

REVIEW



A review of government policy on irrigation schemes in Ethiopia

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ABSTRACT

This paper reviews the scope, objectives, and implementation of the previous Ethiopian Government's policies on agriculture, with special consideration given to the policy elements of the Irrigation policy subsector. The country started using traditional irrigation techniques for an extended period, but this did not result in major changes in farming households or national income contributions. This is because the policy implementation still faces several obstacles and challenges that prevent it from producing the desired results, including lack of electrification, inadequate infrastructure development, lack of private investment and financial resources, political unrest, and economic constraints. In the meantime, the Ethiopian government prioritized the development of irrigated wheat to achieve food self-sufficiency and minimize food imports from other countries. To attain food self-sufficiency and decrease the need for foreign food aid, this document, therefore, sends a message to all stakeholders: it is their obligation to invest in agriculture and correctly implement the country's irrigation strategy.

KEYWORDS

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Introduction

Water resources are abundant in Ethiopia. Ethiopia's twelve river basins are a result of its estimated 122 billion cubic meters of surface water resources. Although it is widely known that Ethiopia can produce 2.61 billion cubic meters of groundwater, the actual potential of its subterranean water resources is unknown [1].

Despite having excellent irrigation potential (water, land, climate, etc.), Ethiopia's economy is mainly dependent on smallholders who depend on rain for their food, making them vulnerable to food insecurity. Over the previous five years, agricultural commodity exports have been reported for 80% of the country's external exchange earnings. An alarmingly high number of people require food assistance. Food crop costs are increasing. Food and industrial crops like wheat, sugar, food oil, and barley are still imported in large quantities, which skews the balance of payments. Nearly 90% of the people and 95% of the land are cultivated under the current rainfed agricultural system, and as a result, poverty and food insecurity are more frequent due to resource degradation and climate unpredictability [2].

Irrigation is viewed as a key technique in Ethiopia for reducing poverty and guaranteeing food security. A mixed rain-fed and irrigated agricultural system has advantages over the rain-fed agricultural system, which is dependent on rainfall. This is considered to be the most popular strategy for long-term growth in the nation [3].

By increasing food production in arid and semi-arid regions, promoting economic growth and development, generating jobs, and improving the living conditions of small-scale farmers, irrigation contributes to the reduction of poverty. It also shields the environment from pollution and

degradation. Nonetheless, this study evaluates the effects of the government of Ethiopia's agricultural policy through irrigation and the economic contribution of irrigation to Ethiopia.

General objective of the review

The general objective of this review would be to critically assess the Ethiopian government's policies and strategies related to irrigation development, with a focus on their effectiveness, challenges, and potential for improvement.

Agricultural policy initiatives of Ethiopia

Since 1991, the Ethiopian government has implemented many agricultural policies aimed at enhancing productivity and production in agriculture, as well as improving efficiency in the processing and marketing chain. These policies have had a significant positive impact on the welfare of rural households. The policy instrument utilized in the structural adjustment program is market liberalization. This aims to improve crop productivity and production, encourage rural households to participate in emerging markets, increase their income through commercialization, and ultimately improve the welfare of rural households. The agricultural markets have undergone liberalization, resulting in the transfer of resources from suppliers to farmers in the fertilizer markets. Additionally, the government has deregulated fertilizer prices and eliminated input subsidies [4].

Normally, sub-policies that promote the expansion of each agricultural sector work in conjunction with agricultural policy to help it reach these goals. For the objectives of agricultural policy to be fully achieved, small-scale sector policy must play an important role, like irrigation policy [5].

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Historical Perspectives of Irrigation Development Policy in Ethiopia

Ethiopia has long used traditional irrigation methods. Since ancient times, irrigation techniques have been used in the highlands of Ethiopia to grow crops for subsistence. Soldi et al. underlined that supplemental irrigation has been a long-standing solution adopted by Ethiopian smallholder farmers to solve their problems with a lack of income [6].

Ethiopia has an estimated 3.5 million hectares of irrigation potential, of which only 5.2 percent was reported to have been utilized during the 2015–16 crop year. The majority of Ethiopia's traditionally irrigated land is supplied by surface water sources, and groundwater utilization has only lately begun on a trial basis in the East Amhara region [3]. Accordingly, Fincha State Farm, Eastern Amhara, Southern Tigray, and several private farms in the Rift Valley once used pressurized sprinkler irrigation systems.

However, modern irrigation was first implemented in the early 1950s thanks to a two-sided agreement between the Dutch business community and the governments of Ethiopia about sugar cane farms. The Rift Valley is where modern irrigation in Ethiopia gets its start, especially in the Awash River Basin, where pump irrigation is first used. Surface irrigation techniques that mainly used furrow irrigation and basin irrigation were used for the development of commercial fruits like bananas, wheat, and cotton, respectively [7].

Future plans for Ethiopian irrigation

The Irrigation Development Plan (IDP) for Ethiopia places a strong emphasis on the growth of small-scale irrigation schemes by giving the analysis, design, and implementation of irrigation projects the highest priority. There will be an increased focus on the development of large irrigation schemes- and medium-scale. Ethiopia has developed a program to advance the water industry. As a result, under the irrigation development plan for large and medium-scale irrigation developments, the federal government and regional governments will begin new irrigation work to develop a total of 274,612 ha of farmland. As of right now, the governments of Ethiopia have prioritized irrigation-based wheat production [8].

Government role in irrigation development in Ethiopia

For effective irrigation management and development, the

government has served as a handy enforcement body. Farmers leave farming and the private sector also declines as a result of sophisticated irrigation service externalities in the community, making it unable to effectively replace capital with labor [9]. The irrigation potential of Ethiopia is projected to be 3.5 million hectares. In 2005/2006, the country had a total estimated area of 625,819 hectares dedicated to irrigated agriculture, which accounts for approximately 18% of the overall potential area. The country has a planned expansion of irrigation development by an additional 528,686 hectares by the year 2010, which will represent approximately 33% of the total potential [10].

Private sector role in irrigation development in Ethiopia

The private sector has historically had little to no involvement in the development of irrigation systems. The private sector should be further encouraged through alluring business models, investment opportunities, and other incentives given the scale of the challenge that public waterworks companies are already seeking to close. Ethiopia has successfully worked with the private sector to deliver domestic water, and it may similarly build agricultural water infrastructure. For instance, the need for equipment (such as excavators, loaders, and drilling rigs) to construct irrigation projects will be fairly high over the next five years. According to Awulachew et al. 400 additional excavators and loaders and other machinery totaling about Ethiopian Birr (ETB) 10 billion will be needed for the medium-scale investment (MSI) and large-scale investment (LSI) programs alone [11].

Appraisal of the Impact of Agricultural Policy on the Ethiopian Economy

Ethiopia's economy is mostly based on agriculture, which is aided by the irrigation strategy. One of the elements contributing to the increase in agricultural production has been the development of irrigation. About income generation, job creation, and export revenue generation, it makes a sizable contribution to the national economy [12]. Despite a slight decline over time, as seen in Table 1, its contribution to GDP has remained very significant at about 31%. This decline in contribution is a reliable sign of the industry's transition. In addition to this industry, crop production has been a major driver of agriculture's GDP contribution, accounting for more than 20% of GDP in 2020.

Table 1. Agriculture sector Contribution to GDP (in thousands os).

Year	GDP at Current Market prices	Agricultural GDP	Crop GDP	Agricultural contribution to GDP (in %)	Crop contribution to GDP (%)
2001	65,687.3	27,750.6	16,333.3	0.47	0.25
2002	63,461.6	24,460.7	13,135.2	0.39	0.21
2003	68,898.0	26,207.9	14,963.3	0.38	0.22
2004	81,754.5	32,2310.0	19,747.9	0.39	0.24
2005	98,397.9	42,196.4	27,349.0	0.43	0.28
2006	115,589.5	50,893.9	32,246.4	0.44	0.28
2007	170,281.0	52,889.8	35,424.5	0.31	0.21
2008	254,836.0	256,996.4	156,165.3	0.61	0.61

2009	796,697.6	358,944.5	215,075.1	0.45	0.27
2010	896,687.5	386,339.2	233,879.2	0.43	0.26
2011	996,921.8	421,172.8	258,009.7	0.42	0.26
2012	1,083,133.7	441,832.9	270,881.6	0.41	0.25
2013	1,197,753.9	473,132.2	293,063.1	0.41	0.24
2014	1,320,688.1	498,733.6	312,338.7	0.40	0.24
2015	1,145,857.6	530,341.5	334,768.6	0.38	0.29
2016	1,568,097.5	542,700.2	346,293.6	0.46	0.22
2017	1,717,127.2	579,022.9	374,649.8	0.35	0.22
2018	1,834,066.5	599,331.4	392,291.8	0.33	0.21
2019	1,987,157.5	622,220.3	404,049.6	0.31	0.20
2020	2,109,122.2	648,711.8	422,966.5	0.31	0.20

Sources: FDRE, 2021

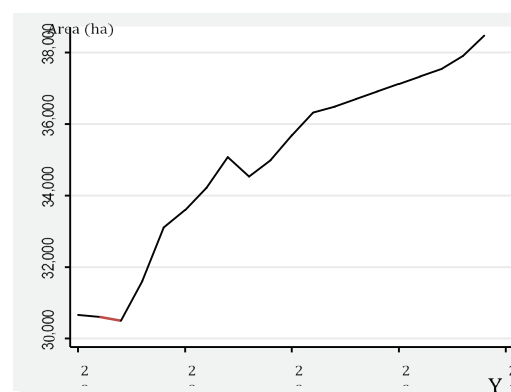
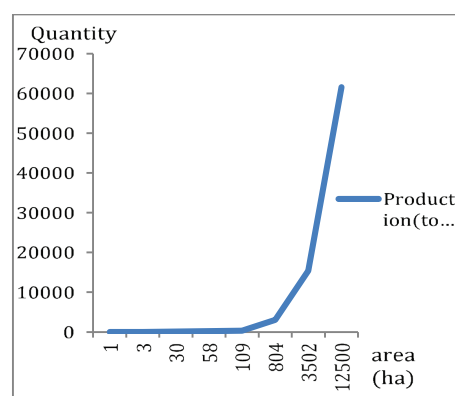
Furthermore, it's crucial to note that despite an increase in agricultural production, the sector's contribution to GDP has decreased, indicating that more crops are being produced for local use, such as wheat, which is necessary to ensure domestic food security. Therefore, it is not surprising that agriculture's contribution to GDP has decreased. However, it is significant to note that Table 1 shows that agricultural food production has increased over time. The so-called Plan for Accelerated and Sustainable Development to End Poverty initiative has as its primary objective, the objectives of the Federal Ministry of Agricultural Policy [13].

Additionally, this understanding of the sector's evolution is a reminder that agricultural policy draws attention to the volume of production rather than to increasing foreign earnings.

Role of irrigation and target crops

Ethiopia has abundant water resources, but over the years, the nation has not taken advantage of them by irrigating its land to boost food production. But beginning in 2017, the Ethiopian government planned and attracted attention to use this endowment through irrigation, boost food production by implementing a new variety, and end hunger [7].

Given the good agro-ecological conditions for wheat, maize, and teff production of the country at the moment gave priority to increase food production through an increase in the production of wheat including adapting improved wheat variety. It was important, to demonstrate that the production of improved wheat through irrigation technology was started in 2012 on a hectare of land and gradually expanded throughout the year with an increase in production as shown in Figure 1(a). The production improvement in this variety portrays the opportunity to produce in bulk with area expansions under irrigation. Similarly, Figure 1(b), reports that throughout the year the devotion of farmland to irrigation increased except for a decline in the year 2008 to 2010. This importantly portrays that the government of Ethiopia has given attention to improving agricultural production through irrigation [14].



Sources: Adapted from Gebrie, (2022) (a) and World Data Atlas Ethiopia between 2000-2020 (b)

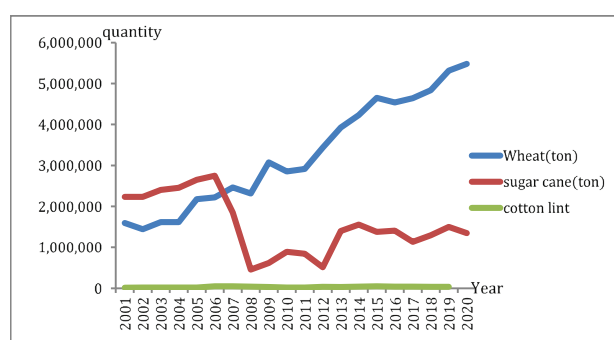
Figure 1. (a) . Improved wheat variety production [8] and **(b)** area under irrigation.

Irrigation increased wheat yield and this information was spread to various areas of the nation's provinces. Gebrie estimates that 15, 400 tons of this variety's production were generated in 2019 on a 3502-ha area using irrigation, which encourages allotting more space to take advantage of growing more of this crop [8]. It is undeniable that Ethiopia's

government is focusing on raising wheat output at the moment to decrease food imports and food insecurity.

The output of wheat, which ranks second in the world behind rice, is reportedly trailing behind that of other crops [15]. It was ranked third in Ethiopia behind teff and maize and contains 14% of total calories, making it the second-most produced crop after maize [16]. Amazingly, wheat was cultivated in many agroecological zones, making it the preferred crop for ensuring food security at the moment [17]. Figure 2 depicts Ethiopia's production of products like sugar cane, cotton, and partially irrigated wheat in the early 1950s [7].

The country's government paid no attention to wheat during these years up until 2007. But surprisingly, it gained attention in 2017 thanks to an increase in manufacturing. Figure 2 made it abundantly evident that its production was rapidly rising, demonstrating its status as the country's principal irrigation target crop. Wheat production is rising as a result of trade-offs with cotton and sugar cane. In fact, ending hunger and ensuring food security are goals of contemporary government policy. Focus on the previous decline in wheat production area and expansion in sugar cane output.



Sources: Computation in the World Bank time series data set of Ethiopia.

Figure 2 . Irrigation-produced crops.

Not forgetting Ethiopia, which relies on foreign food aid and has spent hundreds of millions of dollars on wheat imports, the government is expanding irrigation farming throughout the nation with an increase in production in the short term to achieve self-sufficiency in wheat by 2025 and a significant decrease in wheat imports by 2023. Indeed, it is evident that the yield of wheat grows more steadily over time than that of sugarcane. This is due to Ethiopia's government placing more focus on the production of irrigated wheat to achieve food self-sufficiency [18].

Strategies for implementation

Irrigation was one of the subsectors of the Ethiopian Water Resource Management Strategy (Ethiopia Water Resources Management Program), according to the National Smallholder Irrigation and Drainage Strategy [19]. The strategies in this sector were developed to implement irrigation policy and were able to effectively and sustainably use the vast irrigation potential for the raw materials and the production of food crops needed for agro-industries, without compromising the fertility of the production fields and the base of water resources. The directive specifies the following particular strategies: (Minister of Natural Resources (MoANR)):

1. Enhancement and expansion of small, medium, and large-scale irrigated agriculture to meet local agro-industrial demand and achieve national food security and self-sufficiency, including export revenue.
2. To develop the proper institutional structures for the implementation and management of irrigated agriculture, it is important to assess current institutional capacities regarding regulatory and implementation roles and responsibilities. This will help to strengthen institutional and regulatory frameworks at the federal and regional levels.
3. Assuring the effective implementation, monitoring, and enhancement of irrigated schemes and systems requires the development of standards, guidelines, manuals, and procedures.
4. Emphasizing water gathering techniques in an introductory manner for small-scale irrigation development in regions where runoff from the rainy season can be retained and utilized to grow crops.
5. Improve Existing and Development of New Irrigation Infrastructures aimed to upgrade existing and develop new Irrigation infrastructures to ensure irrigation water supply.
6. Offer bank loans and credit facilities to help with the construction of irrigation projects, especially small-scale plans that neighborhood associations will implement.
7. Encourage the development of partnerships at various levels between pertinent government agencies, non-governmental organizations, and local communities to provide bulk water storage, flood control, and transfer programs.
8. Increase the availability, education, and marketing of irrigation technologies and services for smallholder farmers, including drip kits, sprinklers, well drilling, and pump maintenance.
9. Given that, generally speaking, the list bidder method had not proven successful in building works, due consideration was given to prior performance and technical capacity when choosing contractors and consultants for the implementation/construction of irrigation projects.
10. Establish a step-by-step framework for project authorization that covers the phases of management, implementation, and planning (including studies and design). Examine and describe the needs for management, upkeep, and operation concerns.
11. Enhancing the state of environmental health by giving a sizable segment of the population access to water and sanitary facilities.
12. Producing more hydroelectric electricity.
13. Improving the role that water resources play in achieving national development goals.
14. Endorsing integrated water resources management concepts.
15. Taking into account scientific and technological solutions that prevent the spread of vector breeding grounds, minimize the loss of forests, lessen seepage, and guard against pollution, erosion, siltation, and salinization.

The government has established programs that have been put into effect to its specialized components for agricultural advancements to implement these policies in agriculture. According to Wang et al. one of the sub-sector projects included in the water sector development program is the irrigation sub-sector program [20]. These program's primary goals were:

- To raise the nation's degree of food security and self-sufficiency at the household and national levels.
- To enhance the population's overall well-being and nutritional condition.
- Assisting in the provision of sufficient inputs of raw materials for industries.
- To increase regional and national capacity for irrigation project planning, execution, and management.
- To utilize underutilized land and water resources for irrigated agriculture that is sustainable.
- To lessen reliance on rain-fed agriculture and the climatic fluctuations that go along with it in Ethiopia.
- To boost cropping intensity to increase employment in rural areas.
- To increase land productivity by growing two crops at once.

Constraints of irrigation policy achievement in Ethiopia

Ethiopia has traditionally utilized agriculture, from antiquity to the present, yet it has had little impact on the growth of the nation. This is because the country's food supply and output mostly depend on rain-fed agriculture and the poorly implemented irrigation strategy, making man-made and natural limits important considerations for adopting the policy. From scheme identification through several operational phases to irrigation management, Ethiopia's irrigation scheme policy is subject to and suffers from numerous limitations and difficulties. The implementation of Ethiopia's irrigation policy is beset by significant issues regarding infrastructural development, such as roads, farm equipment, and tools, electrification issues, low levels of private investment and a lack of financial resources, political unrest, and economic constraints [21]. Waterlogging in marshland areas, salinity in dry and semi-arid areas, poor rainfall, the acidity of the soil, weak institutions, and outdated farming practices are other major obstacles to Ethiopia's irrigation strategy implementation. Sedimentation and salinity issues pose a significant threat to several irrigation projects throughout the nation, including the wash basin, Tekeze River basin, and other smaller projects. The difficulties have impacted the policy in many ways, and it is important to consider how the repercussions vary among the various nations [22].

Obstacles to implementing this policy include the quantity of arable land, its fragmentation, the low irrigation productivity caused by low fertility soil, and the ownership issue with the land. However, the country's population is expected to increase by 2.5% annually, reaching 171.8 million by 2050, in this case, there will be a major demand-supply imbalance [23]. According to data, the size of the land restricts the mechanization of irrigation policy for roughly 38% of smallholder farmers and households, 23.6 percent have access to between 0.51 and 1.0 hectares, 24% have between 1 and 2 hectares, and 14. percent have more than 2 hectares of land [21]. The size, fragmentation, and low fertility of the arable land reduce irrigation production and owner.

The absence and lack of legally binding standards that direct project identification and development, as well as climate variability that limits the amount of water that is available, are the main and most pressing issues that irrigation policy implementation must deal with. Low community participation in the identification and implementation of irrigation schemes,

combined with a top-down development strategy that largely disregarded farmers' innate knowledge, hurts the outcome [24].

Ethiopia experienced small-scale irrigation (SSI) before the 1970s by the Ministry of Agriculture (MOA) to cope with drought, climate change, and low rainfall that led to failure of production and leads to unable to supply food to the markets. Generally, the irrigation policy of Ethiopia is constrained by socioeconomic challenges, imperfect information, technical barriers to implementation, weak institutions to enforce the policy and coordinate the activity, the problems of property rights, lack of capital investment, and financial constraints are sedimentation of schemes and many others are the hinders that limit the implementation of irrigation policy in Ethiopia.

Potential Agricultural Irrigation Policy Focus Areas of Ethiopia

Over the past ten years, there has been a notable increase in attention and financial resources dedicated to irrigation development in Ethiopia. The primary focus of the Government of Ethiopia's (GoE) second Growth and Transformation Plan (a five-year plan) was the allocation of resources towards irrigation investment. The economic development plan from 2015 to 2020 includes the greatest portion (almost one-third) of the Ministry of Agriculture's Agricultural Growth Program budget, which amounts to a total of US\$582 million. Presently, there are a minimum of 13 current extensive irrigation projects including a total command area of over 400,000 hectares [25].

The priority of the country's policy agenda is to concentrate on small-scale irrigation projects to increase and promote smallholder farmers' participation and make use of the higher water potential. Additionally, the policy places a focus on fusing contemporary technology with indigenous knowledge as well as political and governmental pledges to promote private and public enterprise participation in irrigation.

The Ethiopian Agricultural Growth Led to Industrialization (ADLI) is also the main emphasis of policy that encourages industrialization development by mechanizing agriculture and using cutting-edge technology to supply enough food and inputs to the market and industries. The Ethiopian Irrigation Development Plan (IDP) prioritizes potential irrigation schemes, capacity building, training, and infrastructure development with a focus on small-scale irrigation [26].

Conclusions

One of the high-land nations in Africa, Ethiopia has a lot of rivers and streams that are good for irrigation development. To ensure food security, the country began using conventional irrigation techniques over an extended period without seeing a substantial change in agricultural households or their contribution to the national economy. The country's food supply is primarily reliant on food aid and imports, but thanks to increased diversification efforts and the development of irrigation policies that support the production of crops meant to replace imports. Due to numerous limitations and difficulties, such as poor electrification, lack of private investment, political unrest, and inadequate infrastructure development for roads, farm equipment, and tools, Ethiopian irrigation development has not yet produced the desired results. Indeed, also the implementation of irrigation strategy is hampered by financial limitations. Meanwhile, it is the good news that the government of Ethiopia currently drawn attention

to irrigation to alleviate hunger and ensure food insecurity.

As a result, this paper forwards its message to all stakeholders that they should take responsibility by investing in agriculture and properly implementing the nation's irrigation strategy to achieve food self-sufficiency and reduce foreign food aid. Furthermore, government subsidies and other programs should promote policies like small farmers' participation in both small and large-scale irrigation systems in individual plots of land.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

1. Smith MD, Sikka A, Dirwai TL, Mabhaudhi T. Research and innovation in agricultural water management for a water-secure world. *Irrig Drain*. 2023;72(5):1245-1259. <https://doi.org/10.1002/ird.2872>
2. Kedir Y. The stumbling irrigation sector of Ethiopia: critical review and analysis. *Irrig Drainage Sys Eng*. 2021;10:257.
3. Gebremedhin Gebremeskel Haile GGH. Irrigation in Ethiopia, a review. *CABI Databases*. 2015;5(15):141-147.
4. Shikur ZH. Agricultural policies, agricultural production and rural households' welfare in Ethiopia. *J Econ Struct*. 2020;9(1):1-21. <https://doi.org/10.1186/s40008-020-00228-y>
5. Asresie A, Zemedu L, Adigrat E. The contribution of livestock sector in Ethiopian economy. *Adv Life Sci Technol*. 2015;29:79-90.
6. Soldi A, Aparicio Meza MJ, Guareschi M, Donati M, Insfrán Ortiz A. Sustainability assessment of agricultural systems in Paraguay: A comparative study using FAO's SAFA framework. *Sustainability*. 2019;11(13):3745. <https://doi.org/10.3390/su11133745>
7. Muchie GG. A review on: The over-view of irrigated wheat production and the research achievements of lowland irrigated wheat in Ethiopia. *Int J Agric Plant Sci*. 2022;4(1):40-45.
8. Tadesse W, Zegeye H, Debele T, Kassa D, Shiferaw W, Solomon T, et al. Wheat production and breeding in Ethiopia: retrospect and prospects. *Crop Breed Genet Genom*. 2022;4(3):e220003. <https://doi.org/10.20900/cbagg20220003>
9. Tadesse N, Bairu A, Bheemalingeswara K. Suitability of groundwater quality for irrigation with reference to hand dug wells, Hantebet Catchment, Tigray, Northern Ethiopia. *Momona Ethiop J Sci*. 2011;3(2):31-47. <https://doi.org/10.4314/mejs.v3i2.67711>
10. Hagos F, Makombe G, Namara RE, Awulachew SB. Importance of Irrigated Agriculture to the Ethiopian Economy: Capturing the Direct Net Benefits of Irrigation. Colombo, Sri Lanka: International Water Management Institute. 2009;37.
11. Awulachew SB, Merrey D, Van Koopen B, Kamara A. Roles, constraints and opportunities of small-scale irrigation and water harvesting in Ethiopian agricultural development: Assessment of existing situation. In ILRI workshop. 2010;14-16.
12. Hagos F, Makombe G, Namara R, Awulachew SB. Does access to small scale irrigation promote market oriented production in Ethiopia? IWMI: Colombo, Sri Lanka, 2008.
13. Getu M, Devereux S (eds.). *Informal and formal social protection systems in sub-Saharan Africa*. Fountain Publishers: African Books Collective; 2013.
14. Mersha AN, de Fraiture C, Masih I, Alamirew T. Dilemmas of integrated water resources management implementation in the Awash River Basin, Ethiopia: irrigation development versus environmental flows. *Water Environ J*. 2021;35(1):402-416. <https://doi.org/10.1111/wej.12638>
15. Schnepf RD, Monke J. COVID-19, US agriculture, and USDA's coronavirus food assistance program (CFAP). *Congressional Research Service*. 2020;1-28.
16. Minot N, Warner J, Lemma S, Kasa L, Gashaw A, Rashid S. The wheat supply chain in Ethiopia: Patterns, trends, and policy options. *Gates Open Res*. 2019;3(174):174. <https://doi.org/10.21955/gatesopenres.1115226.1>
17. Khater A, Fouda O, El-Termezy G, El-Tantawy M, El-Beba A, Sabry H, et al. Modification of the rice combine harvester for cutting and binding wheat crop. *J Agricultural Food Res*. 2023;14:100738. <https://doi.org/10.1016/j.jafr.2023.100738>
18. Tesfaw M. Small scale irrigation development. *Irrig Drainage Syst Eng*. 2018;7(1):1-7. <https://doi.org/10.4172/2168-9768.1000206>
19. Minister of Natural Resources (MoANR). *National Smallholder Irrigation and Drainage Strategy*. Addis Ababa: State Ministry of Natural Resources, Ethiopia, 2016.
20. Wang J, Dai A, Mears C. Global water vapor trend from 1988 to 2011 and its diurnal asymmetry based on GPS, radiosonde, and microwave satellite measurements. *J Clim*. 2016;29(14):5205-5222. <https://doi.org/10.1175/JCLI-D-15-0485.1>
21. Diriba G. Agricultural and rural transformation in Ethiopia: Obstacles, triggers and reform considerations. Available at: https://africaportal.org/wp-content/uploads/2023/05/Agricultural_and_rural_transformation_in_Ethiopia-1.pdf
22. Merga B, Ahmed A. A review on agricultural problems and their management in Ethiopia. *Turkish JAF Sci Tech*. 2019;7(8):1189-1202. <https://doi.org/10.24925/turjaf.v7i8.1189-1202.2626>
23. Tangcharoensathien V, Sudhakar M, Birhanu Z, Abraham G, Bawah A, Kyei P, et al. Health policy and systems research capacities in Ethiopia and Ghana: findings from a self-assessment. *Global Health: Science and Practice*. 2022;10(suppl 1): e2100715. <https://doi.org/10.9745/GHSP-D-21-00715>
24. Gamachu A, Beyisa M, Tadale G. Assessment of status of irrigation practice and utilization in western Hararghe zone, Oromia, Ethiopia. *Civ Environ Res J*. 2018;10(5):1-13.
25. Mekonnen DK, Abate GT, Yimam S. Irrigation and agricultural transformation in Ethiopia. *Intl Food Policy Res Inst*. 2023;2159:1-36. Available at: [https://books.google.co.in/books?hl=en&lr=&id=HRupEAAAQBAJ&oi=fnd&pg=PP3&dq=25.%09Mekonnen,+Abate+%26+Yimam.+\(2022\).+Irrigation+and+Agricultural+Transformation+in+Ethiopia.+International+Food+Policy+Research+Institute,+1-2&ots=bUD3xuAURu&sig=bL562pNb94oDqSnt55JsQXVdHTto&redir_esc=y#v=onepage&q&f=false](https://books.google.co.in/books?hl=en&lr=&id=HRupEAAAQBAJ&oi=fnd&pg=PP3&dq=25.%09Mekonnen,+Abate+%26+Yimam.+(2022).+Irrigation+and+Agricultural+Transformation+in+Ethiopia.+International+Food+Policy+Research+Institute,+1-2&ots=bUD3xuAURu&sig=bL562pNb94oDqSnt55JsQXVdHTto&redir_esc=y#v=onepage&q&f=false)
26. Raghavan R. Need for further research on the freshwater fish fauna of the Ashambu Hills landscape: a response to Abraham et al. *J Threat Taxa*. 2011;3(5):1788-1791.