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Irrigation Schemes in Ethiopia's Awash River Basin

An Examination of Physical, Knowledge, and Governance Infrastructures

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Abstract

Using a representative sample of irrigation schemes, the study documents the physical, knowledge, and governance infrastructures of irrigation schemes in Ethiopia's most intensively used river basin, the Awash. The findings show that about 20 percent of the equipped area of irrigation schemes in the basin is not being irrigated, while the number of actual beneficiaries on average exceeds the number of planned beneficiaries. The results also show significant knowledge gaps among irrigation scheme managers, extension agents, and leaders of water users' associations (WUAs): 96 percent of them do not know the total water withdrawals or the irrigation water requirement per season. About 14 percent of the surveyed irrigation schemes have neither traditional water committees nor WUAs, and only 21 percent are organized in legally registered WUAs despite a substantial number of identified benefits of these organizations. Moreover, only 58 out of 489 irrigation schemes have women committee members. Many schemes lack a clear strategy for covering maintenance costs: almost 40 percent of schemes collect contributions from members only when the system fails, while 17 percent report no contributions for maintenance at all suggesting considerable risk of system deterioration and failure. The results challenge some of the assumptions about irrigation infrastructure in Ethiopia and confirm and quantify other assumptions in the literature.

Keywords: Awash River Basin, scheme survey, irrigation, Ethiopia, irrigation performance

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1 Introduction

Agriculture continues to play a key role in the Ethiopian economy, contributing 35 percent to gross domestic product (GDP), employing 73 percent of the labor force, and generating 78 percent of export earnings (Tesfaye et al., 2020; Ojulu, 2020). While agricultural growth has been rapid during 2004-2014, at 7.6 percent per year (Bachewe et al., 2015), population growth has also remained considerable (Alemu et al., 2017) Further, the agriculture sector's growth and contribution to GDP have both declined in recent years (NBE, 2021/22).The country's agriculture is characterized by rainfed, fragmented, and small landholdings, leading to reduced efficiency and productivity (Alemu et al., 2017); and yield per hectare for major cereal crops is below international levels (Seyoum et al., 2013).

Smallholder farmers constitute the backbone of agricultural development in Ethiopia. Nevertheless, they face challenges such as technical inefficiency, lack of adoption of climate-smart agriculture practices, limited market participation, and impacts of climate change (Tenaye, 2020; Zerssa et al., 2021; Matewos, 2019). Despite the considerable attention given to agriculture over the last three decades, its performance is unsatisfactory mainly because of small landholdings, soil fertility loss, pest invasion, climate change and rainfall variability, untimely availability of inputs, use of outdated farm technologies, and market-related challenges (Welteji, 2018; OECD/PSI, 2020). Additionally, insufficient public spending has been allocated to agriculture relative to its significance (Sánchez & Cicowiez, 2023). Consequently, enhancing the productivity of smallholder farmers remains a paramount rural policy interest in Ethiopia.

Ethiopia boasts abundant water resources, accessible from both surface and underground water (Kassa & Andualem, 2020). The country possesses approximately 124.4 billion cubic meters (BMC) of water from rivers, 70 BMC from lakes, and 30 BMC from groundwater, offering a potential irrigable land area of 3.8 million hectares (Melesse et al., 2013; Seleshi et al., 2014). Its 12 river basins have substantial irrigable potential, but only a fraction of these resources have been harnessed (Worqlul et al., 2017). While precise figures are elusive, literature suggests that only small percentage of Ethiopia's irrigable land is currently under cultivation. For instance, Kassa and Andualem (2020) estimate that less than 5 percent of overall irrigated land is used, whereas Haile (2015) suggests that only 10–12 percent of potential irrigable land is in production. Underutilization of water resources carries several consequences, including heightened food insecurity, land degradation, and increased vulnerability to climate change impacts. It exacerbates imbalances in food supply and demand amid population growth. In least developed countries, prioritizing the development of irrigation schemes emerges as a critical strategy to reduce reliance on rainfed agriculture, mitigate climate risks, ensure food security, safeguard the environment, and enhance farm productivity (Haile, 2015).

Among Ethiopia's 12 river basins, the Awash stands out as the most used river basin and the Awash River is the only one entirely contained within the country's borders. The Awash River Basin covers a catchment area of 112,696 square kilometers (km^2) and extends for 1200 km through parts of Amhara, Oromia, Afar, and Somali regional states, as well as the city administrations of Addis Ababa and Dire Dawa (Awulachew et al., 2007). Keraga et al. (2017) report that approximately 77 percent of irrigable land in the Awash River Basin is cultivated.

Ethiopia has made significant investments in small- and large-scale irrigation schemes over the past decade to meet the needs of its growing population. Small-scale irrigation scheme development has been particularly targeted to enhance production, productivity, and food security among smallholder farmers (Berhe et al., 2022).

While the potential for irrigation schemes to alleviate poverty and enhance livelihoods is recognized, their effectiveness remains questionable in Ethiopia (Hirko et al., 2023). Existing irrigation schemes in the country exhibit poor performance and lack of sustainability. Numerous challenges have impeded the development of irrigation projects. In arid areas, factors such as inadequate infrastructure (for example, power supply and road networks), the high prevalence of malaria, and harsh climatic conditions have hindered irrigation projects' expansion and effectiveness (Alemayehu, 2014). Similarly, administrative and institutional factors have constrained their effectiveness and sustainability countrywide (Yami, 2016).

Gebul (2021) identifies these challenges across various stages including study and design, construction, irrigation management, and technical support. Generally, success stories of irrigation projects in Ethiopia are limited due to insufficient monitoring and evaluation, lack of reliable and site-specific data, inadequate stakeholder participation, limited capacity among clients, contractors, and consultants, frequent design alterations, and institutional capacity constraints (Yami, 2016; Abo et al., 2024).

This study's main purpose is to explore the patterns of irrigation management, information sharing, and stakeholder participation at different levels in the Awash River Basin irrigation schemes. Focusing on the Awash River Basin can inform the operation and management of other irrigation schemes in the country. Thus, this paper attempts to identify the gaps that exist in the performance of Awash River Basin irrigation schemes in terms of their management, stakeholder participation, stakeholders' knowledge of water usage, and costs.

The existing literature on irrigation performance in Ethiopia typically relied on data collected from farmers within one or a select few schemes. Such studies often lacked information obtained from representative scheme-level surveys in the country or in a river basin. In this study, we present information collected from scheme managers, extension agents, and leaders of water users' associations (WUAs) on the physical, knowledge, financial, and governance aspects of 500 irrigation schemes in the Awash River Basin, representing approximately 68 percent of all schemes located there.

The rest of this paper is organized as follows: Section 2 outlines the sampling strategy and overall characteristics of the survey data and data collection procedures. Section 3 examines issues pertaining to physical infrastructure while Section 4 discusses knowledge infrastructure. Section 5 focuses on governance infrastructure, emphasizing the gendered aspects of irrigation water management. In Section 6, environmental and human health issues within the irrigation schemes are discussed. Finally, Sections 7 and 8 conclude with major findings of the study and provide recommendations based on these conclusions, respectively.

2 Data

To list the irrigation schemes in the Awash River Basin, we relied on administrative scheme data from regional and federal authorities. We initially identified 898 irrigation schemes throughout the basin, spanning the Oromia, Afar, and Amhara regions, based on administrative datasets that are about 10 years old. However, due to security concerns at the time of the survey, we excluded 43 schemes in the Afar region.

Additionally, *woredas* (districts) with fewer than 8 irrigation schemes were omitted from the sampling frame. This decision was motivated because districts with few irrigation schemes tend to incur higher transportation and overall survey costs per unit of scheme surveyed. As a result, 119 irrigation schemes from 37 woredas in the Amhara and Oromia regions were excluded.

Table 1: Sample and Sampling Frame Distribution, by Irrigation Scheme Type

Category of Irrigation Scheme	Sample Frame		Sample	
Typology, scale, and water source	Frequency	Percent	Frequency	Percent
Modern and small with river water	87	11.8	59	11.8
Modern and medium with river water	16	2.2	12	2.4
Traditional and small with river water	389	52.9	265	52.9
Traditional and medium with river water	25	3.4	17	3.4
Modern and small with spring water	27	3.7	18	3.6
Traditional and small with spring water	192	26.1	130	26
Total	736	100	501	100

Source: Authors.

Our final sampling frame comprised 736 irrigation schemes, from which 500 (68 percent) were selected using a stratified proportional random sampling technique. Stratification was based on water sources for irrigation (rivers versus springs), scheme size (small versus medium), and irrigation typology (traditional versus modern).[1] Proportional random sampling ensured the representativeness of each category within the overall sampling frame (see Table 1 for details).

The irrigation scheme-level survey stands out for several unique reasons. First, it comprehensively covers various aspects of representative irrigation schemes in the Awash River Basin. Given the data-intensive nature of irrigation management, having such a detailed dataset from representative irrigation schemes is invaluable for understanding existing practices, challenges, and opportunities.

Second, the dataset includes geographic and spatial information regarding water abstraction sites, secondary canal offtakes, and GIS shapefiles of irrigation schemes. This geospatial data holds significant importance as it enables integration of the dataset with other remote sensing-based biophysical datasets, such as soil moisture, vegetation indices, and rainfall and temperature data.

Third, the scheme-level survey captured details on crop types and includes photos of irrigated plots. This information could greatly assist in efforts related to machine learning and remote sensing-based prediction of crop identification, as well as trends in water consumption for various crops, among other applications.

The International Food Policy Research Institute (IFPRI), in collaboration with the Association of Ethiopian Microfinance Institutions (AEMFI), collected the scheme-level data for the study. The questionnaire was translated into the local languages spoken in the areas of interest, including Amharic and Afan Oromo. AEMFI employed 12 qualified fieldworkers—2 supervisors and 10 enumerators—who, in addition to participating in a week-long training on the specificities of the survey, brought extensive field experience and proficiency in the local languages to the study. Data collection took place over a period of 61 days, from March 24, 2021, to May 23, 2021.

During data collection, most effort was made to ensure that responses were gathered from individuals knowledgeable about the scheme. At every scheme, three knowledgeable respondents were engaged to discuss and provide answers to survey questions. Priority was given to incorporate scheme managers, water committee members, and extension agents (called development agents). Deputy managers, WUA members, and *kebele*[2] administrators were allowed only in cases where the primary respondents were unavailable.

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[1] Only a handful of schemes reported groundwater as a source of irrigation. Given our interest in focusing on small- and medium-sized schemes, we excluded irrigation schemes with command areas of less than 10 and greater than 3,000 hectares.

2 Kebeles are the lowest administrative units in Ethiopia.

As a result, of the total 1,473 respondents, 21 percent were scheme managers, 50 percent were water committee members, and 22 percent were development agents.

3 Key Parameters of Irrigated Areas

Several aspects of the irrigation infrastructure were examined: a comparison of equipped and actually cultivated irrigated areas, primary water sources, water application mechanisms, and water distribution mechanisms. Equipped area refers to the irrigated area with physical infrastructure. Actual area cultivated with irrigated crops denotes the portion of the land that is actually cultivated within the equipped area but could also include irrigation outside the equipped area. A substantially lower cultivated area as compared to equipped area might denote poor infrastructure design that does not allow irrigating the area equipped for it, or other challenges, such as disputed land ownership within the equipped area. However, occasions sometimes arise when irrigated production is conducted outside the physically equipped area. Depending on the situation, irrigated area in proximity to but outside the equipped irrigated area might be using irrigation water illegally. Table 2 illustrates the differences between equipped and cultivated irrigated areas by irrigation scheme size. Generally, the area equipped for irrigation surpasses the cultivated irrigated area. Moreover, the gaps between equipped and cultivated irrigated areas tend to widen as the scale of the irrigation schemes increases.

Table 2: Average Equipped and Cultivated Irrigation Areas, by Scheme Size (hectares)

Scheme Size (hectares)	Observations	Equipped	Cultivated	Cultivated/Equipped
<=20	219	13.0	11.1	0.86
21–40	147	31.4	26.0	0.83
41–60	52	50.8	41.2	0.81
61–80	28	74.3	57.1	0.76
>80	44	137.6	106.8	0.79
All sizes	496	37.1	30.0	0.83

Source: Authors.

Note: The cultivated, equipped, and ratio values in the table are averages. See also Annex Figure 1.

The ratio of cultivated to planned irrigation area varies across the scale of the irrigation scheme. For instance, in irrigation schemes with less than 20 hectares, 86 percent of the land equipped for irrigation is cultivated, leaving the remaining 14 percent uncultivated. The ratio of cultivated to equipped land for irrigation in larger schemes—those covering 61–80 hectares—is 76 percent, while this ratio is 79 percent for schemes greater than 80 hectares. On average, the findings indicate that approximately 17 percent of the area equipped for irrigation is not fully used in many of these schemes.

Respondents cite various reasons for the variance of the cultivated area with equipped irrigation areas in the schemes. The three primary factors are water scarcity due to upstream users' abstraction (31 percent), diminished natural river flows (29 percent), and damage to irrigation infrastructures (11 percent) (Table 3, and Annex Figure 2).

Table 3: Primary Factors Contributing to Reduced Irrigated Area Relative to Equipped Capacity

Factor	Frequency	Percent
Shortage of water due to upstream user	103	31.3
Reduction of natural river flow	97	29.5
Damage to irrigation infrastructure	36	10.9
Inefficient pump operation	15	4.6
Flood damage	15	4.6
Salinity	11	3.3
Damage to irrigation system	8	2.4
Waterlogging	8	2.4
Damage to headwork	5	1.5
Other (specify)	24	7.3
No response	7	2.1
Total	329	100

Source: Authors.

Table 4 presents the ratio of households that have actually benefited from the schemes to the initially planned number of beneficiaries, categorized by scheme size: on average, more households benefit than originally anticipated. However, it should be noted that this surplus could strain water resources, potentially leading to scheduling difficulties among users and conflicts due to increased instances of water theft.

Table 4: Ratio of Actual to Planned Beneficiaries, by Scheme Size

Scheme Size (hectares)	Observations	Percent
<=20	204	103.2
21–40	130	114.8
41–60	48	108.5
61–80	25	120.1
>80	44	116.7

Source: Authors.

Table 5 illustrates the percentage of women-headed beneficiary households among the total actual beneficiaries. Across all sampled irrigation schemes, nearly 15 percent of beneficiaries are from women-headed households. Minimal variation arises across scheme sizes in the average share of women beneficiaries.

Table 5: Average Percentage of Women-Headed Beneficiary Households Among Actual Beneficiaries, by Scheme Size

Scheme Size (hectares)	Observations	Percent
<=20	265	14.6
21–40	130	14.3
41–60	38	15.3
61–80	18	14.4
>80	29	15.5

Source: Authors.

As previously documented by Awulachew et al. (2007), surface water is the primary source of irrigation in Ethiopia. Our survey confirms this for the schemes visited in the Awash River Basin. Specifically, surface water is the principal source of water for 91 percent of the irrigation schemes (60 percent from rivers and 31 percent from springs) (Table 6, Annex Figure 3). Consequently, most of the surveyed irrigation schemes rely on river diversion or simple intake methods for water acquisition. Among the total sample of irrigation schemes, approximately 17 percent and 3 percent use diesel and electric pumps, respectively, for lifting irrigation water to fields.

Table 6: Primary Sources of Irrigation Water

Source	Frequency	Percent
River	298	60.0
Spring	153	30.8
Dam	16	3.2
Deep well	14	2.8
Hand-dug well	7	1.4
Others (specify)	4	0.8
Natural lake	2	0.4
Shallow well	2	0.4
Pond	1	0.2
Total	497	100

Source: Authors.

The predominant type of irrigation scheme in the Awash River Basin is traditional (72 percent), while 28 percent use modern surface systems (Table 7A). Nine out of 10 irrigation schemes in the basin use a canal breach for water distribution (Table 7B). Approximately 8 out of 10 use diversions and simple intakes to abstract irrigation water from the source to the scheme, 2 out of 10 use pumps (mostly diesel), and 1 scheme uses solar pumps (Table 7C).

Table 7A: Irrigation Types Used in Schemes

Irrigation Type	Frequency	Percent
Traditional	348	72.2
Modern surface system	133	27.6
Equipped spate	1	0.2
Total	482	100

Table 7B: Water Distribution Method

Distribution Method	Frequency	Percent
Canal breach	453	91.5
Siphon	33	6.7
Plastic tube	9	1.8
Total	495	100

Table 7C: Main Water Abstraction Method

Water Abstraction Method	Frequency	Percent
Diversion/Simple intake	389	78.4
Diesel pump	89	17.9
Electric pump	17	3.4
Solar pump	1	0.2
Total	496.	100

Note: See also Annex Figure 4.
Source: Authors.

Ethiopia experiences two major production seasons. The *Kiremt* or *Meher* rains, running from June to mid-September, are more reliable and conducive for rainfed agriculture across most regions of the country. The *Belg* season, spanning from February to May, supplies rainfall crucial for agriculture in central Ethiopia and supports approximately 10 percent of the Ethiopian population (Degefu, 1987). This is also the period with peak irrigation activity. During this primary irrigation season, irrigation water is insufficient for 37.5 percent of schemes and only partially sufficient for 28.2 percent (Table 8). Only about one-third of schemes report a sufficient quantity of irrigation water.

Table 8: Share of Respondents' Perception of Water Availability, by Irrigation Season (%)

Respondents' Perception of Quantity of Irrigation Water	Meher/Rainy (Season 1)	Belg (Season 2)	Belg (Season 3)
Sufficient	89.5	34.3	9.7
Sufficient only for part of the season	7.7	28.2	11.5
Never sufficient	2.8	37.5	12.3
No third season	-	-	66.5
Total	100	100	100

Source: Authors.

4 Knowledge Infrastructure

Respondents in this scheme-level survey are scheme managers, extension agents, and leaders of WUAs within the irrigation scheme. They are typically presumed to possess the most knowledge about scheme operations. However, 96 percent of these respondents lack knowledge about both the total water withdrawal per season and the total irrigation water requirement per season (Table 9). This underscores the critical importance of enhancing the capacity of scheme operators and leaders to ensure optimal scheme operations.

Only a small fraction of respondents possess knowledge regarding schemes' irrigation and rehabilitation costs. Merely 3 percent and 4 percent of respondents were aware of the engineering and construction costs, respectively, spent during scheme construction, and only 5 percent and 2 percent demonstrated familiarity with the same costs for rehabilitating irrigation schemes.

Table 9: Percentage of Respondents Familiar with Total Seasonal Water Withdrawal and Irrigation Water Requirements

	Knows about seasonal water withdrawal		Knows about seasonal water requirements	
	Frequency	Percent	Frequency	Percent
Yes	19	3.9	19	3.9
No	471	96.1	471	96.1
Total	490	100	490	100

Source: Authors.

The most knowledgeable respondents were tasked with identifying and ranking factors influencing irrigation scheme performance from a list of 10 commonly reported challenges found in the literature: infrastructure damage, improper irrigation system layout, lack of appropriate water regulation structures, water shortage, waterlogging, canal seepage, lack of improved seeds, absence of fertilizer, dearth of agrochemicals, and insufficient market for irrigated agricultural products.

Respondents were requested to assess the severity of each factor on a scale of 0 (not a problem at all) to 5 (the most serious problem). Lack of markets (57 percent), water shortages (50 percent), and lack of chemicals (49 percent) and improved seeds (45 percent) were ranked most often as either a serious problem or the most serious problem affecting performance. Of note, three of the main perceived challenges affecting irrigation performance are not directly linked to irrigation but to complementary inputs and outputs that help irrigation systems thrive.

Other irrigation system-related challenges judged as either a serious problem or the most serious problem included infrastructure damage and improper irrigation system layout (40 percent), lack of appropriate water regulation structures (40 percent), and canal seepage (36 percent) (Table 10).

Notably, 93 percent of the tertiary canals are earthen, making them vulnerable to canal seepage. Furthermore, restricted input supply and inadequate market access for irrigated agricultural products are observed to affect scheme performance.

Table 10: Respondents' Rating of Problems Affecting Schemes' Irrigation Performance (%)

Rank	Not a problem	Least problem	Somewhat a problem	A major problem	A serious problem	The most serious problem
Lack of market	11.0	5.7	10.8	15.5	18.9	38.1
Water shortage	11.6	8.6	14.3	15.3	18.5	31.8
Lack of chemicals	4.5	9.0	17.3	20.2	21.8	27.3
Improved seeds	7.3	10.0	18.3	19.1	23.2	22.0
Structure damage	11.2	15.9	17.1	11.4	13.4	31.0
System layout	12.2	18.2	17.1	8.8	18.4	25.3
Lack of fertilizers	4.1	9.6	20.4	24.9	19.6	21.6
Lack of regulation	9.8	20.8	19.4	10.2	13.9	26.1
Canal seepage	14.3	21.4	17.1	11.0	14.9	21.4
Water logging	37.3	28.1	17.7	5.9	3.9	7.1

Source: Authors.

5 Governance Infrastructure

In this section, we assess the governance structures of the irrigation schemes within the Awash River Basin, addressing issues such as the legal framework governing the schemes, organizational management, the roles played by WUAs, the criteria for irrigation scheduling, overall irrigation performance, and conflict resolution. According to Article 11 of Ethiopia's Water Resource Management Proclamation No. 197/2000, it is expressly prohibited to undertake the construction of waterworks, use water for own use, transfer water abstracted from a water resource or received from another source, or discharge waste into water resources without obtaining a permit from the overseeing body (Bekele & Mekonnen, 2021a). Among the schemes included in our sample, approximately 63 percent have acquired permits from the relevant regulatory body, while 37 percent operate without them. The Proclamation provides exemptions for traditional irrigation methods and hand-dug wells to operate without permits. Nonetheless, 22 percent of the modern irrigation schemes in the sample do not have the required permits.

Ethiopia's Irrigation Proclamation No. 841/2014 mandates that all public irrigation projects establish legally registered irrigation WUAs (FDRE, 2014; Bekele & Mekonnen, 2021b). Despite the proclamation's requirement for compulsory membership in formal WUAs, 14.5 percent of the surveyed irrigation schemes lack both traditional water committees and WUAs. Traditional water committees manage nearly one-half (48 percent) of the irrigation schemes. Only 21 percent of schemes have organized themselves into legally registered WUAs for scheme management (Table 11, Annex Figure 5). Additionally, approximately 12 percent are organized as cooperatives. The key distinction between organizing as an irrigation cooperative and a formal WUA is that the former operates as a private law organization, while the latter operates under public law.

Table 11: Types of Irrigation Organizations Managing Schemes

Type of Organization	Frequency	Percent
Traditional water committee	237	47.8
Legally registered irrigation WUA	104	21.0
Irrigation cooperative	58	11.7
Nonregistered irrigation UUA	25	5.0
Not organized	72	14.5
Total	496	100

Source: Authors.

Membership within irrigation schemes can be either formal or informal, each with its own characteristics. On average, WUAs include approximately 62.2 formal members and 37.2 informal members. However, irrigation cooperatives typically boast larger memberships, with an average membership of around 111, while maintaining an average of 51.3 informal members (Table 12).

Table 12: Average Number of Formal and Informal WUA Members, by Organization Type

Type of Organization	Average number. of formal WUA members	Average number of informal WUA members
Irrigation cooperative	111.1	51.3
Legally registered irrigation WUA	74.1	28.5
Nonregistered irrigation WUA	68.2	22.4
Traditional water committee	56.1	32.0
Not organized	24.4	60.2
Aggregate	62.2	37.2

Source: Authors.

Legally registered WUAs have an average of 74 formal members and about 24 informal members. The data shown in Table 12 underscore the diverse membership structures across different types of irrigation organizations, shedding light on their varying degrees of formality and informality.

It is noteworthy that the average size of formal membership within WUAs correlates with the size of the irrigation scheme. In smaller schemes spanning less than 20 hectares, the average formal membership is about 34. However, for schemes exceeding 80 hectares, this figure increases to more than 150 (Table 13). Intermediate-sized schemes demonstrate a steady rise in average membership. Smaller irrigation schemes tend to exhibit larger average informal memberships than formal ones.

Table 13: Average Number of Formal and Informal WUA Members, by Scheme Size

Scheme Size (hectares)	Average number of formal WUA members	Average number of informal WUA members	Informal/formal
<=20	34.5	25.1	0.7
21–40	61.8	39.0	0.6
41–60	92.0	34.4	0.4
61–80	93.5	24.9	0.3
>80	150.6	103.8	0.7

Source: Authors.

Women's representation within irrigation WUA and water user committees is notably lacking: only 58 out of the 489 irrigation schemes have women committee members. Most (about 88 percent) of these schemes do not include women in leadership roles within the irrigation water users' group.

Respondents were asked to identify three benefits resulting from the presence of WUAs without ranking them. Eighty-five percent of the respondents believe that the existence of WUAs has enhanced various aspects of water management within the irrigation schemes. This underscores the significant role played by WUAs in driving improvements, particularly in sticking to watering schedules, disseminating irrigation information, and mitigating water theft.

Almost three-quarters of respondents (73 percent) highlighted punctual water delivery as the primary benefit of WUAs. Additionally, 45 percent of respondents identified increased dissemination of information regarding water delivery as the second most important outcome, while 41 percent reported fewer conflicts and water thefts (Table 14).

Table 14: Perceived Key Advantages of WUAs

Perceived Advantage	Frequency	Percent	Observations
Punctual water delivery	306	72.9	420
More info on water arrival time	190	45.2	420
Less conflicts	172	41.0	420
Less water theft	171	40.7	420
Improved maintenance	112	26.7	420
More information on crops and technologies	51	12.1	420
Improved learning from other areas in the canal through better linkages	45	10.7	420
Enhanced financial situation	27	6.4	420

Source: Authors.

In the literature, a widely held notion is that many irrigation schemes in low- and middle-income countries, including Ethiopia, rely on acreage-based irrigation scheduling instead of considering crop water requirements. However, our survey reveals a diverse range of parameters used by scheme leaders to schedule irrigation turns. Over one-half of schemes based their scheduling decision on crop type (57 percent), 48 percent on crop symptoms, 50 percent on crop growth stage, and 46 percent on topsoil moisture levels (Table 15).

Table 15: Water Scheduling Criteria in Irrigation Schemes (%)

Criteria	Percent
Crop type	56.9
Crop symptom	47.6
Cropping stage	50.2
Topsoil dryness	45.8

Source: Authors.

The survey collected information on the three primary crops cultivated within each irrigation scheme, collectively comprising 52 different crops. Three in four irrigation schemes cultivated at least 10 crops (such as onions, tomatoes, maize, potatoes, cabbage, *chat*, wheat, red and green peppers, and teff). Onions

(14.8 percent), tomatoes (10 percent), and maize (8 percent) emerge as the top three dominant crops grown in the sampled irrigation schemes in the Awash River Basin.

Many schemes lack a clear strategy for covering maintenance costs. Approximately 39 percent of schemes collect contributions from members only when the system fails, while 15 percent rely on annual water charges. Another 17 percent report no contributions for maintenance at all. More than 20 percent depend wholly or partially on resources from local and regional administrations (Table 16).

Table 16: Coverage of Maintenance Costs

Who Covers Maintenance Costs	Frequency	Percent
Users contribute at system failure	191	38.5
No one	83	16.7
Users' annual water charge	75	15.1
Region/woreda	74	14.9
Partial support from region/woreda	33	6.7
Don't know	27	5.4
Private owner/Company	13	2.6
Total	496	100

Source: Authors.

Limited coverage of maintenance is directly linked with limited water charges. Out of 496 surveyed irrigation schemes, only 16 percent reported using water charges and maintenance fees on a seasonal basis (Table 17). On average, these payments amount to 149 *ETB* and 235 *ETB* per irrigation season, equivalent to US$3 to US$5 based on December 2021 exchange rates.

Table 17: Members Are Charged for Water Use and Contribute to Maintenance

Beneficiaries	Frequency	Percent	Observations
Pay for water charges	77	15.5	496
Pay for maintenance	80	16.1	496

Source: Authors.

In 87 percent of schemes, maintenance fees are calculated based on a fixed rate contribution set for all users, while water fees in 51 percent follow a similar fixed rate approach (Table 18). Such limited commitment and contribution by users in managing irrigation water resources could potentially lead to disputes, especially since most scheme users are not actively involved in scheme maintenance.

Table 18: Basis for Calculating Water Charges and Maintenance Costs

	Water charges		Maintenance costs	
Basis for Charges	Frequency	Percent	Frequency	Percent
Only irrigated area	24	31.2	8	9.6
Crop type and area	1	1.3		
Fixed rate by all users	39	50.7	72	86.8
Volumetric	11	14.3		
Other, specify	2	2.6		
Current costs			3	3.6
Total	77	100	83	100

Source: Authors.

Conflict emerges as a key challenge in irrigation practice and management: nearly 66 percent of surveyed schemes report conflict primarily linked to water use (Table 19, Annex Figure 6). The most common cause of conflict among irrigation water users is water allocation, affecting almost 41 percent of the 201 schemes. Water theft ranks as the second most frequent reason for conflict (15 percent). Issues concerning system maintenance constitute primary sources of conflict in 6 percent of the sampled irrigation schemes. It is also worth noting that approximately 34% of the reported no conflict.

Table 19: Sources of Conflict Among Irrigation Water Users

Source of Conflict	Frequency	Percent
Water allocation	201	40.5
No conflict	168	33.9
Water theft	75	15.1
System maintenance	30	6.1
Multiple uses of water	13	2.6
Cropping mix	7	1.4
Others	2	0.4
Total	496	100

Source: Authors.

6 Environment and Health Issues within Irrigation Schemes

This section presents evidence concerning the environmental and health conditions of irrigation schemes in the Awash River Basin, using four indicators:

(i) The availability and proportion of the command area with a drainage system,

(ii) The proportion of waterlogged area in relation to equipped area,

(iii) The proportion of area affected by flood and soil erosion within the schemes, and

(iv) Incidences of malaria and bilharzia reported by irrigators.

Many irrigation schemes in the Awash River Basin suffer from inadequate drainage: approximately 78 percent of the equipped areas either lack a proper drainage system or have none. Moreover, 15 percent of the equipped area suffers from poor drainage, while only 3 percent of irrigation command areas have well-constructed drainage systems. Table 20 shows the percentage distribution of areas with and without drainage by irrigation scheme size.

Table 20: Drainage System, by Scheme Size

Scheme Size (hectares)	Has well-constructed drainage (%)	Has poor drainage (%)	Has no drainage (%)
<=20	1.9	11.1	66.1
21–40	3.1	15.2	64.0
41–60	5.1	22.3	48.2
61–80	2.3	17.5	68.2
>80	5.1	24.9	55.5
All schemes	2.9	15.2	62.6

Source: Authors.

The availability and quality of drainage systems across most irrigation organizations is notably poor (ranging from 45–81 percent). However, irrigation schemes with a nonregistered WUA present a contrasting picture: only about 25 percent lack a drainage system, while approximately 12 percent are equipped with a well-constructed drainage system; poorly constructed systems characterize around 43 percent of schemes with nonregistered WUAs (Table 21 and Annex Figure 8).

Table 21: Drainage System, by Irrigation Organization*

Scheme Size (hectares)	Has well-constructed drainage (%)	Has poor drainage (%)	Has no drainage (%)
Irrigation cooperative	3.7	14.8	45.1
Legally registered WUA	4.5	8.7	81.3
Non-registered WUA	11.7	43.0	23.2
Traditional WUA	2.0	16.0	61.1
Not organized	0.0	12.1	71.1

*The rows do not add up to 100% because the sums of areas provided for each drainage system do not add up to the total area for which the scheme has been constructed.

Source: Authors.

On average, excess rainfall leads to waterlogging on 5 percent of the equipped area within the irrigation schemes, although this issue is less pronounced in schemes below 21 hectares and those 61–80 hectares (Table 22 and Annex Figure 9). However, less than 1 percent of the equipped irrigation area has encountered waterlogging problems due to excessive irrigation water use, except for schemes of 41–60 hectares, where 2.3 percent of the irrigated area experienced this problem. These conditions are directly linked to the lack of drainage infrastructure.

Table 22: Environmental Problems Encountered, by Scheme Size (%)

Equipped Size (hectares)	Waterlogged due to excess irrigation	Waterlogged due to excess rainfall	Area damaged by flood	Area destroyed by soil erosion
<=20	0.5	2.7	1.7	1.0
21–40	0.1	6.2	1.7	1.1
41–60	2.3	5.3	0.6	0.5
61–80	0.2	4.0	0.9	0.1
>80	0.1	8.3	0.7	0.4
All	0.6	4.6	1.5	0.9

Source: Authors.

Table 23 and Annex Figure 10 illustrate that excess rainfall causes waterlogging, affecting 6 percent of the irrigation area within schemes governed by traditional water committees. Similarly, the share of irrigated area affected by waterlogging due to excess irrigation is higher in schemes administered by traditional water committees than in other water management types. Overall, respondents in 11 percent of the sampled schemes indicated that unused irrigation water flows back into the irrigation canal from farms.

Flooding and soil erosion are not widely reported as significant environmental issues in the irrigation schemes of the Awash River Basin (less than 2 percent) (Tables 22 and 23).

Table 23: Environmental Problems Encountered, by Irrigation Organization (%)

Organization	Waterlogged due to irrigation	Waterlogged due to excess rainfall	Damaged by flood	Destroyed by soil erosion
Irrigation coop	0.0	2.9	1.3	0.2
Legally registered WUA	0.3	4.7	1.1	0.7
Nonregistered WUA	0.0	4.5	0.3	0.7
Traditional committee	1.0	6.0	1.7	0.9
Not organized	0.0	1.1	1.9	1.5

Source: Authors.

The survey gathered data on issues concerning human health and irrigation within the Awash River Basin. Among the 491 irrigation schemes surveyed, respondents from only 6 percent (31 schemes) reported observing health problems related to the irrigation system. Of these, 29 reported cases of malaria, while the remaining 2 reported cases of bilharzia. The findings did not indicate significant variation in these health effects based on scheme size. Instead, human health-related problems were primarily associated with agroclimatic conditions, predominantly reported in irrigation schemes situated in the *Kola* agroecological zone.

7 Conclusions

Ethiopia's agricultural systems are subject to severe rainfall variability, impacting millions of farmers. In recent years, the government and development partners have heightened their focus and commitments toward tapping into the country's extensive irrigation potential. However, studies suggest that only 5–12 percent of this potential has been exploited thus far.

Yet in some river basins, considerable irrigation development has taken place. The Awash River Basin is by far the most used of the country's 12 river basins. As such, experiences here can provide insights as the country considers developing more irrigation in the rest of the Awash and other river basins. Scheme-level survey information is often scarce, and irrigation performance studies usually rely on information from a few nonrepresentative schemes. This study provides information on the physical, knowledge, and governance structure of irrigation in the Awash River Basin based on data collected from a representative set of 500 irrigation schemes. The paper developed here accompanies an online tool that describes the same data in graphic form: the Awash Irrigation Dashboard.

The results of the study challenge some traditionally held beliefs about irrigation performance in Ethiopia, while confirming and providing quantitative evidence for others. Crop selection for irrigation in the basin is focused on high-value crops: onions, tomatoes, and maize are the three dominant irrigated crops. On average, cultivated irrigated land is about 20 percent less than the equipped area, primarily, according to scheme managers, because of water scarcity due to upstream users' abstraction and diminished natural river flows. Only one-third of schemes provide enough water for the Belg season, when peak irrigation occurs.

Gaps between equipped and cultivated irrigated areas tend to widen as the scale of the irrigation scheme increases. At the same time, the average number of actual beneficiaries is about 9 percent greater than the number of planned beneficiaries. This could result in a scarcity of water resources which, in turn, could cause water-scheduling challenges and conflicts among users.

Less than 4 percent of irrigation scheme managers, extension agents, and leaders of WUAs know the total water withdrawal per season, the total irrigation water requirement per season, or the amount of money invested to construct or rehabilitate the scheme. This suggests the need for capacity building, coupled with investments in actual measurements of how much of water is needed and withdrawn by each scheme.

Some schemes need to be brought into legal entities: 22 percent of the modern irrigation schemes in the sample do not have the permits required by Ethiopia's Water Resource Management Proclamation No. 197/2000 for water use.

The major challenges affecting the Awash River Basin's irrigation performance identified by scheme managers do not relate directly to water, but to market challenges and access to non-irrigation inputs. Water-related challenges include water shortages, infrastructure damage, improper irrigation system layout, lack of appropriate water regulation structures, canal seepage, and waterlogging. The most frequent sources of conflict among irrigation water users in the basin are water allocation, water theft, and issues related to system maintenance. Respondents noted that many of these challenges are being addressed in systems where WUAs are functioning. In particular, irrigation schemes with nonregistered WUAs show the lowest absence of drainage systems. However, despite the requirement for registered WUAs, 15 percent of the surveyed irrigation schemes lack both traditional water committees and WUAs. Only 21 percent have organized into legally registered WUAs for scheme management. Women's participation in managing irrigation schemes in the Awash River Basin is limited: only 58 out of the 489 irrigation schemes have female committee members.

Limited collection of water charges for operation and maintenance and repairs means that these schemes are at constant risk of failure and likely contributes to several of the water infrastructure challenges cited by the expert respondents. As an example, 39 percent of schemes collect contributions from members only when the system fails, and only 15 percent rely on annual water charges. Once irrigation systems fail, irrigators are unlikely to have funds available for repairs.

Though some studies still use risks to human health such as malaria to caution against irrigation development, only 6 percent of irrigation managers reported health problems related to the schemes. These were mostly linked to the agroecology where the irrigation is located, rather than the result of irrigation development.

8 Recommendations

Our findings carry significant policy implications for the sustainability of irrigation schemes within the Awash River Basin and beyond. Implementing a comprehensive development and management strategy that integrates key aspects, including technical, socioeconomic, and environmental considerations, is imperative to address the challenges facing the schemes.

First and foremost, a participatory approach should underpin the design, implementation, and management of irrigation schemes. Engaging local communities in the associated decision-making processes can enhance efficiency, equity, and long-term sustainability. Increasing the involvement and leadership roles of women in local institutions might improve irrigation water management. This would need further study. The role of local institutions should extend beyond managing irrigation water use to include strengthened governance, decision-making, and planning functions to ensure efficient water use.

Second, enhancing the capacity of irrigation scheme operators and managers is essential, as they often lack the requisite knowledge and skills for efficient water use, fundamental to optimal scheme operations.

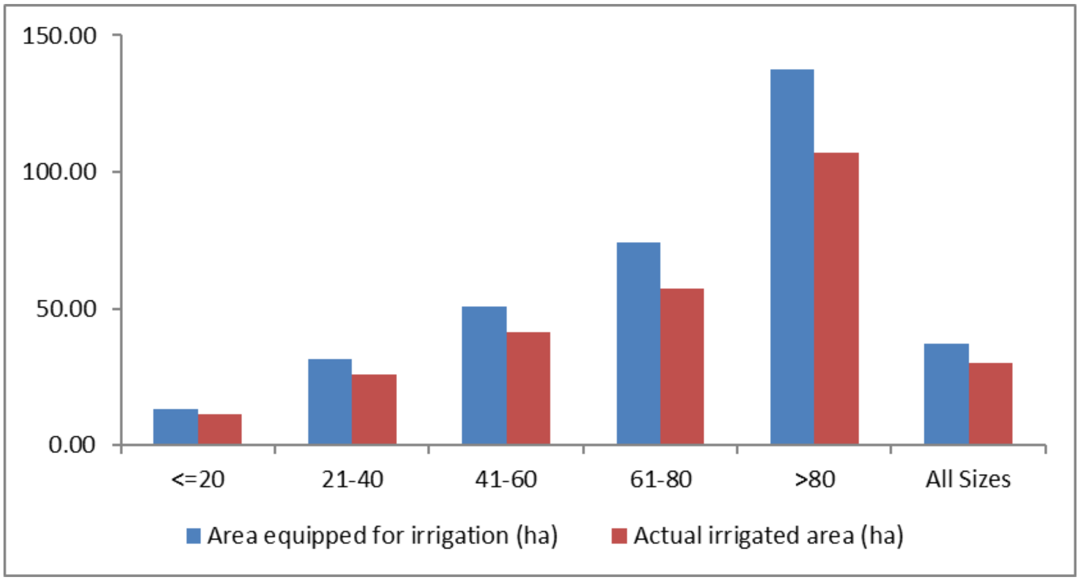
Third, an effective irrigation drainage system coupled with timely maintenance and a plan for efficient water allocation are necessary to ensure the efficient use of irrigation water and to address issues such as water scarcity, conflicts over water allocation, and theft.

Fourth, existing policies, strategies, and regulations must be effectively implemented to mitigate risks associated with irrigation water usage. Prior to commencing irrigation activities, users should obtain permits from the appropriate regulatory body; and after the scheme becomes operational, they should fulfill water and maintenance fee obligations. This would reduce the risk of scheme deterioration and failure.

Finally, addressing the challenges facing irrigation schemes requires integrated efforts and support from many stakeholders. These extend beyond irrigation to include input suppliers, particularly of fertilizer and seeds; as well as output off takers, with a particular need for effective markets. Without functioning markets, sustainable irrigation is not feasible.

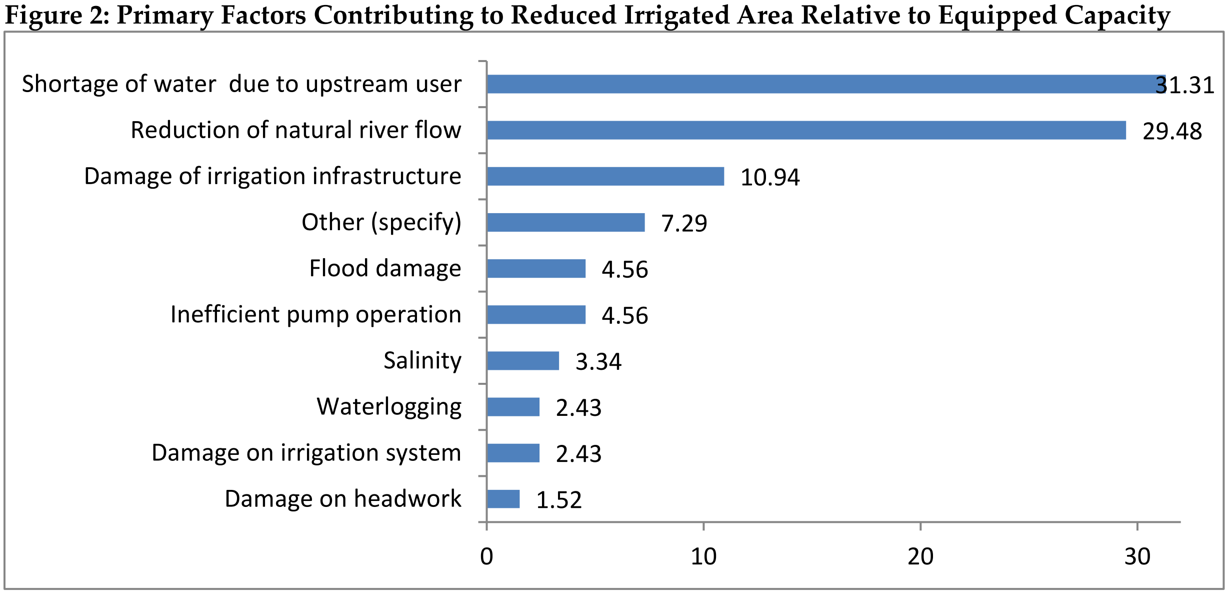
Annex

Figure 1: Average Equipped and Cultivated Irrigation Area, by Scheme Size (hectares)



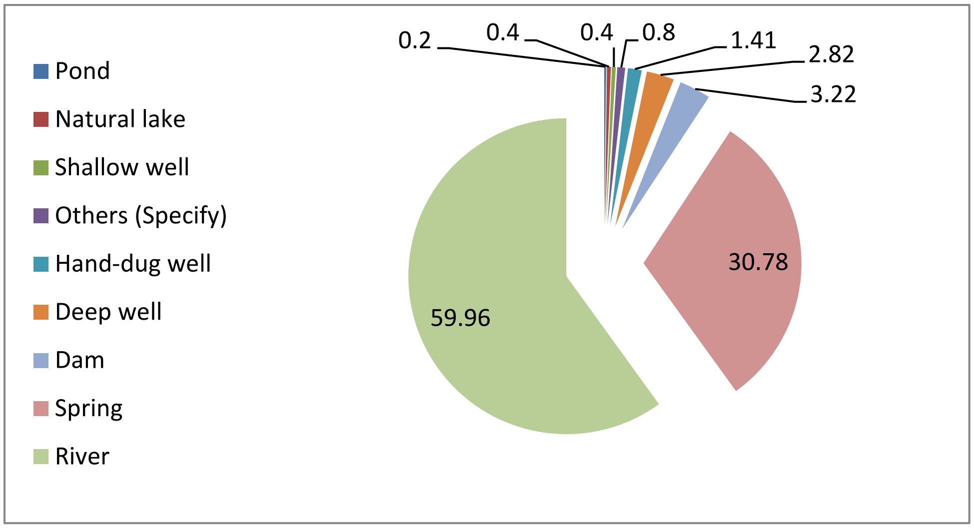
Source: Authors.

Figure 2: Primary Factors Contributing to Reduced Irrigated Area Relative to Equipped Capacity



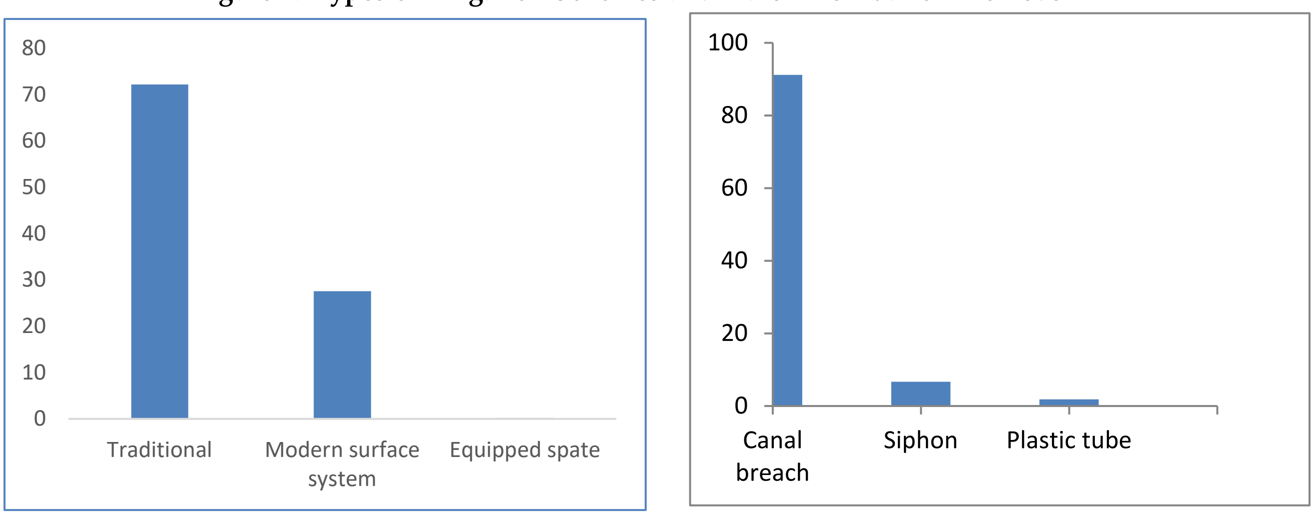
Source: Authors.

Figure 3: Primary Source of Irrigation Water



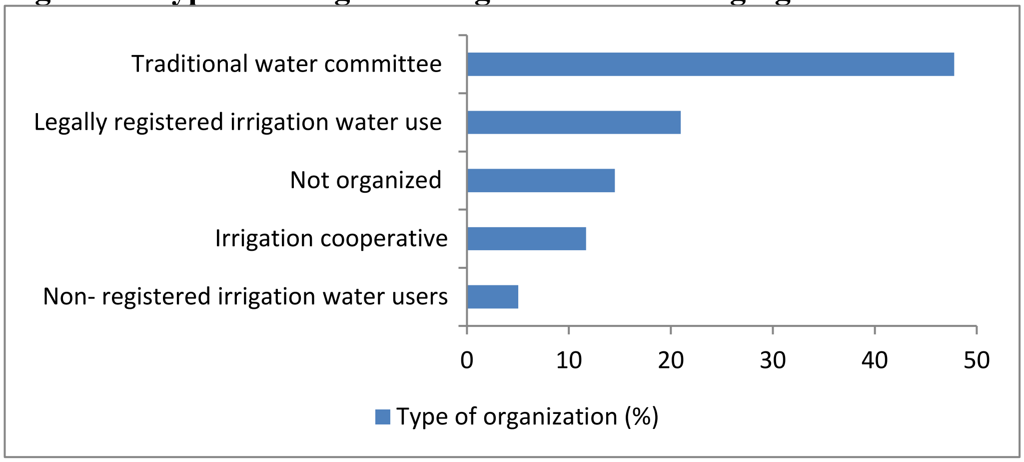
Source: Authors.

Figure 4: Types of Irrigation Schemes and Water Distribution Methods



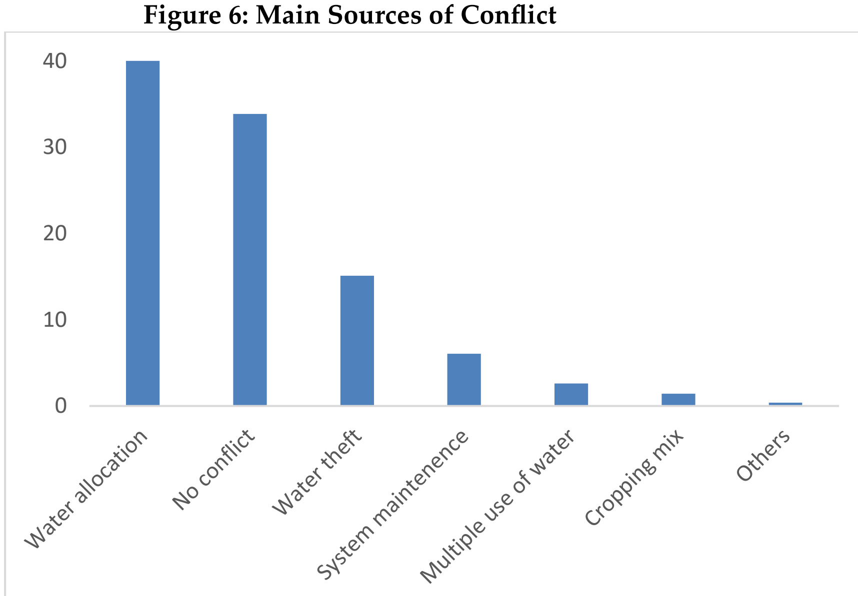
Source: Authors.

Figure 5: Types of Irrigation Organizations Managing Schemes



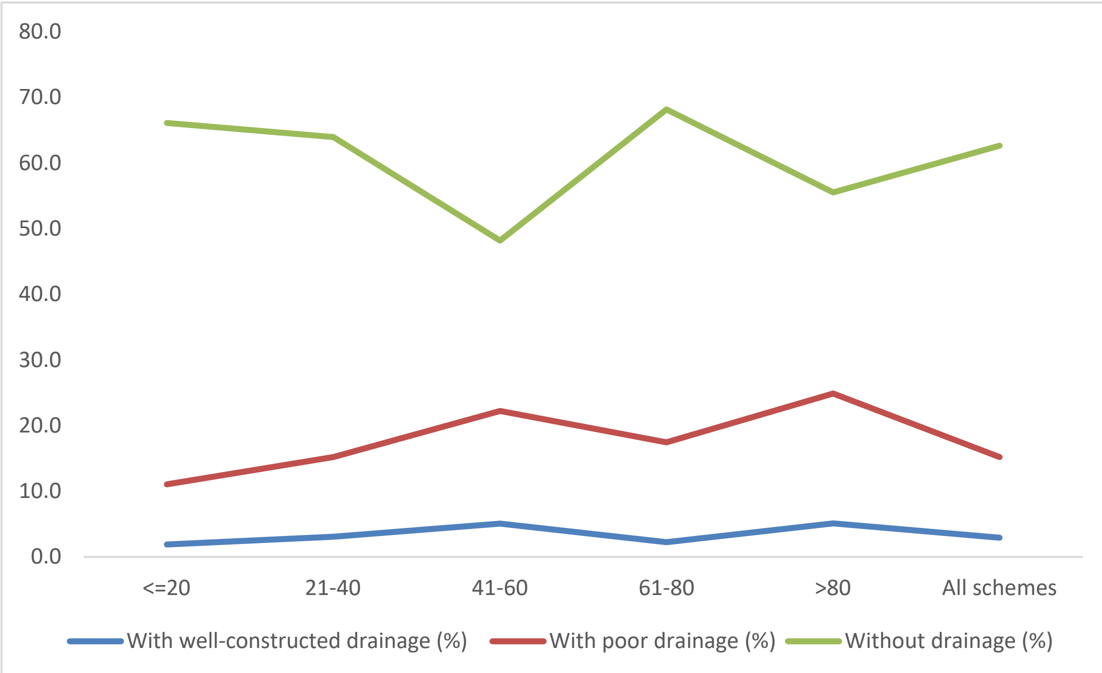
Source: Authors.

Figure 6: Main Sources of Conflict



Source: Authors.

Figure 7: Drainage System Quality, by Scheme Size

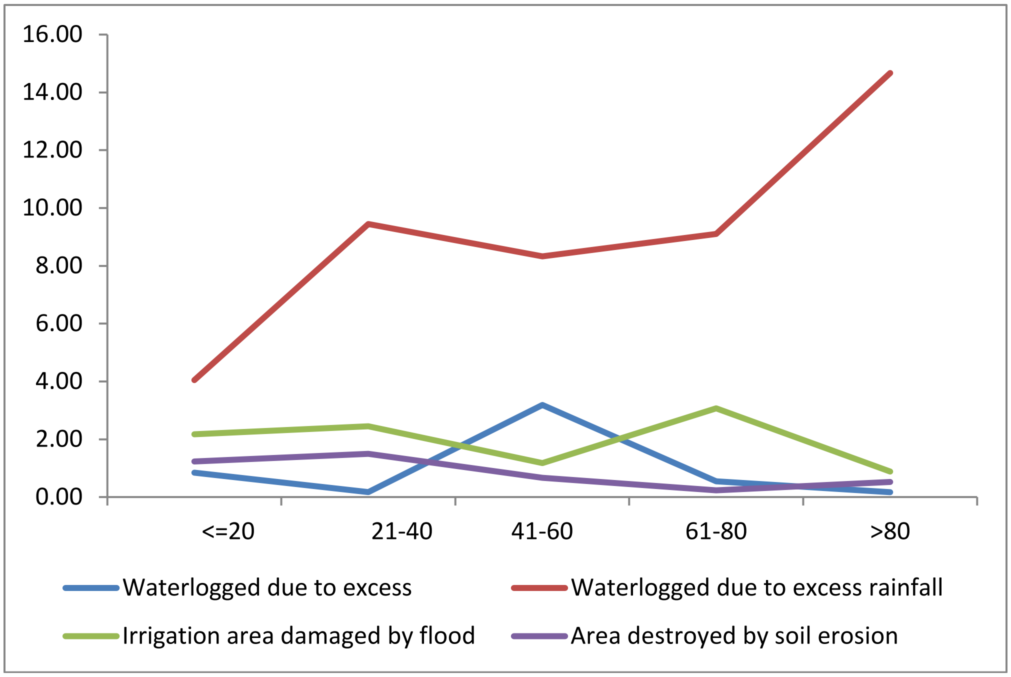


Source: Authors.

Figure 8: Drainage System Quality, by Organization Type

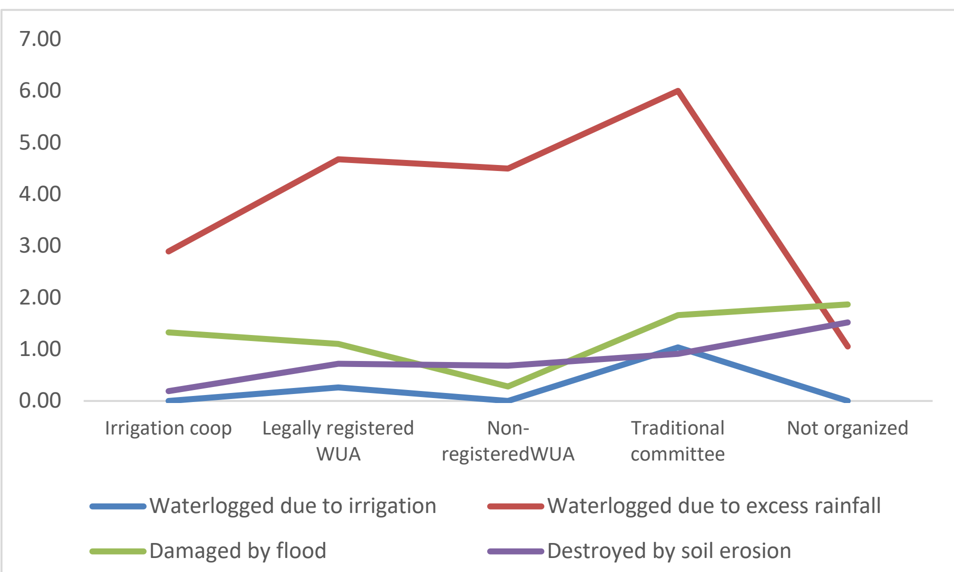
Source: Authors.

Figure 9: Environmental Problems Encountered, by Scheme Size



Source: Authors.

Figure 10: Environmental Problems Encountered, by Irrigation Organization



Source: Authors.

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