



Review

Trend, Status, and Challenges of Irrigation Development in Ethiopia—A Review

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Abstract: Ethiopia's food supply and economy in general is largely dependent on rain-fed agriculture. Hence, irrigation development is vital to minimize the risk of crop failure and sustain agricultural production. The purpose of this review was to collect published and unpublished information from relevant sources and then review and synthesize key information on the trends and status of irrigation development and challenges threatening its implementation and sustainability. Historically, traditional irrigation based on farmers' own initiative and indigenous knowledge has been practiced in Ethiopia for over 2000 years. However, well-planned, government-funded medium and large-scale irrigation development started only three decades ago. Specifically, significant progresses have been registered during the implementation of two consecutive five-year plans, the "Growth and Transformation Plans". Currently, the total area equipped for irrigation has reached some 3.07 million hectares. However, the actual area irrigated is lower than this figure. The challenges facing the irrigation sector are related to study and design, construction or implementation, irrigation management, and lack of other support services such as extension, input services, and market. While the expansion of irrigation is still important, the poor performances and operational management of existing irrigation schemes needs to be given equal attention. As many of the problems are related to capacity and capability limitations, there is an urgent need for institutional and capacity development for the irrigation sector.



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Keywords: irrigation; irrigation development; development trends; status; challenges

1. Introduction

Irrigation has been the main driver of increasing food production worldwide. Irrigated land produces 40% of the total grain output from only 20% of global arable land, while 80% of land under rain-fed agriculture produces about 60% of grain output [1]. According to [2], irrigation contributes to agricultural production fundamentally in three ways. First, it stabilizes the harvest fluctuations, with attendant improvements in average yields brought about through the provision of dependable water throughout the growing season. Second, in some circumstances, improved control over available water resources may make a second or even third cropping possible. Finally, the availability of reliable water supplies makes it possible to use improved seeds, to introduce new farming technologies, and to increase the use of chemical fertilizer.

Cognizant of the poverty reduction and food security enhancement potential, the area equipped globally for irrigation has increased by 117% during the period from 1961 to 2009 [3]. Such expansion of irrigation coupled with the diversification and intensification of irrigated agriculture has enhanced food supply, which enabled the provision of more food with progressively falling prices to half of their levels in the 1960s and 1970s [4]. It is evident that most growth in irrigated agricultural production in Asia has come through horizontal expansion even into areas where conditions for production are less favorable as well as increasing the production per unit area of land through intensification [5]. Nevertheless, in most African countries, including Ethiopia, there is still untapped irrigation potential

that needs to be developed to boost agricultural production for ensuring food security and poverty alleviation.

In Ethiopia, agriculture is the dominant economic sector and food supplier to the nation, and it relies largely on rainfall. It contributes 43% of the GDP, about 80% of employment, and approximately 75% of export commodity values [6]. The vulnerability of the sector to rainfall amount and distribution is more pronounced as crop production dominates (67%) the agricultural GDP [7]. In view of the increasing population growth and food demand on one hand and increasing pressure on rain-fed agriculture due to land degradation and climate variability on the other, the important role of irrigation development is indispensable. However, despite the recognition of the important role of irrigation in minimizing the risk of crop failure due to drought and sustaining agricultural production, well-planned irrigation development targeting medium and large-scale schemes has started only two decades ago. Just for the purpose of planning and development convenience, irrigation typology of Ethiopia is classified under three categories: namely as small-scale (<200 hectare), medium scale (200–3000 ha), and large-scale (> 3000 ha) irrigation.

Disappointingly, the total area under irrigation is not well known, as irrigation is implemented by different actors (Federal Government, Regional Governments, Sugar Corporation, Development Partners, Private Investors, and Farmer), and no one is responsible for data collection and management. The major problem in relation to the irrigation development trend in this country is that the scant sources provide different figures related to the extent of area under irrigation in the country, and one is not certain which is more accurate. Hence, the purpose of this review work was to gather published and unpublished information from relevant sources and then review, analyze, and organize the results in such a way that it provides historical trends and the current status of irrigation development as well as challenges facing the sector.

2. Literatures and Procedures Used for the Review

Modern irrigation development has relatively short history in Ethiopia. Research, monitoring, and evaluation of the development of irrigation are rarely done. Hence, published materials related to irrigation development are scanty. Even irrigation-related facts and figures cited in different reports are different. For this review, the following materials were used: the published articles or unpublished articles, annual and strategic plans, reports of the Ministry of Water, Irrigation, and Energy as well as Ministry of Agriculture, proceedings of workshops and symposia, etc.

In terms of procedures, the review was designed to provide the brief picture of historical evolution of irrigation development and management as well as the current status and challenges facing its development. The problems of irrigation development are multi-faceted and interrelated; thus, they can be presented in the form of problem nest. The causes and effects of the major problems are discussed and improvement options are implied. An overall summary of the review and conclusions is also provided.

3. History and Status of Irrigation Development in Ethiopia

3.1. Brief History of Irrigation Development

Cursory reports indicate that small-scale irrigation development in Ethiopia has a long history that probably pre-dates the Axum empire more than 2000 years ago [8]. However, it might have been less important because rain-fed agriculture, terraces, and small-scale irrigation were found sufficient to sustain ancient populations [9]. In many parts of the country, traditional irrigation that involves small-scale river diversions, recession framings, and rainwater harvesting has been practiced for several years. However, greater attention was given to small-scale peasant-based irrigation development following the recurrent drought and famine experienced by the country in the 1970s and 1980s as a strategy to boost agricultural production and achieve food self-sufficiency [8]. Kloos H. [8] pointed out that the government-funded initiatives of irrigation development were unsustainable partly

due to the social instability created during the national villagization program that led to the resettlement of peasants and abandonment of irrigated lands in the old settlement areas.

Medium and large-scale commercial irrigated farms have started in the Upper and Middle Awash River Basin (Figure 1), which is one of the most intensively developed basins of the country.

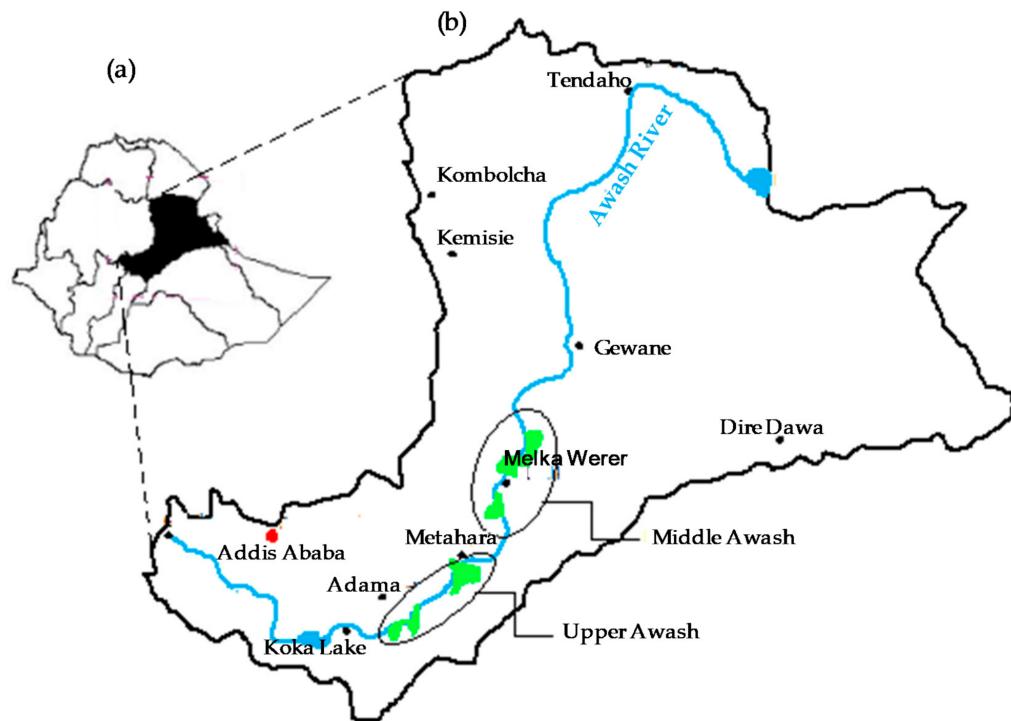


Figure 1. Location map, Ethiopia with its major river basins (a) and Awash Basin (b) and areas where modern irrigation has started (in the Upper Awash—Wonji and Metahara Sugar Estates, Merti Nura Era, Tibila and in the Middle Awash—Amibara, Kesem Sugar Estate and Gewane Cotton farm) (modified and adapted from [10]).

The early irrigation development was entirely initiated by joint concession with companies from abroad. More specifically, irrigated sugarcane farms and factories of Wonji (5000 ha) and Metahara (11,000 ha) commenced operation in 1954 and 1965 respectively by bilateral agreement between the Imperial Government of Ethiopia and a Dutch company, Hangler Vondr Amsterdam (HVA). Following the inauguration of the Koga dam in 1960, several large-scale irrigation projects were developed by private companies in the whole Awash Basin. Around Merti and Jeju areas, about 1638 ha farm was developed in 1961/62 by an Italian named Seignior Tiliota Santo. Both farms, Merti and Jeju, were producing cotton. Later, after the nationalization of land, both farms were merged and formed a horticultural crops farm in 1975 which is called the Metri fruit processing plant. Then, in 1976/77, the first orange and mandarin orchard farms were established at Merti and Jeju, respectively. Tibila irrigated farm was also nationalized in 1974 and used to grow citrus fruits, banana, avocado, and papaya. The farm was first owned by the Haile Selassie First Prince Trust Leul Ras Astrat Kassa [11].

As part of state-owned agricultural enterprise, the Amibara irrigated farm comprising of Melka Sedi and Mekla Werer, with a total area of 10,000 ha, started operation in 1980. Initially, the major industrial crop targeted was cotton, among others. In 1983, the Nura Hira horticulture farm and Merti agro-industry started operation. In the rift valley lakes basin, there were a number of concessions and estates that started operation in the early 1960s. These include Sille farm (1957), Bilate Tobacco Monopoly (1962), and Meki Ziway (1967), among others. Later on, the Finchaa irrigated sugar estate was inaugurated in 1997. The chronological of the early irrigation development is summarized in Table 1.

Table 1. Chronological development of medium and large-scale irrigation [12].

Year	1954	1957	1962	1965	1980	1997
Scheme name Area (ha)	Wonii Sugar estate 5900	Sille state farm 1500	Merti and Bilated 1638, 1000	Metahara sugar estate 11,000	Melka Werer Melka Sedi 10,000	Fincha 8500

As highlighted above, modern irrigation development started in Awash Basin more than 80 years ago. However, public investment-supported development of irrigation was particularly stimulated following the drought and famine in 1973 and 1984. As a result, in addition to communal irrigated farms, large numbers of state farms were created through the nationalization of most of the private irrigation farms in the 1970s and 1980s. Although with slow pace, specifically in the 1990s, the irrigation development has continued to expand to other river basins.

3.2. Irrigation Management

3.2.1. Evolution of Water Resources and Irrigation Management Institutions

Similar to modern irrigation development, the water management institution has a short history in Ethiopia. The chronological evolution of the water institutions is depicted in Figure 2. The first water sector institution, Water Resources Department, was created in 1956 under the then Ministry of Public Works and Communication. Since then, the water sector in Ethiopia has passed through considerable institutional changes and development. Before a Federal Political administrative system was established in early 1991, the public agencies involved in the water sector include the Valley Development Studies Authority (1962), National Water Resources Commission (1971), Ethiopian Water Resource Authority (1975), Valley Agricultural Development Authority (1977), and National Water Resources Commission (1981).

As indicated in the previous section, the early history of irrigation development in Ethiopia was dominated by small-scale irrigation. The development of small-scale irrigation was carried out by different institutions such as the surface water division of the soil and water conservation department under the then Ministry of Agriculture (MoA). In 1984, the division was restructured to the Irrigation Development Department (IDD) under the MoA, which was entrusted with the planning and construction of small-scale irrigation that was mostly utilized by agricultural co-operatives [13]. With the establishment of the Ministry of Natural Resources Development and Environmental Protection (MoNREP) in 1993, the IDD was dissolved and its responsibility transferred to MoNREP.

Based on the new federal administrative structure implemented in 1991, the regional bureaus of natural resources development took over the responsibility to undertake small-scale irrigation development. MoNREP was dissolved in 1995, and its responsibility was shared among MoA and the newly established Ministry of Water Resources (MoWR). While the MoWR had a regulatory role in water resources development and management, regional bureaus of Water, Mines, and Energy Resources Development were responsible for small-scale irrigation development in their respective regions.

Accordingly, the MoWR has facilitated the issuance of several water resources regulatory frameworks, namely Water Resources Management Policy (1999), Water Resources Management Proclamation (2000), National Water Resources Development Strategy (2001), Fifteen year (2002–2016) Water Resources Development Program (2002), and Water Resources Regulation (2005). In 2005, the MoWR was restructured to encompass the energy sector and named as the Ministry of Water and Energy (MoWE). In all these regulatory frameworks and development programs, irrigation expansion was given due attention. Under both Ministries (MoWR and MoWE), irrigation was represented by the Irrigation Department, which was largely responsible for the study, design, and implementation of medium and large-scale irrigation projects.

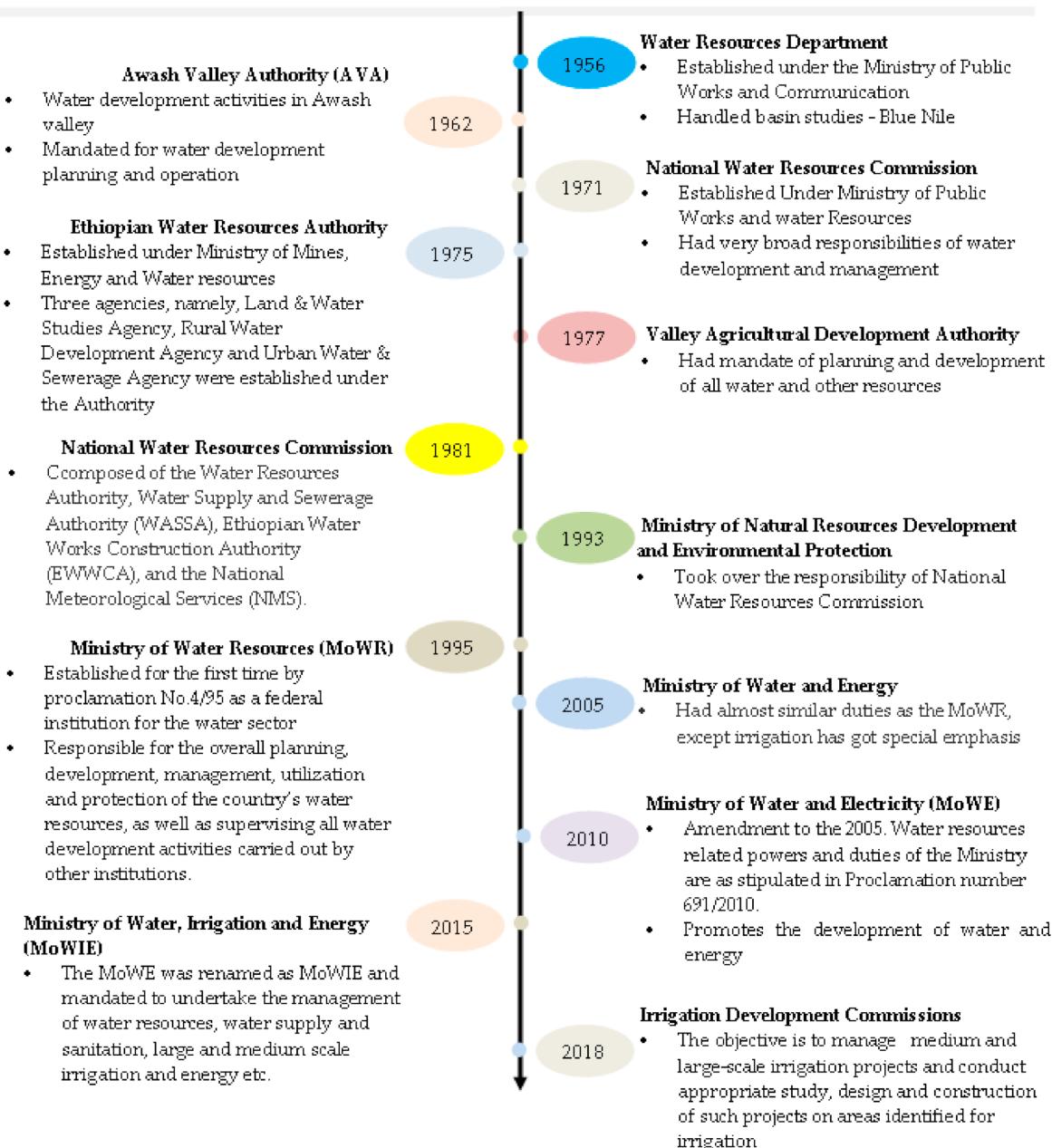


Figure 2. Chronological evolution of water sector institutions in Ethiopia (author's own presentation).

Later, the Ministry was renamed as the Ministry of Water and Electricity in 2010 and the Ministry of Water, Irrigation and Energy (MoWIE) in 2015. Here, the name irrigation was included in the Ministry's naming for the first time. Toward the end of the year 2018, the Irrigation Development Commission (IDC) was established under the MoWIE. The Commission has the responsibility to manage medium and large-scale irrigation projects and conduct the appropriate study, design, and construction of such projects on areas identified for irrigation with an overall aim of enhancing the socio-economic development of the country through ensuring food security, job creation, and raw material supply to industries and export earnings. The Commissioner of IDC assumed its office in November 2018 by staffing its seven directorates, namely the Directorate for Irrigation and Drainage Study and Design; Irrigation and Drainage Construction Supervision; Irrigation Infrastructure Administration; Capacity Building and Technology; Procurement and Contract Administration; Finance, Planning, and Administration; and Social and Environmental Development.

There are also federal and regional subsidiary enterprises that have been widely engaging in the study, design supervision, and construction of irrigation projects. The major ones are Ethiopian Construction, Design and Supervision Works Corporation, Regional Enterprises such as Water Works Design, and Supervision Enterprise and Water Works Construction Enterprise.

In general, water resources and irrigation management instructions are characterized by frequent restructuring that involved also the movement of human and physical resources. Institutional instability causes staff frustrations that might lead to migration (staff turnover) and lack of interest to join the institution. In all these courses, important institutional memories including project documents are lost, threatening the overall development of the sector.

3.2.2. State of Irrigation Management

In addition to the federal institutions highlighted in the previous section, the regional states have been engaging in the development and management of irrigation in their respective regions through appropriate organs. For this purpose, many regional states have established irrigation development authorities toward the end of the 1990s (for example, Oromia Irrigation Development Authority in 2000 for Oromia Region in Ethiopia). Other regions had also similar authorities or bureaus to deal with irrigation development activities in their respective regions, specifically small-scale and to some extent medium-scale irrigation projects. These authorities and bureaus have also undergone frequent restructuring in a similar fashion as that of federal level institutions. Currently, the irrigation development activities of the regions are carried out by Regional Water, Irrigation, and Energy Development Bureaus. While these bureaus jointly with regional water works design and supervision enterprises and regional water works construction enterprises are actively engaging in the study, design, and construction of irrigation projects, bureaus of regional and zonal agriculture are responsible for providing irrigation management support services to farmers.

Medium and large-scale irrigation schemes are developed to serve three categories of users and operators. These are (1) the Ethiopian Sugar Corporation (ESC) for sugarcane production and processing; (2) private investors for the production of commercial crops; and (3) smallholder farms for subsistence farming and surplus production to be marketed. However, the involvement of private investors in the irrigation sector remained low due to the high investment cost of irrigation development. Hence, irrigation infrastructure development such as dams and big canals are carried out largely by the government within the framework of its political and socio-economic development policies and programs.

Following the increasing demand for sugar production in the country both for domestic and export markets, more and more emphasis was given to the expansion of sugar factories and sugarcane production during the last decade. To address the demand, the ESC was established in 2010 as autonomous government enterprise to manage the production and processing of sugarcane. At present, the ESC is managing some 160,921 hectares of irrigated land for sugarcane production distributed over eight projects area located in different potential areas of the Ethiopia (Wonji Showa, Metahara, Fichaa, and Arjo Didessa projects in Oromia Region, Kesem project in Afar Region, Omo Kuraz project in the region of Southern Nations, Nationalities and Peoples Region (SNNPR) and Tana Beles project in Ahmara Region, and Wolkit project in Tigray Region). While some of these sugar estates are old, others are operating far below their design capacities due to excessive delays in the installation of factories and construction of irrigation infrastructures. In total, some 300,000 hectare irrigation command area is operated by the ESC, which is more than 50% of the total irrigated area under medium and large-scale projects in the country.

However, the growing concern about schemes operated by the ESC is that focus has been given to sugarcane agronomy only and without due consideration for irrigation management. Once implemented, all projects including the old schemes have never experienced substantial rehabilitation. There is a lack of considering irrigation management

as an integral part of the organizational structure of the corporation. Thus, schemes are operated by unskilled and on-job trained staff with no adequate irrigation engineering knowledge and technical skill. The visible consequences of such unwise management of irrigation are widespread salinity development, groundwater rise, and related waterlogging and deterioration of soil fertility and loss of agricultural land.

Next to the ESC, the smallholder farming community is the largest beneficiary of medium and large-scale irrigation development implemented and managed by the government. Such projects are used by hundreds and thousands of smallholder farmers and jointly managed by the Irrigation Development Commission (IDC) and the users. The IDC is responsible for water allocation and distribution through operation of the headwork and main system. Irrigators are organized and form irrigation water users associations (IWUAs) that are responsible for tertiary and quaternary level irrigation management. Local agricultural bureaus facilitate the establishment of IWUAs and with limited support services to enhance their capacities. The major operation and maintenance works remain the responsibility of the government, which is not properly undertaken. There is a lack of coordination among these parties involved in irrigation development and management.

Generally, irrigation development in Ethiopia has been largely focusing on infrastructure construction. That means that the important role of irrigation management is largely overlooked. Consequently, several studies indicate that the performance of irrigation schemes, measured with several applicable indicators, is poor [14–20]; While the causes for low performance are diverse, it is largely attributed to inadequate management of schemes. Not only are the productivity and efficiency of schemes low but also the areas irrigated are far below the potential irrigable areas created by project implementation. Reports indicate that currently, about 50% of the irrigation schemes are considered as proving functional services, the remaining 34% of the implemented schemes are not utilized with full capacity, and 16% are non-functional [21].

In most instances, the performances of irrigation schemes implemented by the government and development partners and operated either by the community or jointly by a government body and the community are poor compared to traditional schemes. Solomon and Kitamura [22] studied Betmera-Hiwane, one of the ancient traditional irrigation schemes in Tigray, and found the management peculiarities contributing to its enduring success to be the presence of communally constructed local rules, locally designed hydraulic control structures, ownership feeling of the irrigators and accountability of water distributors to the irrigation management, the culture for mobilizing communal resources, and the culture of self-initiating local water management strategies. Sometimes, the scheme management decisions made by government-delegated authorities in guiding smallholder irrigators may not yield positive results. It is important to recognize that farmers have a better site-specific understanding of their farms and resources in the area and can make problem-solving decisions. The authors of [23] studied farmers' participation in the management decision making of the Gumselassa irrigation scheme in the Tigray region of Ethiopia. Water shortage was found to be the major problem threatening the scheme. The government authorities advised the farmers to reduce their irrigated land, which was not welcomed by the users. Their study result reviled that when farmers were allowed to make their own decisions to solve the recurrent problems such as water shortages, they came up with innovative adaptation strategies to the prevailing water scarcity. With minimal technical supports, farmers' collective action-based small-scale irrigation management has demonstrated success histories in many parts of the country.

The success of small-scale traditional irrigation has been attracting the attention of many farmers and even that of the government. Consequently, the number of irrigators and area irrigated in some small-scale schemes has increased over time [24]. The secret of the success lies in the indigenous knowledge used to address problems, traditional institutional systems, and rules that are understood and respected by the community. Irrigation development and management in Ethiopia is highly dominated by a top-down approach and could not benefit from the golden opportunity of existing local knowledge [25]. Lack

of ownership feeling by the local community toward schemes planned, implemented, and operated by government support without consultation is considered one of the many reasons for unsustainable irrigation system.

3.3. Trends and Status of Irrigation Development in Ethiopia

Actually, there is no official document that clearly shows the total area under irrigation. Different sources provide figures that vary greatly. As indicated in the previous Section 3.2.2, irrigation development has been undertaken by many different parties with no coordination mechanism between them. Not only the lack of functional institution for irrigation development and management but also their frequent restructuring and instability have been the major causes for the nonexistence of consistent records and institutional memories.

During the pre-revolution (before 1974), the chief purpose of irrigation was to provide industrial crops to the growing agro-industries in the country, many of which were controlled by the interest of foreign companies and to boost export earnings. The main crops grown were sugarcane, cotton, sesame, fruit, and vegetables [13]. Following the 1975 land reform and agricultural policies, greater emphasis was given to the development of large-scale state farms. This was done by converting the majority of large-scale commercial farms owned by individuals and cooperatives into state farms (see also Section 3.1). As documented by [8], all these reforms could not yield positive results in terms of producing adequate agricultural products to feed the growing population. Moreover, the country was hit by frequent drought that yearly intensified from 1980 to 1984. As a result, serious famine prevailed in many regions of the country. Generally, the 1984/85 famine provided a major stimulus for the development of the government-sponsored small-scale irrigation program in areas affectively controlled by the central government, and especially in communities where producer cooperatives had been established. Furthermore, the peasants have shown a great deal of initiative in developing irrigation schemes on their own in various parts of the country, which is widely known as traditional irrigation. The government, on its part, has also prepared and implemented the ten-year development plan to fight against drought and famine that has occurred from 1984/85 to 1993/94. One of the targets of the plan was to develop 57,000 hectares of land under small-scale irrigation in private and cooperative farms. However, the success of this target was not evaluated due to the collapse of the socialist Government (the Derg regime).

The trend of irrigation development after the downfall of the Derg regime is indicated in Figure 3. The period between 1991 and 1995 was considered as a transitional period (to federalism) during which no significant irrigation development activity was carried out. It was with the issuance and implementation of a series of national economic development plans and programs that the development of medium and large-scale irrigation showed a significant increase. Examples of these development programs and plans during that time are among others: the Sustainable Development and Poverty Reduction Program (SDPRP, from 2002/03–2004/05); Plan for Accelerated and Sustained Development to End Poverty (PASDEP, from 2005/06–2009/10); and the Growth and Transformation Plan (GTP I, from 2010/11–2014/15) and GTP II, from 2015/16–2019/20. In all these plans, irrigation development was given greater attention.

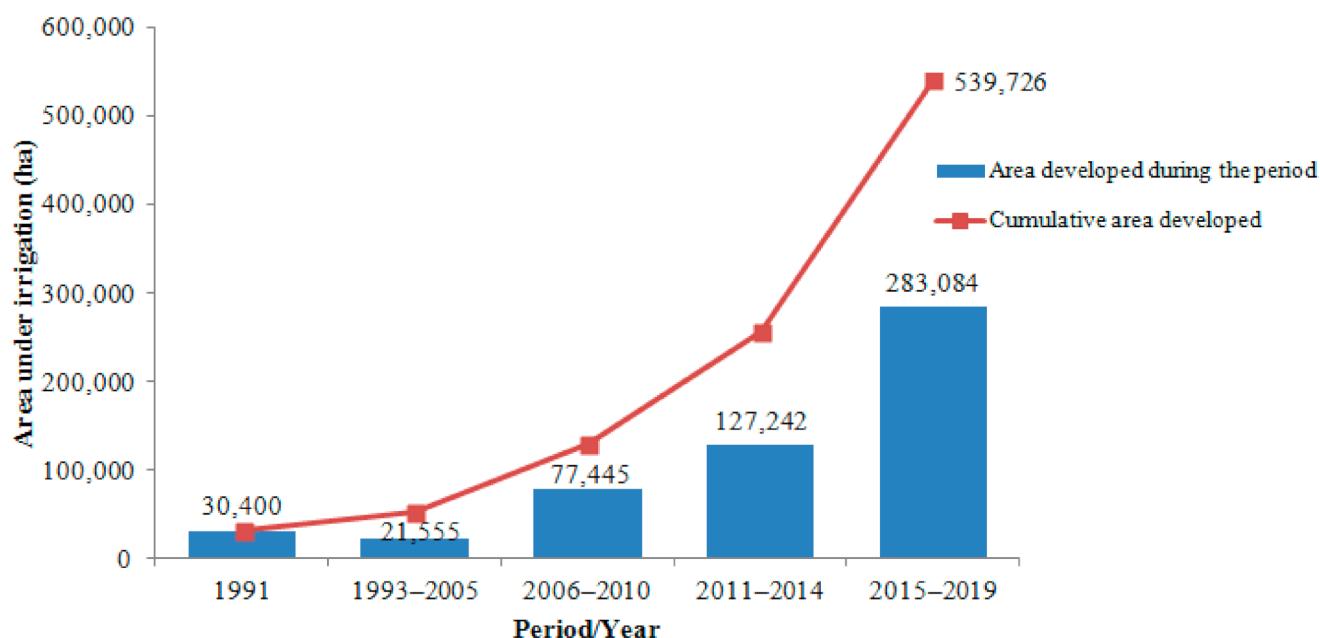


Figure 3. Area equipped for medium and large-scale irrigation over three decades (source of information: plans and reports from MoWIE).

Before the implementation of the development plans, the expansion rate of the area equipped for medium and large-scale irrigation was very slow, i.e., only 21,555 hectares over 12 years. This has increased to an additional area of 77,445 hectares after the implementation of the PASDEP. Then, after the two consecutive plans of GTP I and GTP II additional irrigated area, expansion of about 127,242 and 283,084 hectares, respectively, was achieved. This marks an annual expansion rate of 12.9% and 24.5%, respectively.

As depicted in Figure 3, the total area equipped for medium and large-scale irrigation by 2019 is about 539,726 hectare. However, it must be noted that the actual irrigated area is far less than the figure indicated here. For instance, information collected from fifteen large-scale irrigation projects showed that only 34% of the 382,060 hectares of land potentially equipped for irrigation was actually irrigated. There were two main reasons for this discrepancy. (1) First, there was delay in the construction of some component parts of the irrigation system, for instance, canals and field channels, intake structures, head/cross regulators, land leveling and shaping, etc. This means that there is a lack of end-to-end planning of projects. (2) The second reason was the malfunctioning or non-functionality of important canals and structures. In most cases, dams are constructed and filled with water long before the construction of conveyance and distribution canals, field channels, and land preparation for irrigation are done. It is common that some years elapse until the water reaches the field and the provision of irrigation services commences. Due to this and other reasons, irrigation systems serve only a limited area, which is often less than the area projected during feasibility study and detail design.

Moreover, the shrinkage of irrigation area is also attributed to many problems such as lack of proper provision of farm level irrigation facilities, headwork and canal sedimentation, seepage through foundation, deterioration of major structural facilities, unsuitable field and canal layout and construction, missing of important hydraulic structures, shortage of water, low efficiency, etc. [17,26,27].

Table 2 presents the plan targets and achievements of medium and large-scale irrigation development over the last one and half decades.

Table 2. Baselines and targets for medium and large-scale irrigation development during the three major planning periods (Planning and evaluation document of MoWIE, 2016).

Plans	Plan Period 1		Plan Period 2		Plan Period 3	
	Baseline 2005/06	Target (achieved %) 2009/10	Baseline 2009/10	Target (achieved %) 2014/15	Baseline 2015/16	Target (achieved %) 2019/20
PASDEP	51,955	247,130 (51%)		127,242	658,337 (43%)	
GTP I						
GTP II					283,084	954,000 ¹ (51%)

¹. 490,000 ha is reportedly achieved until the end of the year 2020 (MoWIE) which is 51% of the target (954,000 ha).

While the ambiguous targets set during different planning horizons show the commitment of the government to accelerate the expansion of irrigation, the low accomplishment performances imply that there is a critical capacity limitation to implement the plans.

Small-scale irrigation development has been crucial in the plans of the governments of Ethiopia to sustain food security and livelihoods of more than 80% of the population living in rural areas. However, its implementation during pre- and post-revolution was stagnant and challenged by lack of political stability and directions. Following the announcement of the national development strategic direction known as “Agricultural Development Led Industrialization” in the early 1990s and many other rural development plans in the early 2000s, the attention given to small-scale irrigation has also increased. With the implementation of the three consecutive plans, namely PASDEP, GTP I and II, encouraging progresses have been achieved in the development of small-scale irrigation (Figure 4).

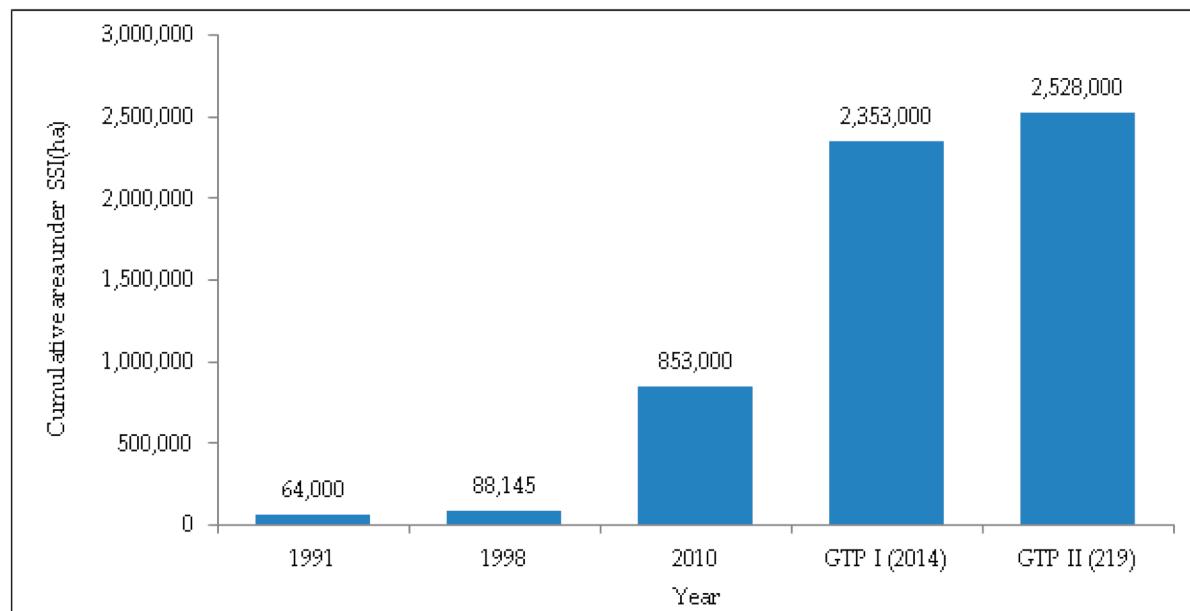


Figure 4. Cumulative area equipped for small-scale irrigation over the last three decades (traditional small-scale irrigation schemes not included) (source of information: plans and reports from MoA and MoWIE).

According to Ref. [28], the area under small-scale irrigation in Ethiopia has increased from 176,105 ha in 1991 to 197,250 ha in 1998 and to 853,000 ha in the year 2009/10 to about 2.353 million ha in 2014 and 2.528 million ha at the end of 2019. The GTP was found to be a new approach through which massive public and donor supports as well as resources were mobilized particularly during GTP I. Thus, during these two consecutive GTPs, small-scale irrigation expansion has increased specifically by 15.2% per year during the first plan period. The GTP II target was to expand small-scale irrigation by an additional 1.75 million hectares and thereby ensuring that 80% of all smallholder farmers have at least one source of water for irrigation and 50% will be supported to use the full package for

modern irrigation [21]. However, the accomplishment of the second plan period is not fully evaluated yet.

4. Challenges of Irrigation Development

Irrigation in Ethiopia is facing multitudes of constraints in all phases of its development (project identification, feasibility study and detail design, construction, operation, and management). The major problems and resulting consequences are summarized in Figure 5. The end effects of these interconnected problems are project cost and time overrun, poor scheme performances, and unsustainable irrigation.

Unresolved problems encountered during study and design could lead to design faults that in turn affect the whole irrigation system. Failures created during design can seldom be corrected during construction and finally influence the overall performance of irrigation. The major problems indicated in Figure 5 are highlighted as follows:

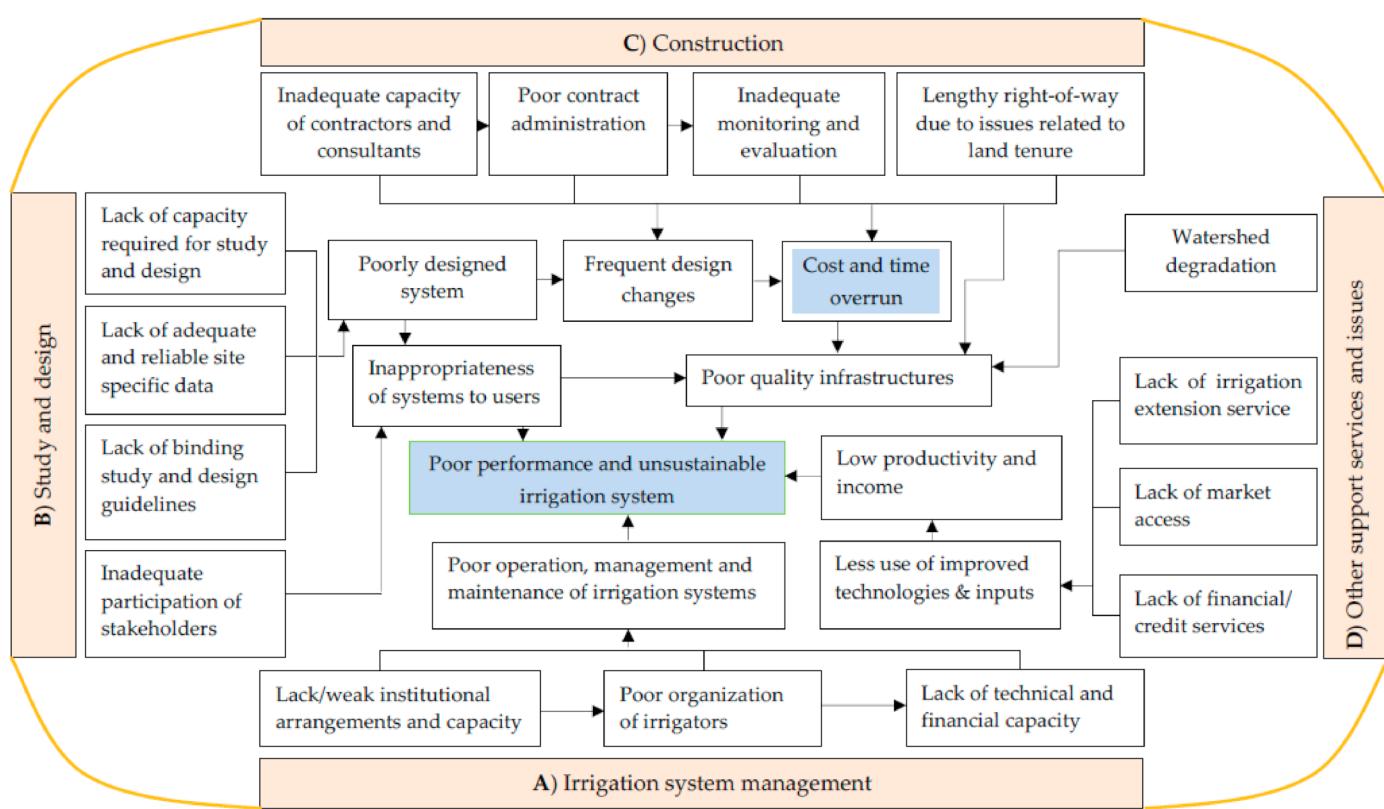


Figure 5. Irrigation development constraints and their interconnections (author's own presentation).

4.1. Study and Design

Irrigation project study and design are the most important components of irrigation development. Multidisciplinary professionals from the fields of hydrology, irrigation engineering, soils, agronomy, geology, and socio-economics are involved at this stage. The major tasks involved are identification of problems and development of engineering solutions that enable adequate and reliable diversion, conveyance, and distribution of water. However, the works at this stage are constrained by problems such as lack of technical skills and knowledge required for study and design, lack of adequate and reliable site-specific data, lack of standards and guidelines for study and design, and inadequate participation of stakeholders. The most critical problem facing the study and design of irrigation projects is the lack of binding standards and guidelines [10]. Consulting firms and individual engineers engaged in the study and design of irrigation projects are adopting different guidelines of their preferences. For instance, the US Bureau of Reclamation (USBR), FIDIC (Federation Internationale Des Ingénieurs-Conseils, Geneva, Switzerland),

British standards, and FAO–Irrigation Manuals. As a result, there is a widespread inconsistency in study and design practices across the country.

There is little or no community consultation on project identification, study, and design follow the top–down approach [25,29], which prevents the incorporation of users' special needs and indigenous farmers' knowledge into the planning and construction of irrigation schemes [30]. Often, systems designed under such conditions are portrayed by meager quality and inappropriateness to users. Poorly designed systems are considered as the root causes for frequent design changes and the resulting cost and time overruns. Many research reports identified the study and design faults as among the major challenges of irrigation development and management in Ethiopia [16,25,26,31–35]. Such design faults have wide-reaching impacts, as design documents are seldom reviewed before construction commences [10].

4.2. Construction

The construction of irrigation systems involves the conversion of engineering solutions provided in the design document to a physical reality that enables safe storage or diversion, conveyance, distribution and application of water. In this regard, the selection of competent consultants and contractors as well as the use of appropriate construction materials, following standard construction procedures etc. are essential. The major problems during this implementation phase are among others inadequate capacity of the client, consultants and contractors that invariably lead to poor contractual administration, inadequate monitoring and evaluation, frequent design changes that result in excessive cost, and time overruns.

The study conducted by [34] on ten large-scale irrigation projects in Ethiopia showed that 78% of the reasons for project cost overrun were attributed to design, scope, and quality changes. The authors also found that the average time overrun in irrigation project implementation is about 145%, which has direct and indirect cost implications. The authors of Ref. [34] also did an assessment of ten large-scale irrigation dam projects and found an aggregate average cost and time overrun of 176% and 151%, respectively. For a poor country such as Ethiopia, such inefficiency in project implementation has wide-reaching consequences. Reasons for such wasteful resource use were found to be incomplete design, design change, scope and quality change, poor construction time estimate, constructors' low capacity, client's inactions, and shortage of material.

The IAG [10] also conducted an assessment on the effectiveness of contact administration on two large-scale irrigation projects (Megech-Seraba and Zarema May-Day in Tigray Region in Ethiopia) that are under construction. It was found that the poor performance of these projects was partly attributable to weak institutional capacities of implementing bodies including the Ministry of Water, Irrigation, and Energy, which were characterized by slow decision-making processes, inadequate monitoring and evaluation, and weak contract administration and coordination capacity. As long as institutional capacity remains inadequate, it seems unlikely that the next large-scale project will be timely and successful, leading to the same pitfalls in different projects [29].

4.3. Irrigation System Management

The provision of irrigation service involves collective actions, which are the results of effective communication and coordination among users and service providers. In addition to having functional physical infrastructures in place, management institutions are also required. They are responsible for the mobilization of resources required for the effective operation of irrigation systems, making proper decisions on water diversions, equitable distribution, and maintenance as well as resolving conflicts. The sustainability and productivity of irrigation system depends on the capacity of the management organization to deliver these responsibilities.

Tertiary-level management is commonly carried out by irrigation water users associations (IWUAs). However, such organizations are not well established and lack technical and financial capacities to properly discharge their duties of irrigation management [22,25,35].

Concerning irrigation management, there is a clear vicious circle of the arc “weak management capacity → poorly operated and maintained system → poor system performance → low productivity → low income → weak management capacity”. Converting this vicious circle into a virtuous circle requires building the capacity of irrigation management institutions including that of irrigators’.

Apart from the poor performances of irrigation schemes, unwise management of irrigation water has been causing multitudes of undesirable consequences on the environment. The development of salinity, sodicity, and water-logging in many large and medium-scale irrigation schemes in lowland areas of the country is increasing [13,36]. Hence, the rate at which the country is losing its fertile agricultural land to these unwanted consequences of irrigation has been rising. Although there are many factors that are contributing to these problems, low irrigation efficiencies as a result of inadequate knowledge and the skill of irrigators can be considered as the major factor [12,32,36].

4.4. Other Support Services and Issues

Water application through irrigation is only one input to the agricultural production system. Timely and reliable water supplies enhance greater cropping intensities which when integrated with other appropriate agricultural inputs can push up agricultural productivity [36]. The adoption of improved irrigated agricultural innovations by farmers is believed to be of prime importance for improving farming practices that enhance the productivity, profitability, and sustainability of their farms. Such innovations include high-yielding varieties, new types of fertilizers, modern farm technologies and practices of land and water management, and new strategies of market engagement, among others [25,37–40]. While extension services are necessary to help farmers adapt and implement improved practices, access to credit and market provide financial capacity and thereby enable farmers to invest in improved agricultural inputs and technologies.

However, unlike agriculture, the irrigation sector in Ethiopia is not well supported by extension services. Most often, irrigation is practiced without adequate know-how, which resulted in undesirable consequences such as soil salinity, groundwater rise, water-logging, and the degradation of soil fertility. Moreover, the lack of appropriate financing mechanisms and access to market has been threatening the success of irrigation, which in turn affected the likelihoods of irrigators and limited their capacity to invest in improved farm inputs and technologies [27,30,33,41]. The overall consequence is the deterioration of many of the irrigation systems and poor performances. The effects of low farm income and inadequate capacity to afford improved technologies can be explained by a vicious circle of the form “poor irrigation management combined with low use of improved farm inputs cause decreases in crop yields and production, which in turn leads to low income and finally the inability to purchase improved inputs and technologies.”

Moreover, the sustainability of irrigation systems is largely threatened by watershed degradation and the resulting floods, soil erosion, and sedimentation [24]. Irrigation infrastructures such as dams, diversion headworks, and canals are frequently damaged by floods, and their projected life is shortened by excessive sedimentation from the degraded uplands [2,13]. Many schemes are facing water shortage due to drought and the overuse of the available water, hence reducing their irrigable areas [31].

5. Summary and Conclusions

In this study, the irrigation development in Ethiopia, historical background, development trends, current status, and challenges threatening its implementation and management are reviewed, synthesized, and presented. Smallholder farmers’ own initiative and indigenous knowledge-based irrigation has been practiced in Ethiopia for over 2000 years. Recognizing small-scale irrigation as an important intervention to sustain agricultural production and thereby minimize the risk of crop failure due to drought or dry spell has started following the droughts of 1980 to 1984/85. Nevertheless, some private concessions driven by foreign interests have started modern irrigation development in Awash Basin in

1960s, mainly for the production of industrial crops. Although the potential of irrigation in boosting agricultural production is widely understood, its development remained more or less stagnant until 2010. This is largely due to political and institutional instability and a lack of clear direction for the development of the sector.

The development and implementation of the five-year plans over three consecutive terms brought increasingly accelerated development trend in irrigation. These plans were the Development and Poverty Reduction Program (SDPRP, from 2002/03–2004/05); Plan for Accelerated and Sustained Development to End Poverty (PASDEP, from 2005/06–2009/10); and the Growth and Transformation Plans, such as GTP I, from 2010/11–2014/15 and GTP II, from 2015/16–2019/20. During the two later plan periods, medium and large-scale irrigation development has registered an average annual expansion rate of 20% and 22% respectively and reached an estimated area of 539,736 hectare in the year 2019.

Small-scale irrigation practice to supplement rain-fed agriculture has had a long history in Ethiopia. Such schemes have a number of advantages over medium and large-scale schemes; namely the following: (1) they are less expensive; (2) they are easier to implement and manage and hence, provide larger opportunity for farmers' participation; (3) there is better coherence between farmers as one scheme serves a limited number of beneficiaries; and (4) equity can be addressed, as its implementation does not require extensive potential areas. Reportedly, the area equipped for small-scale irrigation until the year 2010 was about 0.85 million hectares only. With the annual expansion rate of 35% during GTP I, the area under small-scale irrigation has reached 2.35 million hectares in the year 2014, which was followed by only a 2% annual expansion rate during GTP II.

Despite the higher emphasis given to the irrigation sector, the effectiveness of its development and management is far from the desired level. In general, the major challenges facing the sector are related to (1) study and design—inadequate capacity, lack of reliable and site-specific data, lack of binding guidelines, inadequate participation of stakeholders; (2) construction—inadequate capacity of the client, consultants, and contractors that invariably lead to poor contractual administration, inadequate monitoring and evaluation, frequent design changes that result in excessive cost and time overruns; (3) irrigation management—inadequate organization and capacity of institutions, lack of technical and financial capacity; (4) support services—lack of irrigation extension service, market access, and inadequate financing mechanism for irrigation development.

The inability to build the capacity of irrigation development implementing institutions including the Irrigation Development Commission of the MoWIE and the inefficiency as a result have been dearly costing the country its scarce capital resources. Exemplifications of such poor contact administration are the excessive cost and time overruns affecting all large-scale irrigation projects.

Irrigation development, in terms of expansion during the last two decades, might look encouraging, which is basically investment-driven. However, there is an increasing concern due to the fact that some projects are not operating at their full capacity and many others are deteriorating due to lack of timely maintenance and hence, poor performances. While developing new irrigation projects, it is also important to note that there is substantial scope to increase food production, enhance livelihoods, and reduce poverty by properly managing existing irrigation schemes. This has to be done in an integrated manner that address the rehabilitation of irrigation infrastructures, putting in place appropriate institutions and innovative management styles as well as improving input services to enhance irrigated agricultural productivity. Management institutions and organizations need to be supported by qualified professionals, skills, and technology for efficient operation and maintenance, sustainable financial sources, and effective regulatory and enforcement mechanisms.

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