closing the gender gap in the long run, hence contributing to the SDGs.

Generally speaking, irrigation has been shown to improve the overall food security status of households. About 70% of farmers deployed in small-scale irrigated crop production in the Ada-liben district of Oromia tend to be food secure whereas the food security status of rainfed-based producers stands at only 20% [54]. A study in the Sibu-sire district found that food insecurity was 27% and 56% among small-scale irrigation users and non-users respectively, whereas the respective food security status was 73% and 44% for the former and the latter[55]. Moreover, studying the role of agriculture in food security in Ethiopia, [56] concluded that the future of agricultural development and food security in Ethiopia to a great extent is a factor of to what degree the country endeavors to intensify irrigated crop production. Hence all these studies in aggregate indicate the importance of irrigation in general or small-scale irrigation in particular to the attainment of food security, hence realization of the SDGs in Ethiopia.

6. Trends in Irrigation Status during the SDGs

6.1. Number of irrigators and area irrigated

The number of smallholder farmers practicing irrigation and the area under irrigated crop production has not been increasing or decreasing linearly. For instance, the number of irrigators declined by 17% from 2015 to 2016, which then showed a dramatic peak of 52.4% (Figure 2).

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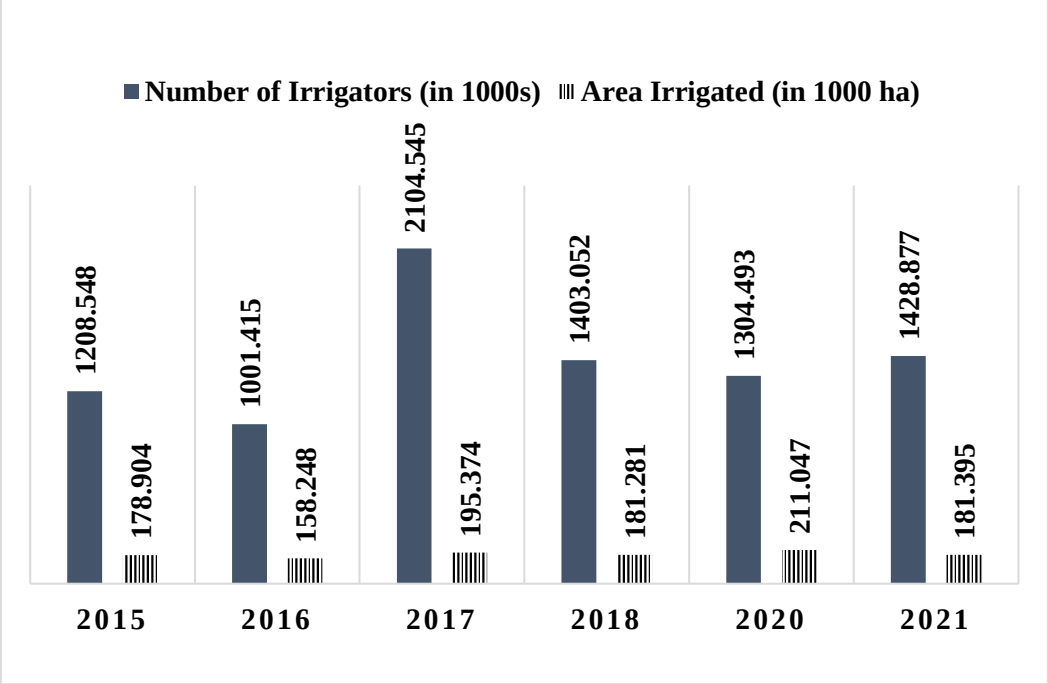

Figure 2. Trends in the number of irrigators and area irrigated since the launch of SDGs (2015-2021)

However, in 2018, a 33.3% decline was registered, followed by another 7% decline in 2020 and an increase of 8.7% in 2021. Overall, the number of smallholder irrigators increased by 15.21% in 2021, compared to the number of irrigators back in 2015 at the launch of the SDGs. This 15.21% makes 220,329 farmers, which implies new farmers of this number have started irrigated crop production between 2015-2021. Well, with the general assumption of farmers engaged in irrigated crop production would get out of poverty and become food self-sufficient, it can be said that the household incomes and food security of these farmers have been improved due to irrigation. This is not unrealistic, as many studies have emphasized the importance of practicing irrigation farming in generating more income, securing food self-sufficiency, and alleviating poverty [57,58].

If the same trend continues, it may also mean irrigated crop production would put only 1% (220,329 farmers) of the 22 million poor people above the poverty line in the remaining years of the SDGs. This is a very small fraction, especially when realizing the country's irrigation potential has the capacity to support an estimated 6,176,898 farming households. In addition, there is no guarantee that the number of irrigators will not decrease in the coming years, as the number of farmers practicing irrigation fluctuated over the past seven years. Under such a scenario, the contribution of irrigation to poverty and hunger alleviation would even become lesser, thus hampering the success of SDGs.

Similar to the number of irrigators, irrigated hectares of land have also fluctuated over the past seven years. The percentage change in hectares of land irrigated, calculated in comparison to their respective preceding year, is -11.6, 19, -7.8, 14, and -16.4% for the years 2015, 2016, 2017, 2018, 2020, and 2021, respectively. Realizing the government has been working by allocating USD 18 billion of the PIF, expecting a yearly 8% increase in arable irrigated land between 2010 and 2020 this trend is a huge disappointment. Even when the total increase in irrigated land between 2015 (178.904 hectares) and 2021 (181,395 hectares) is considered, there is only a 1.4% increase. Still, this is almost insignificant and is a small impediment to the improvement of the irrigation sector in terms of the amount of capital invested by taxpayers and fund providers.

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This largely seems an indication of the lack of strong determination of the government to implement well-planned strategies aimed at increasing the number of farmers practicing irrigation and thereby increasing the irrigated land area to exploit the country's irrigation potential. In this regard, the figures discussed here in terms of economic and food security gain are very helpful but are based on rough assumptions. Therefore, there is a need for further studies into why, despite the massive investments, the irrigation sector failed to yield significant improvement over the years and its possible link and impact on the economy and food security in relation to SDGs.

6.2. Irrigated production area of major crops

Crop types didn't exhibit a unidirectional increase or decrease in the area of production through the years. When all crops are examined in aggregate, 2020 was the year in which crops were produced in the largest irrigated area with a production area of 211,047 ha, whereas 2015 was the year with the least irrigated crop production area (Figure 3).

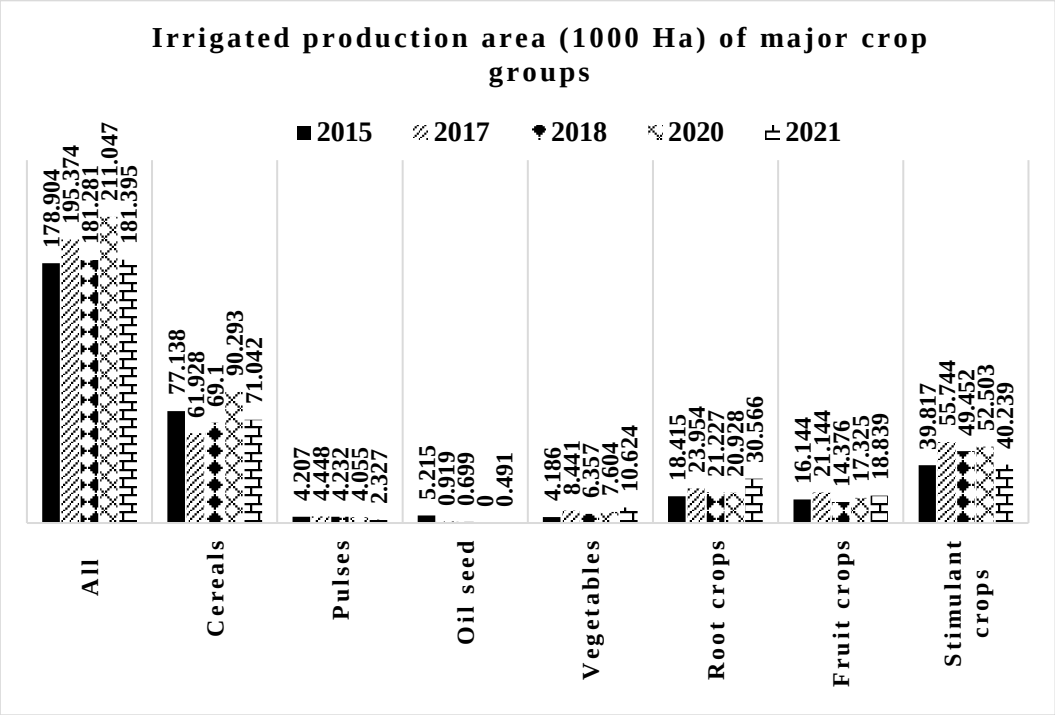

Figure 3. Area (ha) covered with irrigated production of different crop types since the launch of the SDGs.

The area under irrigated production at the start of the SDGs(2015) was 178,904 ha, compared with the irrigated area at the midterm of the SDGs period(2021), 181,395 ha, there is only a 1.3% peak. Well, this again is an underachievement, realizing the huge investment and considering what can be achieved with the available tremendous irrigation potential (> 3 million ha) of the country.

The trends in irrigated production of individual crops are in line with what is witnessed for aggregated crops. With the exception of vegetables and root crops, all crop types decreased in irrigated production areas compared to 2015 (Table 2).

Table 2. Percentage change in the area under irrigation through the years in comparison with 2015.

year	Crop Types

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		Cereal crops	Pulse crops	Oil crops	Vegetables	Root crops	Fruit crops	Stimulant crops
2015	Area (ha)	77.1	4.2	5.2	4.19	18.4	16.0	39.8
2017	% Change from 2015	-19.7	5.7	-82.0	101.6	30.0	30.0	40.0
2018	% Change from 2015	-10.4	0.6	-86.6	51.9	15.3	-11.0	24.0
2020	% Change from 2015	17.0	-3.6	*	81.7	13.7	7.3	31.8
2021	% Change from 2015	-8.0	-44.6	-90.5	153.8	66.0	16.6	1.0

Source; calculated from CSA data (*Not reported; Complete data for 2016 and 2019 were not available)

Irrigated cereals, pulses, and oilseeds by 2021 were down by 8%, 44%, and 91%, respectively, compared to 2015 when the SDGs were announced. This raises concerns because these crops are the staple food crops in almost all the regions of Ethiopia[59]. Thus, lower production of these crops may result in food insecurity and reduced income, which also implies an increase in production of such crops contributes a lot to the improvement of nutrition and poverty alleviation in the country. On the other hand, the 1% increment in the production area of stimulant crops (coffee, khat, etc) is not enough either, as these crops are among the major cash crops at the household level and export commodities at the national level [60-62].Hence, irrigated production of stimulant crops would have contributed a lot to improving the incomes of households and the overall GDP of the country if expanded more. Therefore, a thorough investigation of such underperformance of these crops is needed to identify possible measures to make up for the remaining periods of the SDGs.

On the other hand, the irrigated production area of vegetables, root crops, and fruit crops increased by 153.8, 66, and 16.6% respectively. This is important because fruits and vegetables are deemed very nutritious and root crops are praised as one of the prominent food security crops in this era of climate change[63,64]. Hence, it's crucial to be resolved to keep this promising trend in irrigated production of fruit, vegetables, and root crops and duplicate the trend in cereals, pulses, oil cops, and stimulant crops to guarantee food security and realize the SDGs.

6.3. Irrigated production area of major cereals

Cereals make up 81.2% (10.54 million ha) of the total (both irrigated and unirrigated) crop production area and nearly 61% (181 thousand ha) of the total irrigated crop production area [37]. This means that irrigated cereals barely account for 1.7% of total cereal production. Similarly, the percentage share of irrigated production of the top five cereal crops, Teff, Sorghum, Wheat, and Barley to their respective total production area is all less than 1%, except for Maize which accounts for 1.62% (Table 3).

Table 3. Percentage share of irrigated area in the total production area of some cereals in 2021

crops	Total production area (ha)	Production area under irrigation (ha)	Share of irrigated area in the total production area (%)
Teff	2,928,206.26	9,325	0.32
Maize	2,526,212.36	40,829	1.62
Sorghum	1,679,277.06	13,451	0.8

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Wheat	1,897,405.05	6,403	0.34
Barley	926,106.90	319	0.03

Source:- calculated from the CSA (2021) survey data

This shows that the country's agriculture dependency is largely on rainfall and that huge irrigation potential is not being utilized properly. It is possible to imagine the impact intensive irrigated production of these crops using the unexploited irrigation potential would have on food security and the economy at the household and national levels.

Trends in the irrigated production area of the individual member crops of the cereal varied through the years. Teff, Barley and Wheat experienced relatively less fluctuation, while maize and Sorghum showed high variability in production area through the past 7 years of SDGs (figure 4).

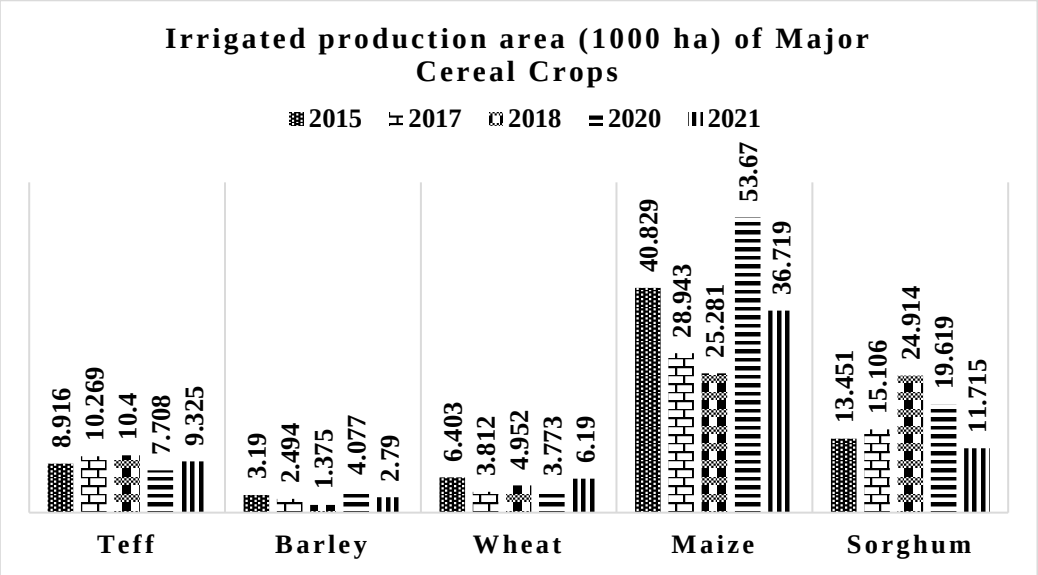

Figure 4. Area covered with irrigated production of different cereal crops (1000 ha).

Source; CSA survey data

Only Teff showed a slight 4.3% overall increase in the irrigated production area, whereas the remaining four major cereal crops were characterized by a significant decline. The percentage decline in the production area of Barley, Wheat, Maize and Sorghum in 2021 compared to 2015 was 12.5%, 3.3%. 11.3%, 12.9%, respectively. The Minister of Agriculture, Umer Hussein, during a briefing to the house of people's representatives (HPR), in 2020, declared that Ethiopia to cut wheat import by more than half by increasing irrigated production of the crop. This was aimed at bringing down the 17 million quintals of annual wheat import of the country to nearly 8.5 million or below [65]. However, the trends on the ground (Table 4) in irrigated wheat production don't seem to be conforming with or helping the effort of the country to cease or decrease its wheat import.

10. Conclusions and Prospects

Despite the huge irrigation potential and the tendency of irrigated crop production to be more productive compared to rainfed agriculture, irrigated farming accounts for only a very small fraction of the country's total crop production. Moreover, Ethiopia's irrigation sector is characterized by underachievement and even declines during the past

seven years of the SDGs.These underachievements were in terms of the number of farmers practicing irrigation and irrigated production area of major crops, including cereals, pulse, oil and stimulant crops.On the other hand, the fact that, some crop types such as vegetables, fruits and root crops showed a dramatic increase is encouraging as these crops are important food security cops.

However, its is very concerning that there was a decline in the overall irrigated production area of pulse, oil and cereal crops as well as the individual members of the cereal family including Sorghum, Maize, Wheat and Barley. Since pulse and cereal crops are the prominent crops produced and consumed as a staple food almost all over the country, the decline in their irrigated production area comes as a threat to the country's effort to ensure food security and alleviate poverty. The unsatisfactory overall increase in the irrigated production area of stimulant crops also has its implication directly on the household income as these crops are the prominent crops grown for cash. Not only that but as stimulant crops include coffee and khat, the major export commodities of the country, increasing their production by expanding their irrigated production area would contribute to the national economy.

Although the government has been working by allocating big budgets to expanding the irrigation sector, the underachievement of the sector discussed in this paper reveals that there is still a long way to go in terms of designing and implementing irrigation development strategies. Hence, there is a need for studies into why the irrigation sector experienced such a disappointing performance especially when it comes to pulse, cereal and oil crops, despite the huge investment going into the sector. Studying the reason behind the overwhelming increase in the irrigated production area of root crops, vegetables and fruit crops would also help to replicate the success in case of cereals, pulses, oil crops and stimulant crops. Systematic studies aimed at the determination of a quantified and direct contribution of irrigated crop production to the national economy, household poverty reduction, food security assurance and the SDGs should be intensified too. This is crucial as it serves as a more precise tool in measuring the progress of the irrigation sector in relation to poverty and hunger alleviation and helps design and implement intervention methods.

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References

1. UN. The seventeen goals. Available online: https://sdgs.un.org/goals (accessed on 02/14/2022).
2. IPC. Acute food insecurity analysis-Ethiopia. Available online: https://www.ipcinfo.org/ipc-country-analysis/details-map/pt/c/1154897/?iso3=ETH (accessed on 23/02/2022).
3. UNDP. Ethiopia's Progress Towards Eradicating Poverty, . In Proceedings of the the Inter-Agency Group Meeting On the "Implementation of the Third United Nations Decade for the Eradication of Poverty (2018–2027), Addis Ababa, Ethiopia, 18-20/3/2018.
4. Hák, T.; Janoušková, S.; Moldan, B. Sustainable Development Goals: A need for relevant indicators. *Ecol. indic.* **2016**, *60*, 565-573.

5. Moreda, T. Large-scale land acquisitions, state authority and indigenous local communities: insights from Ethiopia. *Third World Quarterly* **2017**, *38*, 698-716.
6. Achamyeleh, K. Ethiopia: Integrated flood management. *Integrated Flood Management Case Study* **2003**, 1-15.
7. Kassie, K.E.; Alemu, B.A. Does irrigation improve household's food security? The case of Koga irrigation development project in northern Ethiopia. *Food Security* **2021**, *13*, 291-307.
8. Dawit, D.; Balta, A. Review on impact of small scale irrigations in household food security in Ethiopia. *Journal of Economics and Sustainable Development* **2015**, *6*.
9. Siraw, Z. The Role of Irrigation in Household Food Security in Upper Blue Nile Basin: The Case of Jedeb Irrigation Scheme, Amhara Region, Ethiopia. *International Journal of Agricultural Economics* **2016**, *1*, 108.
10. Gebregziabher, G.; Namara, R.E.; Holden, S. Poverty reduction with irrigation investment: An empirical case study from Tigray, Ethiopia. *Agric. Water Manage.* **2009**, *96*, 1837-1843.
11. Bacha, D.; Namara, R.; Bogale, A.; Tesfaye, A. Impact of small - scale irrigation on household poverty: empirical evidence from the Ambo district in Ethiopia. *Irrig. and Drain.* **2011**, *60*, 1-10.
12. Ahmed, J. The role of small scale irrigation to household food security in Ethiopia: a review paper. *J. Res. Dev. and Manag.* **2019**, *60*, 20-25.
13. USAID. Agriculture and food security In Ethiopia. Available online: https://www.usaid.gov/ethiopia/agriculture-and-food-security (accessed on 13/04/2022).
14. FAO. Ethiopia at a glance. Available online: https://www.fao.org/ethiopia/fao-in-ethiopia/ethiopia-at-a-glance/en/ (accessed on 31/03/2022).
15. MOA. *Small-scale irrigation capacity-building strategy for Ethiopia.*

; Ethiopian Ministry of Agriculture: Addis Ababa, Ethiopia, 2011; pp. 1-30.

16. LI. Irrigation potential Definition. Available online: https://www.lawinsider.com/dictionary/irrigation-potential (accessed on 26/04/2022).
17. Knoame. Ethiopia Irrigation potential. Available online: https://knoema.com/atlas/Ethiopia/topics/Water/Irrigation-Water-Management/Irrigation-potential. (accessed on 25/03/2022).
18. You, L.; Ringler, C.; Wood-Sichra, U.; Robertson, R.; Wood, S.; Zhu, T.; Nelson, G.; Guo, Z.; Sun, Y. What is the irrigation potential for Africa? A combined biophysical and socioeconomic approach. *Food Policy* **2011**, *36*, 770-782.
19. Yimere, A.; Assefa, E. Assessing and mapping irrigation potential in the abbay river basin, Ethiopia. *Russ. j. agric. soc.-econ. sci.* **2021**, *114*, 97-109.
20. Reddy, K.M.; Satyanarayana, T.; Babu, G.R.; Babu, M.R. Estimation of Irrigation Potential Utilization for Kanupur Canal System Using Remote Sensing and GIS. *The Andhra Agric. J.* **2017**, *64*, 402-425.
21. Awulachew, S.B.; Ayana, M. Performance of irrigation: An assessment at different scales in Ethiopia. *Exp. Agric.* **2011**, *47*, 57-69.
22. Awulachew, S.B.; Merrey, D.; Kamara, A.; van Koppen, B.; Penning de Vries, F.; Boelee, E. *Experiences and opportunities for promoting small-scale/micro irrigation and rainwater harvesting for food security in Ethiopia*; IWMI: Addis Ababa, Ethiopia., 2005.
23. Awulachew, S.B. Irrigation potential in Ethiopia: Constraints and opportunities for enhancing the system. *Gates Open Res* **2019**, *3*, 22.
24. Awulachew, S.; Erkossa, T.; Namara, R. *Irrigation potential in Ethiopia–constraints and opportunities for enhancing the system*; IWMI: Addis Ababa, Ethiopia., 2010; 16-53.
25. Awulachew, S.B.; Yilma, A.D.; Loulseged, M.; Loiskandl, W.; Ayana, M.; Alamirew, T. *Water resources and irrigation development in Ethiopia*; Iwmi: Addis Ababa, Ethiopia, 2007; 1-32.
26. FAO. *AQUASTAT Country Profile – Ethiopia*; Food and Agriculture Organization of the united nations: Rome,Italy, 2016.

27. ATA. *Agricultural transformation agency annual report.*; Ethiopian agricultural transformation agency.: Addis Ababa, Ethiopia, 2021; pp. 1-16.
28. Nakawuka, P.; Langan, S.; Schmitter, P.; Barron, J. A review of trends, constraints and opportunities of smallholder irrigation in East Africa. *Global food security* **2018**, *17*, 196-212.
29. ESC. Wonji Shoa Sugar Facory. Available online: https://etsugar.com/wonji-shoa-sugar-facory/ (accessed on 01/04/2022).
30. WFP. Millions face hunger as drought grips Ethiopia, Kenya and Somalia, warns World Food Programme. Available online: https://www.wfp.org/stories/millions-face-hunger-drought-grips-ethiopia-kenya-and-somalia-warns-world-food-programme (accessed on 09/03/2022).
31. MoWE. *Water and Development quarterly bulletin* Ministry of Water and Energy: Addis Ababa, Ethiopia., 2011.
32. Tilahun, H.; Teklu, E.; Michael, M.; Fitsum, H.; Awulachew, S.B. Comparative performance of irrigated and rainfed agriculture in Ethiopia. *World Appl Sci J.* **2011**, *14*, 235-244.
33. Rosegrant, M.W.; Cai, X.; Cline, S.A.; Nakagawa, N. *The role of rainfed agriculture in the future of global food production*; 2002.
34. Hagos, F.; Makombe, G.; Namara, R.E.; Awulachew, S.B. *Importance of irrigated agriculture to the Ethiopian economy: Capturing the direct net benefits of irrigation*; IWMI: Addis ababa,Ethiopia, 2009; 1-21.
35. Nugusse, Z.W. Food Security through Small Scale Irrigation: Case Study from Northern Ethiopia. Ghent University, Brussels, Belgium, 2012.
36. Eneyew, A.; Alemu, E.; Ayana, M.; Dananto, M. The role of small scale irrigation in poverty reduction. *J. Dev. Agric. Econ.* **2014**, *6*, 12-21.
37. CSA. *Agricultural sample survey 2020/21(2013 e.c.);report on farm management practices (private peasant holdings, meher season)*; The Federal Democratic Republic Of Ethiopia Central Statistical Agency: Addis Ababa, 2021.
38. Hagos, F.; Jayasinghe, G.; Awulachew, S.B.; Loulseged, M.; Yilma, A.D. Agricultural water management and poverty in Ethiopia. *Agric Econ.* **2012**, *43*, 99-111.
39. Gross, R.; Schoeneberger, H.; Pfeifer, H.; Preuss, H.-J. The four dimensions of food and nutrition security: definitions and concepts. *SCN News* **2000**, *20*, 20-25.
40. Simon, G.-A. Food Security: Definition, Four Dimensions, History: Basic Readings as an Introduction to Food Security for Students from the IPAD Master, SupAgro, Montpellier Attending a Joint Training Programme in Rome. **2012**, 1-28.
41. Leroy, J.L.; Ruel, M.; Frongillo, E.A.; Harris, J.; Ballard, T.J. Measuring the food access dimension of food security: a critical review and mapping of indicators. *Food Nutr Bull.* **2015**, *36*, 167-195.
42. Pawlak, K.; Kołodziejczak, M. The role of agriculture in ensuring food security in developing countries: Considerations in the context of the problem of sustainable food production. *Sustainability* **2020**, *12*, 5488.
43. Ogunniyi, A.; Omonona, B.; Abioye, O.; Olagunju, K. Impact of irrigation technology use on crop yield, crop income and household food security in Nigeria: A treatment effect approach. *AIMS Agric. Food.* **2018**, *3*, 154-171.
44. Li, J.; Ma, W.; Renwick, A.; Zheng, H. The impact of access to irrigation on rural incomes and diversification: evidence from China. *China Agric. Econ. Rev.* **2020**.
45. Alaofè, H.; Burney, J.; Naylor, R.; Taren, D. Solar-powered drip irrigation impacts on crops production diversity and dietary diversity in Northern Benin. *Food Nutr Bull.* **2016**, *37*, 164-175.
46. Sekyi-Annan, E.; Tischbein, B.; Diekkrüger, B.; Khamzina, A. Year-round irrigation schedule for a tomato–maize rotation system in reservoir-based irrigation schemes in Ghana. *Water* **2018**, *10*, 624.
47. Kim, S.; Meki, M.N.; Kim, S.; Kiniry, J.R. Crop modeling application to improve irrigation efficiency in year-round vegetable production in the Texas winter garden region. *Agronomy* **2020**, *10*, 1525.
48. Hussain, I.; Hanjra, M.A. Irrigation and poverty alleviation: review of the empirical evidence. *Irrig. and Drain.* **2004**, *53*, 1-15.

49. Jambo, Y.; Alemu, A.; Tasew, W. Impact of small-scale irrigation on household food security: evidence from Ethiopia. *Agric. Food Secur.* **2021**, *10*, 1-16.
50. Tefera, E.; Cho, Y.-B. Contribution of small scale irrigation to households income and food security: evidence from Ketar irrigation scheme, Arsi Zone, Oromiya Region, Ethiopia. *Afr. J. Bus. Manage.* **2017**, *11*, 57-68.
51. Passarelli, S.; Mekonnen, D.; Bryan, E.; Ringler, C. Evaluating the pathways from small-scale irrigation to dietary diversity: evidence from Ethiopia and Tanzania. *Food Security* **2018**, *10*, 981-997.
52. Jebessa, G.M.; Sima, A.D.; Wondimagegnehu, B.A. Determinants of household dietary diversity in Yayu Biosphere Reserve, Southwest Ethiopia. *Ethiop. j. sci. technol.* **2019**, *12*, 45-68.
53. Baye, K.; Mekonnen, D.; Choufani, J.; Yimam, S.; Bryan, E.; Grifith, J.K.; Ringler, C. Seasonal variation in maternal dietary diversity is reduced by small‐scale irrigation practices: A longitudinal study. *Matern Child Nutr.* **2021**, e13297.
54. Tesfaye, A.; Bogale, A.; Namara, R.E.; Bacha, D. The impact of small-scale irrigation on household food security: The case of Filtino and Godino irrigation schemes in Ethiopia. *Irrig Drainage Syst.* **2008**, *22*, 145-158.
55. Abdissa, F.; Tesema, G.; Yirga, C. Impact analysis of small scale irrigation schemes on household food security the case of Sibu Sire District in Western Oromia, Ethiopia. *Irrigat Drainage Sys Eng* **2017**, *6*, 2.
56. Adenew, B. The food security role of agriculture in Ethiopia. *J. Dev. Agric. Econ.* **2004**, *1*, 138-153.
57. Alemu, M.; Dessale, M. Impacts of small-scale irrigation on rural households' income in north eastern Ethiopia. *Sustain. Water Resour. Manag.* **2022**, *8*, 1-20.
58. Gebrehiwot, N.T.; Mesfin, K.A.; Nyssen, J. Small-scale irrigation: the driver for promoting agricultural production and food security (the case of Tigray Regional State, Northern Ethiopia). *Irrig. drain. syst. eng.* **2015**, *4*, 1000141.
59. Ameye, H.; Bachewe, F.N.; Minten, B. The rising price of nutritious foods: the case of Ethiopia. *Global Food Security* **2021**, *31*, 100582.
60. Cochrane, L.; O'Regan, D. Legal harvest and illegal trade: Trends, challenges, and options in khat production in Ethiopia. *Int. J. Drug Policy* **2016**, *30*, 27-34.
61. Gizaw, N.; Abafita, J.; Merra, T.M. Impact of coffee exports on economic growth in Ethiopia; An empirical investigation. *Cogent Econ. Finance* **2022**, *10*, 2041260.
62. Ababu, D.G.; Getahun, A.M. Time Series Analysis of Price of Coffee in Case of Mettu Town, Ilu Ababor Zone, Oromia Regional State, Ethiopia. *Asian Journal of Dairy and Food Research* **2021**, *40*, 279-284.
63. Taylor, M.; Lebot, V.; McGregor, A.; Redden, R.J. *Sustainable production of roots and tuber crops for food security under climate change*; John Wiley & Sons, Hoboken, NJ: 2019.
64. Slavin, J.L.; Lloyd, B. Health benefits of fruits and vegetables. *Adv Nutr* . **2012**, *3*, 506-516.
65. FBC. Ethiopia to cut wheat import by more than half. Available online: https://www.fanabc.com/english/ethiopia-to-cut-wheat-import-by-more-than-half/ (accessed on 25/04/2022).