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Livestock–irrigation interaction and its influence on the sustainability of small-scale irrigation schemes in Ethiopia

Hanan Tadele Dessalegn[1] | **Alex Bolding**[2] | **Charlotte de Fraiture**[3] | **Mekonen Ayana**[4]

[1]Faculty of Hydraulic and Water Resources Engineering, Arba Minch University, Arba Minch, Ethiopia

[2]Water Resources Management Group, Wageningen University, Wageningen, The Netherlands

[3]Department of Water Science and Engineering, IHE Delft Institute for Water Education, Delft, The Netherlands

[4]Department of Water Resources Engineering, Adama Science and Technology University, Adama, Ethiopia

Correspondence
Hanan Tadele Dessalegn, Faculty of Hydraulic and Water Resources Engineering, Arba Minch University, Arba Minch, Ethiopia.
Email: hanantad@yahoo.com

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Abstract

Small-scale irrigation (SSI) plays a large role in rural livelihoods and the economy in Ethiopia. Despite considerable investment, overall SSI performance is disappointingly poor. The sedimentation of canals and intakes leads to low performance and the abandonment of systems. Livestock roaming in the command area and around riverbanks are an important contributor to sedimentation. Commonly proposed solutions, including technocratic fixes, institutional arrangements between irrigators and livestock farmers, and collective action by irrigators, have not yielded satisfactory results. Based on three case studies from Ethiopia, we illustrate why existing solutions are not effective and why collective action is not straightforward. Using in-depth interviews and focus-group discussions, we examine the complex intertwined relationships between irrigators, livestock farmers and local government. Without understanding the interrelationship and accounting for the links between irrigation and livestock in the design and governance structures of SSI, the proposed technical and organizational fixes are unlikely to be successful. Addressing conflicting interests and building consensus and trust among irrigators and livestock farmers are prerequisites for solving the performance concerns of many Ethiopian SSIs.

KEYWORDS

Ethiopia, grazing management, livestock, sedimentation, small-scale irrigation, water users' association

Résumé

L'irrigation à petite échelle joue un rôle important dans les moyens de subsistance ruraux et l'économie en Ethiopie. Malgré des investissements considérables, la performance globale des irrigations à petite échelle est décevante. La sédimentation des canaux et des prises d'eau conduit à une faible performance

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et à l'abandon des systèmes. Le pâturage des animaux dans la zone de commandement et autour des berges est un facteur important de la sédimentation. Les solutions communément proposées, y compris des solutions technocratiques, les arrangements institutionnels entre irrigants et éleveurs, et l'action collective des irrigants, n'ont pas abouti à des résultats satisfaisants. Sur la base de trois études de cas menées en Éthiopie, nous illustrons pourquoi les solutions existantes ne sont pas efficaces et pourquoi l'action collective n'est pas simple. Au moyen d'entretiens approfondis et des groupes de discussion, nous examinons les relations complexes et imbriquées entre les irrigants, les éleveurs et les autorités locales. Sans comprendre les liens entre l'irrigation et l'élevage dans la conception et les structures de gouvernance de l'irrigation à petite échelle, il est peu probable que les solutions techniques et organisationnelles proposées aboutissent. Prendre en compte les intérêts contradictoires, établir un consensus et instaurer une confiance entre irrigants et éleveurs sont des conditions préalables pour résoudre les problèmes de performance de plusieurs projets d'irrigation à petite échelle en Ethiopie.

MOTS CLÉS

élevage, petite irrigation, sédimentation, association des utilisateurs de l'eau, gestion des pâturages, Ethiopie

1 | INTRODUCTION

Small-scale irrigation (SSI) is of utmost importance for the rural economy and farmers' livelihoods in Ethiopia. Therefore, the government is investing considerably in the expansion of irrigation. However, small- and medium-scale irrigation schemes in Ethiopia are underperforming compared to their designed capacity, and some of them are dysfunctional (Awulachew & Ayana, 2011). The causes of underperformance and abandonment of the schemes are diverse and complex. One of the major constraints is excessive sedimentation in the headworks and canal network and a lack of funds and labour for operation and maintenance (Awulachew & Ayana, 2011; Gebul, 2021).

Sedimentation is a major challenge, as it draws on considerable labour for maintenance before the start of, and during, the irrigation season. There are three frequently cited causes of sedimentation, each pointing at different solution pathways. The first blames upstream overpopulation and erosion and consequently argues for more catchment protection programmes (Wolancho, 2012). A second reason blames faulty design and lack of institutional capacity by users at the SSI scheme level and identifies technical solutions and institutional fixes to organize users in irrigation schemes (Gurmu et al., 2019). A third reason focuses on the often overlooked cause of sedimentation *during* the irrigation season, namely, livestock–irrigation interactions (Dessalegn et al., 2021). Neglecting the irrigation–livestock interaction often renders other measures to reduce sediment ineffective.

In this paper, we aim to unravel the livestock–irrigation conundrum. Using the example of three SSI systems in Ethiopia, we explore why the commonly proposed solutions are ineffective by disentangling the complex interactions between irrigators, livestock farmers (LFs) and local government. These interactions explain why proposed technical approaches are ineffective but also why collective action is not straightforward.

To do so, we first review the literature on irrigation–livestock interactions before describing the case study area and study method. Next, we describe and analyse irrigation–livestock interactions in the study schemes by looking into the extent of sedimentation caused by livestock; various forms of collective action controlling livestock movements inside the irrigation perimeter, along its margins and on grazing land; various owner groups of livestock and their motives for interaction with the scheme; and finally, the difficulties of devising effective strategies for institutional control over livestock interactions. In the concluding section, we present the major causes and challenges associated with sedimentation caused by livestock–irrigation interactions and present various options to moderate the negative effects of such interactions in the short and long run.

2 | IRRIGATION–LIVESTOCK INTERACTIONS

2.1 | Irrigation is associated with higher livestock densities

Widgren and Sutton (2004), in their book on islands of intensification in Africa, establish a close link between places in Tanzania and Kenya where irrigated production emerged and the routes of trading caravans from the Indian Ocean to the hinterland. This link is not coincidental but based on a mutually beneficial relationship between irrigating agriculturists and nomadic traders (and pastoralists): pack animals (camels, oxen) needed watering and stockfeed, whereas irrigating agriculturalists were interested in manure and draught power. Irrigation facilities provide access to water and fodder even during dry seasons and hence attract livestock.

In Africa, the highest animal densities are found in irrigation settings (Peden et al., 2006). Cattle provide draught power for farming and transport (McMichael et al., 2007) and manure, which produces benefits for both farms (fertilizer) and households (fuel and building material). Furthermore, livestock offers a vehicle for wealth accumulation and a buffer against income fluctuations.

The beneficial uses of livestock explain why irrigation is associated with high livestock densities. However, higher livestock densities around irrigation also create pressures and problematic effects.

2.2 | Problems of livestock–irrigation interactions

The problems caused by livestock in an irrigation setting relate to their needs: grazing and water, which often involve movement from the homestead kraal to the place of feeding/watering. Grazing, drinking and regularly moving about produce negative effects, such as sedimentation from erosive, overgrazed pastureland; destruction and sedimentation of irrigation infrastructure; and crop damage. The incisional and erosive forces of cattle hooves, coupled with overgrazing, can reduce stream bank stability and increase suspended sediment and turbidity, which contribute to in-stream deposited sediment. The trampling effect of cattle is prominent around watering points, where land degradation can be extreme (Brits et al., 2002). Continuous and unrestricted grazing on a riparian margin leads to greater bank erosion, and the laying bare of soils can lead to stream bank deterioration, irrigation infrastructure damage and sedimentation.

2.3 | Commonly proposed solutions to minimize livestock irrigation problems

Sedimentation problems due to livestock–irrigation interactions are not new. Already in the colonial period, the problem of roaming livestock in the newly developed irrigation systems in Rhodesia was recognized (Roder, 1965). Solutions were sought in state regulation and top-down measures, such as grazing bans around canal banks and fields, enforced by fencing, and reducing the cattle density according to carrying capacity (Roder, 1965). Realizing that the destocking and culling of livestock would lead to strong resistance among the local population, other proposed approaches comprised a system of rotational grazing and cultivating feed crops such as alfalfa or elephant grass in part of the irrigated area (Roder, 1965).

These technocratic measures are still commonly proposed and implemented. Restricting livestock access to watercourses by providing cattle troughs and alternative water sources is an effective way to minimize cattle movement (Wolancho, 2012) and reduce intrusion of suspended sediment in the water body and the associated effects on water quality (Madden et al., 2019). Nevertheless, Line et al. (2000) found that the provision of alternative drinking sources alone was ineffective. Cattle exclusion from the grazing area and watercourse through fencing proved effective in reducing bank erosion and suspended sediment in the United Kingdom (Collins et al., 2010) and the USA (Carline & Walsh, 2007). However, fencing may be too costly in large irrigated areas in developing countries (Pekor et al., 2019).

Zero grazing with cut-and-carry grasses helps to exclude livestock and can significantly relieve pressure on grazing land (Meul et al., 2012). However, the presence of communal grazing areas discourages zero grazing, as farmers resort to free-riding strategies (Gebreyohannes & Hailemariam, 2011). Most farmers reject zero grazing on the assumption that they have large grazing lands and can benefit more by having many herds. Others associate zero grazing with confiscation of land. Growing feed crops such as alfalfa or elephant grass on irrigated areas, as proposed by Roder (1965), likely displaces other crops and hence decreases farmers' income.

Recognizing the shortcomings of technical top-down measures and the importance of social interaction in managing sediment and maintaining irrigation infrastructure, another set of solutions emphasizes formal and informal institutions (Beyene, 2009) and collective action (Chun, 2014). Collective action is considered the most promising solution for the sustainable management of common property resources (Gebremedhin et al., 2004; Ostrom, 1990). However, effective collective action

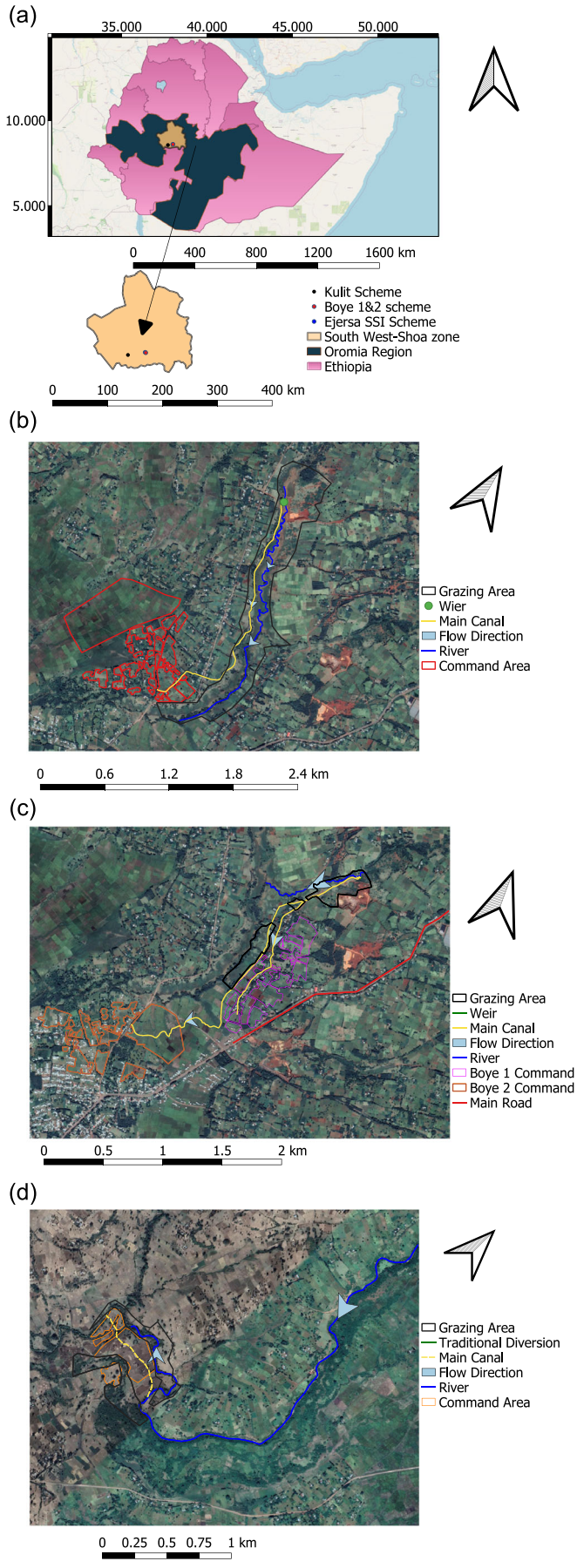

FIGURE 1 (A) Location of the study area with the three case-study irrigation schemes, (B) Ejersa irrigation scheme and part of grazing land, (C) Boye 1&2 irrigation scheme and part of grazing land, (D) Kulit traditional irrigation scheme and part of grazing land.

between LFs and irrigators is virtually non-existent in Ethiopia, and common sediment management strategies in SSI schemes are ineffective. Our case studies illustrate the underlying reasons.

3 | DESCRIPTION OF THE STUDY AREAS

3.1 | Selection of case study schemes

This study was conducted in the South-West Shoa zone of Oromia, Waliso and Ameya districts (Figure 1A). Three SSI schemes were identified according to their accessibility and degree of sedimentation varying from light to heavy sediment loads (Table 1). Ejersa is an upgraded and heavily sedimented scheme serving 120 users from two *kebeles*, the lowest administrative unit in Ethiopia (Figure 1B). Boye 1&2 are a merged and upgraded scheme that represents a lightly sedimented case. It comprises two parts: Boye 1, providing water to 56 households, and Boye 2, with 65 households, irrigating a total command area of 56 ha (Figure 1C).

The Kulit case represents a new scheme that was started by farmers in response to the abandonment of Meri-Megari SSI because of sedimentation. The traditional weir of the Kulit scheme was constructed 5.3 km downstream from the Meri-Megari abandoned weir. Located 151 km from Addis Ababa at an average elevation of 1834 m above mean sea level, it comprises 17 ha and 29 households (Figure 1D).

4 | MATERIALS AND METHODS

As a general methodological approach, we used a 'follow the water' principle to identify the water users and their networks, to map all relevant irrigation infrastructure, grazing areas and institutions and to track the livestock owners and reconstruct their interactions with irrigators. Participants for a qualitative interview were selected using a purposive and snowball sampling technique to identify the key informants from the head, middle and tail-end user representatives. We gathered data during two periods: from June to October 2018 and from September 2019 to February 2020. Open-ended and semi-

TABLE 1 Background information on selected small-scale irrigation schemes.

S. no.	Irrigation schemes	Type of scheme	Year of first operation	Command area hectare (ha)	No. of households	State of the scheme	Average livestock holding per household
1	Boye 1&2 merged scheme	Upgraded	2013	56	121	Lightly sedimented	8.25
2	Ejersa scheme	Upgraded	2013	96	120	Heavily sedimented	11.93
3	Kulit scheme	Traditional	2019	17	29	Lightly sedimented	10

structured in-depth interviews were conducted with older farmers, the water users' association (WUA) committee members, irrigators, LFs, engineers and relevant government officials. The number of interviewees was expanded until the collected information reached a level where no new insights were added beyond those that had already been expressed. Field observations provided first-hand information on the schemes' operation and maintenance practices and the interaction with livestock and LFs. We gathered secondary data from the district and a regional office that had a stake in the respective schemes, and we conducted 9 focus group discussions on the topic with 6–8 participants in each session.

We interviewed 63 persons in total. Among the users of the 3 schemes, we interviewed 15 female and 36 male farmers spread across the head, tail and middle reaches, with some of them acting as WUA committee members. Additionally, 12 officials were interviewed: five irrigation development agents (DAs), one former DA from Waliso District, two active DAs from Waliso District and two DAs from Ameya District. Of the four government officials interviewed, one worked for the Oromia Irrigation Development Agency Addis Ababa, one from Waliso District, one from the Ameya District office and one from the south-west Shoa Province. A further three engineers were interviewed: one from the Oromia Irrigation Development Agency Addis Ababa and two from south-western Shoa Province. The age of the respondents ranged between 14 and 79 years. Interviews were translated and transcribed. Qualitative data analysis was conducted after repeatedly reading each transcription line by line. Field notes and observations contributed to triangulating the findings and interpreting the results (Dessalegn et al., 2021).

5 | RESULTS AND DISCUSSION

The problems of livestock–irrigation interaction in the case study irrigation schemes are driven by the conflicting needs of irrigators and livestock owners: livestock need grazing and drinking water, and this often involves movement from the homestead kraal to the place of feeding/watering. The destruction of irrigation infrastructure is manifested by the main canal of Ejersa SSI, which is broken and leaking in many places. The frequency of interactions is high because irrigation farming, livestock grazing and drinking represent daily activities practised year-round in all study area schemes. Moreover, because of livestock's gregarious, restless behaviour and their free grazing habits, part of the grazing area in the Ejersa and Boye 1&2 study sites was overgrazed despite the livestock farmers' associations' (LFAs) efforts to impose grazing management. Compounding the problem is the fact that livestock have unrestricted access to irrigation systems, and cattle need to cross irrigation canals to reach grazing and watering areas along the river (Figure 1a,b).

5.1 | The irrigation–livestock conundrum: different stakeholders, different perspectives

Because of sedimentation and damage to infrastructure, the interaction between irrigators and livestock owners leads to conflict. The presence of different stakeholders who have partly overlapping interests and who are dependent on functional irrigation systems makes the situation more complex. We categorized the relevant stakeholders into four (partly overlapping) subgroups: irrigators, LFs, trespassers and local government. These will be treated in more detail in the sections below.

5.1.1 | Livestock farmers' perspective

LFs in Ejersa and Boye claim that irrigation schemes are in the middle of their grazing areas (Figure 1b,c), whereby land now included in the irrigated command

area used to be grazing area. During the upgrading of the Ejersa and Boye schemes, responsible government officials agreed with LFs regarding measures to facilitate the safe use of irrigation water for livestock. The regional office agreed to construct cattle troughs in the canal and a bridge to facilitate safe livestock movement in exchange for the LFs' consent for irrigation system construction on their land. The agreed measures implicitly indicate that livestock was expected to drink from the canal. However, at none of the schemes were the promised cattle troughs or watering points constructed. In response, LFs felt cheated and even tried to sabotage the construction of the irrigation scheme to no avail.

The broken promises and the denial of formal access to irrigation water led to the absence of feelings of ownership among LFs, a lack of cooperation for irrigation maintenance and an unwillingness to consider measures to reduce the negative effects of livestock roaming. For example, to facilitate livestock drinking, a common practice among LFs is to put local materials in the canal to block the flow and raise the water level. The herders who construct the blockage never remove the material once the cattle have had its fill, thus disturbing irrigation water supply and, inadvertently, creating local hubs for sediment to accumulate.

Livestock owners who have both irrigation and grazing land in the same system act as silent observers. They neither discuss the problem caused by their livestock nor the infrastructure damaged by the livestock. In the focus group discussion in the Ejersa and Boye schemes, they stated they were afraid to be taken to task either by irrigators who do not own livestock or LFs who do not use the irrigation scheme. Even though they benefit from both resources, grazing land and irrigation systems, they feel trapped in-between. Hence, they prefer to remain silent and contribute to canal maintenance as irrigators and participate in activities of the livestock association.

5.1.2 | Irrigators' interests

Until the schemes were modernized/upgraded by the government, irrigators and LFs in the Boye and Ejersa schemes managed to come to mutually agreed arrangements. The original users in traditional schemes had formed *abba melka's* (committee of elders). The latter maintained a user's list based on either the farmer's labour contribution during the development of the original scheme or a monetary joining fee for compensating users' efforts to keep the scheme functional. This contribution formed the basis for acquiring water use rights (Bolding et al., 2010).

Once the irrigation infrastructure in Ejersa and Boye 1&2 had been upgraded by the government, the schemes were transferred to the irrigators to use it as a common pool resource (CPR) and share the burden of operation and maintenance. To become acknowledged as an official irrigation scheme, the district office instituted a new structure of WUA (or *Korrei*) headed by seven executive committee members. The WUA and the listed members were formally recognized by the district office as the rightful irrigation users. In the Ejersa scheme, soon after completion of the modernization works, new members were registered as water users based on their inclusion in the newly extended command area. In the Boye 1&2 merged scheme, no new members were added due to the limited water supply. By organizing WUAs, it was hoped that irrigators would perceive the irrigation schemes as their own and take responsibility to maintain and sustain them by regularly removing accumulated sediments and repairing damaged canal banks. In both schemes, the irrigators are deemed the only water user with the formal right to use the irrigation system, and LFs are blamed for regular livestock intrusion in the irrigation system.

In 2018, the Ejersa WUA attempted to communicate with the LFs to reduce livestock–irrigation interactions with the help of elders from neighbouring villages. However, the LFs without land in the irrigation system could not see the benefit of limiting cattle movement. In contrast, they claimed the irrigation canal was constructed through their grazing area and blamed the lack of promised cattle troughs to be beyond their remit. Taking their livestock elsewhere to water would involve more work at zero benefit.

5.1.3 | Trespassers

Trespassers are another group of stakeholders who do not have formal water use rights. There are two ways in which trespassers can nevertheless make use of modernized irrigation schemes. One way is through the arrangement made by the WUA in Ejersa; if a farmer has land in different locations in the watercourse within the same command area, they can choose for which of their plots they can use irrigation each year, but they can only irrigate one plot. However, they need to inform the WUA before irrigation scheduling is performed. This is the reason that opens the door for trespassers to use the irrigation scheme for grazing. Some farmers use this opportunity to steal water even though they are registered members, and they will be fined when caught. However, the fine is small relative to the benefit.

The second way in which trespassers can make use of irrigation relates to the way LFs acquire the right to

grazing land. An informal rule allows the LFs to inherit the user right to a specified section of grazing land and pass this on to the next generation. In the Ejersa and Boye schemes, the LFs who inherited the right and may not live or irrigate in that specific area can still use grazing land. They move their livestock to the grazing land and move them back home at night. This is how LFs who irrigate in several or different irrigation schemes and LFs who use rain-fed agriculture maintain access to grazing land. LFs who have the right can have as much livestock as they can afford and graze them with no specific limitation imposed on them.

5.1.4 | District office

In the case study area, the district office pays far more attention to irrigation development than livestock production, as testified by recent efforts to upgrade the Ejersa and Boye 1&2 irrigation schemes and recognize the irrigators as their rightful users. The district office maintains regular communication with irrigators. The irrigators and WUA executive committee interact once or twice monthly. During their meetings, they discuss the status of the scheme, the problems they encountered, and they identify or develop viable solutions and address any other issues that are raised. The irrigators and the district office interact with each other through the WUA committee. The latter works as a communication platform for the district office, presenting issues and questions raised by the irrigators to the responsible government agencies, although in practice their questions are rarely answered by government agencies.

5.2 | Institutional structures governing land and water resources

There are three common resources relevant to livestock–irrigation interactions: irrigation schemes, grazing land, and rivers and riverbeds. For all three, separate collective governance arrangements apply.

The WUA is responsible for the operation and maintenance activities of the irrigation schemes in the study area. Their biggest challenge is organizing maintenance, particularly removing deposited sediments from the canal. Different parties abstract water from the irrigation canal: irrigators, livestock, LFs and trespassers. However, the WUA rules and regulations do not apply to all these uses and users. The WUA lacks the power to enforce measures to regulate livestock movement and prevent damage caused by them. They cannot exclude non-irrigators from accessing canal water. Even for LFs who are also irrigation members, the WUA cannot prevent or punish actions that lead to infrastructure decay.

Similarly, the LFAs manage the grazing lands in Ejersa and Boye SSIs. The LFA aims to manage grazing land, increase stockfeed growth and safeguard livestock against any danger (injury and death of livestock being stuck in the canal while drinking). The LFA groups the livestock in various paddocks of the grazing area and rotates the livestock herd over different sections. However, livestock are unpredictable and often too restless to stay in the designated areas. The habit of free grazing and the absence of fences results in ineffective grazing management practices. Furthermore, unrestricted access has resulted in the overexploitation of grazing land (Gebremedhin et al., 2004).

The management of livestock grazing in riverbeds does not fall under the LFA or WUA mandate. The riverbed is not managed by any formal or informal institution, except in the case of Ejersa SSI. Along the Ejersa River, there are 21 traditional and modern SSI schemes that make use of its waters, with Ejersa SSI being the fifth scheme counted from the upstream end of the river. These 21 schemes have formed a general committee that has the responsibility for ensuring a fair water distribution of the river water. Even though these committees have the responsibility of managing river water, their focus has always been on inter-scheme water allocations. They have thus far not been capable of controlling the tres-passers, nor have they expressed an interest in doing so.

The three resources (irrigation system, grazing area and the river) are governed by separate user-based institutions that hardly overlap in terms of institutional membership. None of these institutions engages with irrigation–river–livestock interactions, thus allowing boundary zones where livestock can freely roam. The burden of damage caused by livestock squarely falls on the irrigators. The position of LFs is similar to that of free-riders: they use a resource (water) without having to sustain it. As Ostrom (2010) argued, different user groups are a serious deterrent to successful collective governance. In addition, the absence of co-ownership for LFs inhibits collective management.

Problems occur at the physical and institutional boundaries of the grazing area and irrigation system. Since both the WUA and the LFA lack institutional coverage to sanction or penalize the uncontrolled behaviour of livestock, the users of both institutions look to the responsible government office to step up and solve the problems (joint focus group discussion [FGD] December 2019).

5.2.1 | The role of the (local) government

The district office is aware of the problem. However, its officials claim they cannot solve the issue of free-riding livestock because there is no assigned body at the district level that deals with boundary-crossing problems, even though both the WUAs and LFAs are linked to the district irrigation development office, thus making it indirectly responsible. The district office has thus far not fulfilled its responsibilities, believing that users who are part of the same community are better situated to resolve this issue. Facing staffing and budget constraints, district officials argue that they can only address problems when they acquire a specific budget and institutional mandate (District officer interview, December 2019).

The governance of SSIs at the district level has been subject to fragmentation, the prevalence of top-down approaches and frequent changes in both policy and placement within different ministries. As a result, there is a lack of coordination and a low level of participation and consultation (Yami, 2016). In addition, reforms have mainly focused on the redesigning of policy documents and restructuring of authorities and not on how to reform the internal organizational/institutional contexts to fit with the plan or vice versa.

Resource users feel that some of the institutions govern each resource but dealing with resource access cutting across these various institutions is proving difficult. Even with dual members, who had a stake in two resources at the same time, it was challenging to initiate the conversation towards a negotiation. Moreover, the WUA's requests to the district office to help resolve the issues fell on deaf ears (FGD, Waliso, December 2019).

5.3 | The livestock–irrigation conundrum—the missing link in the sedimentation debate

One of the biggest challenges affecting the performance of SSI schemes is linked to canal damage, sedimentation and the corresponding maintenance burden caused by different livestock-owning farmers. Some of these farmers are members of the affected irrigation scheme itself. What keeps the different actors from coming up with an effective response to livestock-related challenges?

5.3.1 | Top-down planning

Informants in the study schemes blame the ineffective response to the livestock–irrigation conundrum on the prevailing top-down approach to irrigation development. The planning and implementation of SSI projects do not address the concerns of the local community through their active involvement. For instance, issues related to the suitability of the design for cleaning and maintenance and the trajectory of irrigation canals might cause conflicts within the community. Specifically, this may concern the construction of cattle troughs along with the irrigation canal network or passages where the livestock can safely cross without pushing sediment into the canal. Furthermore, even in livestock-dense areas, water demand calculations for scheme design and management do not consider livestock water demand. All these concerns have not been addressed in the design of the Boye 1&2 and Ejersa irrigation systems. The infrastructural design was made only from the irrigation perspective, ignoring the interaction with livestock. Even after commissioning the newly rehabilitated (upgraded) irrigation schemes, these concerns, while expressed, were not addressed, reflecting a design culture that ignores the concerns of the actual users and owners of the irrigation schemes once the project's construction has been finalized.

Most importantly, the top-down style and sectoral approach of planning and implementing SSIs by various responsible government agencies hinder addressing intersectoral needs and undermine a sense of co-ownership and co-responsibility among users, thus precluding the development of solution pathways that could address the negative effects of livestock movement and watering. This finding is confirmed by the literature, which articulates a lack of pluralistic approaches (Habtu & Yoshinobu, 2006) and lack of integration of users' knowledge and concerns in SSI design (Yami, 2016).

5.3.2 | Rigid designs ignore users' needs and concerns

Even when users explicitly protest about certain upgrades, their needs are rebuffed, as transpires from a key informant's description of the planning and construction of the case study schemes:

> The regional government prepares the plan, provides a framework, and consults the relevant district experts when inputs are needed. Plans are prepared in a top-down manner, and the space given to the district and *Kebele* officials is that of informants to be consulted. In Ejersa and Boye 1 and 2 SSIs, the *Kebele* office was contacted only to inform irrigators about the project. When the irrigators and

> livestock farmers refused the modernization of their irrigation schemes (particularly irrigators of the Boye-1 scheme and livestock farmers of Ejersa), the *Kebele* office was contacted again to negotiate between the irrigators, livestock farmers, and regional government office for their plan to proceed. Ultimately, the regional office promised to build additional components, such as cattle troughs and a bridge, which had not been included in the original design. However, at the end of the day, these were not constructed
>
> (Former *dembeli-keta kebele* Chairperson interview, Waliso, November 2019).

This lack of downward accountability on SSI project planning is compounded by the limited efforts in comprehensive capacity building of project staff and the tendency to recruit underequipped construction companies to implement rigid designs, as transpires from the interview cited below:

> The weak capacity of the study teams and engineers who design and construct the schemes, which results in poorly designed irrigation infrastructure, are challenges of all studied irrigation schemes. The challenge becomes prominent because of the frequent restructuring of the irrigation sector, the confusion on duties and responsibilities of district office staff, understaffing of the district offices relative to the irrigation schemes they should monitor, and missing irrigation system documentation. SSI project documents often state the necessity of capacity building among district staff. Nevertheless, the higher officials do not facilitate the district/*Kebele* staff to undergo training on technical and managerial issues of SSI projects. They do not even consider it their responsibility. Most times, all the project money was used for project implementation without capacity building. Hence, the staff starts implementation without understanding the plans
>
> (Development agent interview, Waliso, October 2019).

5.3.3 | Institutional limitations

In addition to these weaknesses in the design and construction of modernized SSIs, the relationship between the various government agencies, such as the DA, district and *Kebele* officers, and the WUA is highly political. The pursuit of political agendas using the platform of the WUA reduces farmers' motivation to take part in problem-solving discussions and contribute to their resolution. The meetings held on the government's political and development agenda are often long, and farmers who participate in meetings have limited time for raising SSI problems. As a result, farmers are less interested in the meetings. Most no longer show up for them.

Finally, the issuing of standard by-laws for WUAs of modernized SSIs to administer, without user consultation, directly violates several of Ostrom's design principles for successful collective governance of CPRs.

Elinor Ostrom's design principles for CPR management are a set of guidelines that promote sustainable and effective governance of shared resources. They emphasize local participation, collective decision-making and adaptive management. The principles include clear boundaries, collective choice arrangements, proportional benefits, monitoring, graduated sanctions, conflict resolution mechanisms, local autonomy and nested levels of organization. These principles help communities avoid overexploitation and ensure the long-term viability of CPRs.

The Ejersa WUA chairperson claimed that the absence of formal or informal institutions that can be enforced on all stakeholders makes it difficult to control the non-rights-holding users of the scheme, and the irrigators (WUA) committee cannot take any action against the free riders, as they have neither authority over them nor enforceable rules (WUA chairperson interview, November 2019). This confirms (Baggio et al., 2016) findings that all commons are likely to be non-successful when cognitive principles, accountability of monitors and graduated sanctions are absent. Including LFs as a separate subcommittee, with specifically drafted by-laws addressing the right to move across canal infrastructure and watering livestock from canals, would go a long way to make sure that cross-cutting livestock and irrigation uses are addressed. The latter would address the boundary problem that is caused by each resource having its own property arrangement and collective monitoring institution, leaving overlapping resource use at the discretion of a non-responsive district office.

5.4 | Successful irrigation–livestock interaction in traditional schemes

The example of the Kulit traditional irrigation scheme, albeit at a much smaller scale, provides a refreshing contrast, where irrigators and LFs have drafted mutually

agreed resource-sharing arrangements that reduce the damage created by livestock (though they have not constructed cattle troughs or bridges to facilitate this). This traditional scheme, which is not recognized by the government, was established by farmers from a modern SSI that was abandoned due to sedimentation and maintenance problems. There are no formal rules that state who may use Kulit SSI. It is used informally by those users who displayed an interest in continuing irrigation and proved willing to contribute labour to constructing the diversion structure and being involved in the operation and maintenance of the newly established Kulit scheme. The users have formed a group and are open to registering new members, especially to reduce the maintenance burden (FGD: Kulit traditional scheme, Ameya, January 2020).

Most irrigators own livestock that graze near the scheme. They are neighbours and share membership in one or more social groups, such as *Idir* (burial gathering), *Mahber* (religious associations) and *Équib* (rotational saving) clubs. As a result, unlike the users of the other schemes, they do not see themselves separately as LFs and irrigators. The livestock that grazes around Kulit can use the scheme for drinking (interview: *Kulit* traditional scheme WUA committee, Ameya, January 2020). In this scheme, we can observe that the small number of users and an adequate water supply are key in bringing users together in a closely knit community, avoiding conflicts between irrigators and LFs.

This result may be explained by the fact that most irrigators and livestock owners are the same people who established and use the same scheme. Having a smaller user community with adequate water resources could also be the other key reason for bringing users together in a close-knit community, avoiding conflicts between irrigators and LFs. Another possible explanation for this is that the rest of the abandoned scheme (Meri-Megari) is underutilized. It offers a grazing area for their livestock, lacking the degree of overstocking and suffering that affects the other schemes. Furthermore, there is no intervention by the government that disturbs their mutually agreed arrangement, thus allowing them to avoid the conflict and negative effects of livestock interaction.

6 | CONCLUSION

Irrigation–livestock interactions produced both positive and negative effects. Livestock ownership improves farmers' livelihoods, yet their association with irrigation prompts overgrazing, erosion and sedimentation in intakes and canals. Irrigation activities often coincide with higher livestock numbers, irrigation systems are often constructed in grazing areas and canals cut through cattle access routes to the river. This potentially leads to conflict.

The top-down approach to implementing SSI by government agencies inhibits addressing intersectoral needs; undermines a sense of co-ownership and co-responsibility among users and hence fosters conflicts. Furthermore, in making top-down interventions in irrigation systems, livestock–irrigation interactions are insufficiently considered, leading to aggravated conflicts. Standard by-laws for WUAs in modernized SSIs, issued without user consultation, violate Ostrom's principles for successful collective governance and overlook livestock–irrigation interactions. Proposed solutions often fail due to a lack of consideration for underlying conflicts and sociocultural contexts. The irrigation infrastructure design was made only from the irrigation perspective, ignoring the interdependence of livestock and irrigation. It reflects a design culture that ignores the sociocultural context and concerns of the actual users and denies irrigators the opportunity to come up with their own technical/design solution to mitigate the negative effect of the interaction.

An institutional framework for irrigation–livestock interactions is absent. WUAs are for irrigators, LFAs for LFs, each with its own property arrangement. However, these cannot manage the overlap of resource use at boundaries. The absence of cross-cutting (in)formal institutions makes it challenging to control non-rights-holding users. The Kulit scheme contrasts with this, with strong ownership and successful collective action superseding institutional boundaries.

The persisting sedimentation and conflicts in Ethiopian SSIs require strategy development and dispute resolution recommendations. The current approach, marked by a top-down, compartmentalized manner, impedes effective collective action to control irrigation–livestock interactions, highlighting a missing link in the current governance structure.

7 | RECOMMENDATIONS: OPTIONS TO MODERATE THE INTERACTION EFFECT IN THE SHORT AND THE LONG RUN

Over the years, engineers and administrators have racked their brains over devising sustainable solutions to address the negative effects of livestock–irrigation interactions. The mitigation measures that will be introduced in the future should consider resource management, irrigation systems and grazing land. Our main recommendations focus on two points.

Newly developed projects and rehabilitation of existing schemes could emphasize alternative practical measures for better herd and farming management that consider all potential users of the common resource. This could be done by either creating a platform superseding the WUA and LFA or by including LFs as a separate subcommittee on the WUA, with specifically drafted by-laws addressing the right to move across canal infrastructure and water animals from canals. Such inclusive arrangements would go a long way to ensuring that cross-cutting livestock and irrigation uses are addressed. The latter would address the boundary problem that is caused by each resource having its own property arrangement and collective monitoring institution, leaving overlapping resource use at the discretion of a non-responsive district office.

During the design of new and upgraded SSI systems, it is important to consider the intersectoral needs of both irrigation and grazing systems. The design could include the concerns of the actual users (irrigators and LFs), local knowledge and consider the sociocultural context of irrigation and consult both irrigators and LFs and account for their interactions.

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CONFLICT OF INTEREST STATEMENT

The authors declare there are no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

REFERENCES

Awulachew, S.B. & Ayana, M. (2011) Performance of irrigation: an assessment at different scales in Ethiopia. *Experimental Agriculture*, 47(S1), 57–69. Available from: https://doi.org/10.1017/S0014479710000955

Baggio, J.A., Barnett, A.J., Perez-Ibarra, I., Brady, U., Ratajczyk, E., Rollins, N. et al. (2016) Explaining success and failure in the commons: the configural nature of Ostrom's institutional design principles. *International Journal of the Commons*, 10(2), 417–439. Available from: https://doi.org/10.18352/ijc.634

Beyene, F. (2009) Exploring incentives for rangeland enclosures among pastoral and agropastoral households in eastern Ethiopia. *Global Environmental Change*, 19(4), 494–502. Available from: https://doi.org/10.1016/j.gloenvcha.2009.07.002

Bolding, A.; Post Uiterweer, N. and Schippers, J. 2010. The fluid nature of hydraulic property: a case study of Mukudu, Maira and Penha Longa irrigation furrows in the upper revue river, Manica District. What role of law in promoting and protecting the productive uses of water by smallholder farmers in Mozambique: 105–136.

Brits, J., Van Rooyen, M.W. & Van Rooyen, N. (2002) Ecological impact of large herbivores on the woody vegetation at selected watering points on the eastern basaltic soils in the Kruger National Park. *African Journal of Ecology*, 40(1), 53–60. Available from: https://doi.org/10.1046/j.0141-6707.2001.00344.x

Carline, R.F. and Walsh, M.C. (2007) Responses to riparian restoration in the Spring Creek watershed, central Pennsylvania. *Restoration Ecology*, 15(4), 731–742.

Chun, N. (2014) The challenge of collective action for irrigation management in India. *Asian Economic Papers*, 13(2), 88–111. Available from: https://doi.org/10.1162/ASEP_a_00271

Collins, A.L., Walling, D.E., McMellin, G.K., Zhang, Y., Gray, J., McGonigle, D. et al. (2010) A preliminary investigation of the efficacy of riparian fencing schemes for reducing contributions from eroding channel banks to the siltation of salmonid spawning gravels across the south west UK. *Journal of Environmental Management*, 91(6), 1341–1349. Available from: https://doi.org/10.1016/j.jenvman.2010.02.015

Dessalegn, H.T., Bolding, A., de Fraiture, C. & Ayana, M. (2021) Livestock and small-scale irrigation scheme interactions as a key source for sedimentation during the irrigation season: four case studies from south-west Shoa, Ethiopia. *Sustainability*, 13(10), 5745. Available from: https://doi.org/10.3390/su13105745

Gebremedhin, B., Pender, J. & Tesfay, G. (2004) Collective action for grazing land management in crop–livestock mixed systems in the highlands of northern Ethiopia. *Agricultural Systems*, 82(3), 273–290. Available from: https://doi.org/10.1016/j.agsy.2004.07.004

Gebreyohannes, G. and Hailemariam, G. 2011. Challenges, opportunities and available good practices related to zero grazing in Tigray and Hararghe, Ethiopia. 66.

Gebul, M.A. (2021) Trend, status, and challenges of irrigation development in Ethiopia—a review. *Sustainability*, 13(10), 5646. Available from: https://doi.org/10.3390/su13105646

Gurmu, Z.A., Ritzema, H., de Fraiture, C. and Ayana, M. (2019) Stakeholder roles and perspectives on sedimentation management in small-scale irrigation schemes in Ethiopia. *Sustainability*, 11(21), 6121.

Habtu, S. & Yoshinobu, K. (2006) Traditional irrigation management in Betmera-Hiwane, Ethiopia: the main peculiarities for the persistence of irrigation practices. *Journal of Mountain Science*, 3(2), 139–146. Available from: https://doi.org/10.1007/s11629-006-0139-0

Line, D., Harman, W., Jennings, G., Thompson, E. & Osmond, D. (2000) Nonpoint-source pollutant load reductions associated with livestock exclusion. *Journal of Environmental Quality*,

29(6), 1882–1890. Available from: https://doi.org/10.2134/jeq2000.00472425002900060022x

Madden, D., Harrison, S., Finn, J.A. & Huallacháin, D.Ó. (2019) The impact of cattle drinking points on aquatic macroinvertebrates in streams in south-east Ireland. *Irish Journal of Agricultural and Food Research*, 58(1), 13–20. Available from: https://doi.org/10.2478/ijafr-2019-0002

McMichael, A.J., Powles, J.W., Butler, C.D. & Uauy, R. (2007) Food, livestock production, energy, climate change, and health. *The Lancet*, 370(9594), 1253–1263. Available from: https://doi.org/10.1016/S0140-6736(07)61256-2

Meul, M., Van Passel, S., Fremaut, D. & Haesaert, G. (2012) Higher sustainability performance of intensive grazing versus zero-grazing dairy systems. *Agronomy for Sustainable Development*, 32(3), 629–638. Available from: https://doi.org/10.1007/s13593-011-0074-5

Ostrom, E. 1990. *Governing the commons: the evolution of institutions for collective action*. Cambridge: Cambridge University Press. Available from: https://doi.org/10.1017/CBO9780511807763

Ostrom, E. (2010) Analyzing collective action. *Agricultural economics*, 41(s1), 155–166. Available from: https://doi.org/10.1111/j.1574-0862.2010.00497.x

Peden, D.; Freeman, A.; Astatke, A.; Notenbaert, A.; Ayalneh, W.; Baltenweck, I.; El Wakeel, A.; Fadlalla, B.; Elzaki, R. and Faki, H. 2006. Investment options for integrated water-livestock-crop production in sub-Saharan Africa.

Pekor, A., Miller, J.R., Flyman, M.V., Kasiki, S., Kesch, M.K., Miller, S.M. et al. (2019) Fencing Africa's protected areas: costs, benefits, and management issues. *Biological Conservation*, 229, 67–75. Available from: https://doi.org/10.1016/j.biocon.2018.10.030

Roder, W. (1965) *Sabi Valley irrigation projects*. Chicago, Illinois: The University of Chicago.

Widgren, M. and Sutton, J.E. 2004. *Islands of intensive agriculture in Eastern Africa: past & present*. British Institute in Eastern Africa.

Wolancho, K.W. (2012) Watershed management: an option to sustain dam and reservoir function in Ethiopia. *Journal of Environmental Science and Technology*, 5(5), 262–273. Available from: https://doi.org/10.3923/jest.2012.262.273

Yami, M. (2016) Irrigation projects in Ethiopia: what can be done to enhance effectiveness under 'challenging contexts'? *International Journal of Sustainable Development and World Ecology*, 23(2), 132–142. Available from: https://doi.org/10.1080/13504509.2015.1057628

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