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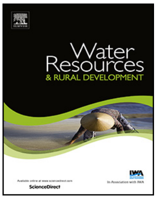

Technical and institutional attributes constraining the performance of small-scale irrigation in Ethiopia

Tilahun Amede *

International Crops Research Institute for the Semi-arid Tropics (ICRISAT), Nairobi, Kenya

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ABSTRACT

Small-scale irrigation is playing an important role in adapting to climate change, achieving food security, and improving household incomes. The Ethiopian Government considers irrigated agriculture as a primary engine of economic growth and plans to increase the current level of irrigation infrastructure three-fold by the end of 2015. However, there has been concern regarding the performance and management of existing small-scale irrigation. Based on the assessment of 52 small-scale irrigation schemes, and three case study sites, we describe the challenges and interventions required to improve irrigation water management in Ethiopia. Though most schemes are operational, many do not operate at full capacity, due to design failures, excessive siltation, poor agronomic and water management practices, and weak local institutions. In addition to low returns, there is competition for irrigation water between upstream and downstream users, vegetable growers and cereal growers, and between farmers with large irrigable plots and those with small plots. Despite these challenges, our field assessment revealed that small scale irrigation increases crop yields, improves crop diversification, and reduces the risk of crop failure. We emphasize in this paper the need for incentives to improve productivity and minimize conflicts, while enhancing innovation capacity, developing scheme-specific intensification strategies, and promoting collective action. We also describe how benefits from water investments could be substantially increased by overcoming design constraints,

* Tel.: +254 116172000.
E-mail address: t.amede@cgiar.org.

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strengthening water user associations, and protecting catchments.

1. Introduction

According to recent FAO estimates (FAO, 2009), farming, industrial and urban water demands in developing countries will increase 40% by 2030. Climate change is likely to intensify the water scarcity and lead to greater competition for water between countries and across watersheds and basins. The poor and vulnerable populations of sub-Saharan Africa, including Ethiopia, will likely face the greatest risk, due to the low adaptation capacity to climate shocks (Intergovernmental Panel on Climate Change (IPCC), 2007). The spiral of water scarcity and variability commonly reduces crop and livestock productivity and farm incomes, while increasing the vulnerability of communities to climatic and market shocks (Amede et al., 2014). The negative effects of water scarcity have been aggravated by expanding agricultural needs, land degradation, poor water management practices, and limited institutional and household capacities to store and efficiently utilize available water resources (Amede et al., 2014). Moreover, limited knowledge and weak financial capacity have limited community investments in water resources and constrained access to other farm inputs. In addition, water use in agriculture must be balanced with the water needed to support ecosystem services (de Fraiture et al., 2007).

Despite the availability of a large volume of fresh water – including 12 river basins with an annual runoff volume of 122 billion m^3 and an estimated 6.5 billion m^3 of groundwater potential (Awlachew and Ayana, 2011), Ethiopia is prone to recurring droughts and food insecurity. Irrigated agriculture is largely characterized by local, traditional, small-scale practices. In 2005/2006, the total reported area of irrigated agriculture in the country was 626,116 ha, of which traditional irrigation, modern small-scale irrigation, medium–large–scale irrigation schemes accounted for 77%, 9% and 14%, respectively (Awlachew and Ayana, 2011). Yet, the potentially irrigable area in Ethiopia is estimated to be about 5.3 Mha (Awlachew and Ayana, 2011). The Ethiopian government in its 5-year Growth and Transformation Plan (GTP) (2011–2015) considers irrigated agriculture to be a primary engine of economic growth and plans to increase the irrigated area from 2.5% in 2011 to 15.6% by 2015 (http://planipolis.iiep.unesco.org/upload/Ethiopia/EthiopiaGTP.pdf). Similarly, there is a move to increase the medium and large scale irrigated agriculture from 127,243 to 785,583 ha (Ministry of Finance and Economic Development (MOFED), 2010). The near future contribution of irrigation to agricultural GDP in Ethiopia is expected to rise to 12%, while the contribution to overall GDP will be about 4% (Ministry of Finance and Economic Development (MOFED), 2010). Hagos et al. (Ministry of Finance and Economic Development (MOFED), 2010) indicate that irrigation in Ethiopia generates an average income of approximately US\$ 323 ha^{-1} under smallholder-managed irrigation systems, compared with an average income of US\$ 147 ha^{-1} for rainfed systems.

Several donors have supported the development of small-scale irrigation in Ethiopia since the 1990s, including the International Fund for Agricultural Development (IFAD). Capitalizing on a small grant 'Small-scale irrigation on special country programme' in Oromia and Southern Nations, Nationalities and People's Region (SNNPR) of Ethiopia, between 1987 and 1996 a Special Country Programme (SCP) Phase II, was conducted to "improve food security and incomes amongst poor rural households, by enhancing their resilience to drought, through intensification, diversification and commercialization of smallholder agriculture." SCP II has operated in the Tigray, Oromia, Amhara, and SNNPR regions of Ethiopia between 1999 and 2004. The project was developed to improve and expand traditional small-scale irrigation schemes, enhance agricultural support services, and strengthen the local and national institutions responsible for small-scale project implementation (Annual Progress Report for F.Y, 2012). This collaboration was strengthened with a new phase, Participatory Small-scale Irrigation Development Programme (PASDIP), between 2004 and 2012, implemented in food-deficit districts, with high population densities and the potential to support sustainable small-scale irrigation (Annual Progress Report for F.Y, 2012).

Despite these increasing investments in small-scale irrigation, the current water management practices and institutional arrangements in the country seem to jeopardize the sustainability of the irrigation

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schemes (IFAD, 2005). As improved irrigation is relatively new to the country, traditional water management and operation still dominate small-scale production in Ethiopia (Hagos, 2005). Moreover, irrigators in government-initiated systems are usually given few incentives to engage in irrigation management, often leading to failure of collective action and low levels of performance (Zerihun and Ketema, 2006).

Ethiopia is characterized by extraordinary biophysical, climate and socio-economic variability. Even within a particular region, micro-variability in hydrology, soils, climate, and cultural management practices could render techniques found effective on some farms ineffective on others. Adaptation strategies must therefore reflect variation in socio-economic conditions. Much of the investment in small-scale water extraction devices, farm ponds, and irrigation facilities in Africa has been made by individual farmers without the involvement of formal institutions (Lam, 1996), which increases the complexity of irrigated agriculture. Moreover, interventions are required not only to minimize risk of crop failure due to drought, but also to improve irrigation water productivity per unit of land and labour (Wichelns, 2014). There still exists a substantial yield gap between achievable and actual yields (Awlachew and Ayana, 2011). If the country is to achieve its stated aims of food self-sufficiency and food security, substantial improvements in water management are needed at farm and watershed scales.

Many assumptions have been made in project appraisals and policy documents regarding the potential benefits of modern schemes, without the foundation of detailed investigation and diagnosis of institutional and technical factors required to fully achieve the perceived benefits. Considering three small-scale irrigation schemes as case studies, and using information collected from an additional 49 schemes, we describe the major technical and institutional constraints affecting the performance of small-scale irrigation in Ethiopia, identify major gaps that constrain agricultural productivity, and suggest innovations for improving scheme management to achieve sustainable intensification of crop and livestock production systems.

2. Methodology and approaches

We gathered quantitative and qualitative information from 52 small-scale irrigation schemes in four regions of Ethiopia (Amhara, Tigray, Oromia and Southern Regions) (Awlachew and Ayana, 2011). All schemes were involved with an IFAD evaluation and support mission conducted between 2004 and 2012 (Amede et al., 2011; Wichelns, 2014). We conducted our data collection effort during the third IFAD supervision and implementation support mission visit in the four regions, from 13 June to 4 July 2011. We also assessed the progress in developing and implementing the agricultural development plan and we identified gaps requiring attention.

The studied schemes were selected through a two-stage procedure. First, we compiled the list of schemes constructed under Small Scale Irrigation II and operated for at least 3 years (i.e. the more "mature" sites for impact assessment). We used five tools to assemble the information: individual interviews, group discussions, key informant interviews, review of relevant documents, and field observations. The evaluation and study team reviewed documents in the implementing offices (Bureaus of Water Resources, Agriculture and Cooperatives), interviewed and discussed with IFAD stakeholders in the federal ministry of water resources in Addis Ababa, team members in the schemes, and farmers. On site, the information gathering techniques included qualitative (through semi-structured interviews) methods with both individual informants and groups, and transect walks combined with discussions.

We gathered secondary data from district, regional and federal institutions that have had a stake in respective schemes, and we conducted 23 focus groups with 15– 20 participants in each session (about 10 men and 5 women in each). Prior to the field trips, we prepared a checklist describing relevant agronomic, natural resource management, and livelihood issues. The mission was supported by a pre-mission socio-economic survey, which enhanced our understanding of the irrigation schemes (Amede, 2004, 2011). We used pair-wise analysis to identify the major constraints affecting small-scale irrigation in Ethiopia, from the perspective of key informants (community leaders and development agents).

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Fig. 1. Ten-year old small-scale irrigation schemes with different levels of intensification: Barley production in the Leza scheme in the Amhara region (left), and an intensified and diversified scheme in Oromia region, Burka woldya, Ethiopia (right) (author's photos).

2.1. *Description of three case study irrigation schemes in Ethiopia*

2.1.1. *Case 1. Burka Woldya scheme, Eastern Ethiopia*

This is an IFAD-supported scheme in Burka Woldya, Oromia, built on traditional irrigation schemes, and completed in 2002. Traditional irrigation has been practiced in Burka Woldya for many decades, in support of both market-oriented crops (e.g. Khat, *Cata Indulis*) and other crops. The planned command area was only 30 ha, while the current command area is about 55 ha. The planned water users were 127, while the current water users include about 210 households. The scheme has limited road infrastructure, yet there is a well-established link with traders from the nearby town of Kombolcha, where many farmers sell their produce. Many farmers in this drought-prone environment depend on the revenue they receive from producing and selling Khat, which is largely exported to Somalia and Yemen.

Traditionally, upstream and downstream water users depended on the same watercourse, with farmers in both landscape positions growing khat along with wheat, sorghum, maize and beans. They diversified their farms (Fig. 1), became food secure, and increased their incomes. After the traditional scheme was upgraded, the Bureau of Agriculture introduced vegetables upstream as an alternative cash source, with a long-term objective of discouraging Khat. Potato became one of the most demanded commodities by traders. This shift in interventions created a strong competition between upstream and downstream water users. The vegetable growers upstream started to consume more water with frequent irrigation than they consumed when producing Khat. Vegetable farmers needed to irrigate their fields at least once a week, while Khat fields could be irrigated only once in 3 weeks. The increase in irrigation frequency accompanied by low water discharge during dry seasons aggravated the conflict between downstream and upstream users to the level that some downstream farmers abandoned their Khat fields, while others opted for community negotiation with upstream users. There have been cases of fighting with downstream users. However, social negotiation between upstream and downstream users was hampered by unclear managerial roles between the multiple local institutions, including government-established irrigation cooperatives, the local water master, Malaka (a traditional chief selected by communities) and the water user associations. Perceptions varied regarding the roles and the accountability of these different institutions. For instance, some stakeholders indicated that the water master is accountable to the Water User Associations committee, while others perceive the reverse.

Although upstream users benefit more from the current scheme than the traditional schemes, the social conflict with their downstream neighbours forced them to think about an improved water allocation strategy, such as allowing night flows, establishing water use bylaws for priority crops and social negotiations using informal methods.

2.1.2. Case 2. Zatta scheme

Zatta is one of the upgraded small-scale irrigation schemes, found in Offa District, Tigray Regional State, Northern Ethiopia. It is a small scheme, placed in a remote area, where market access is limited. Farmers predominantly grow cereal crops where institutional support is limited to occasional visits. It was once a traditional irrigation scheme serving 200 households with a command area of 12 ha, where farmers produced onions, maize and chickpea during the dry season. The modern scheme was intended to increase the command area to 15 ha. Despite the timely completion of the scheme, the farmers claimed that the faulty scheme development process reduced the water yield by blocking the source points of the scheme and reduced the number of beneficiaries from 200 to 77. This has happened even though the farmers suggested that the engineers change the location of the weir, a suggestion, which was ignored. Moreover, landslides and boulders from upstream have been constant threats of the weir and the canals. The topsoil excavated from the primary canal fills the secondary canals each year, requiring farm labour for cleaning and maintenance. There is also continual leakage of water from the canals and weirs, reducing water flow to the farms. Moreover, there is limited coordination between the stakeholder institutions: the Bureau of Water Resources, which is responsible for constructing the scheme, the Bureau of Agriculture, which is responsible for introducing agricultural technologies, varieties and agronomic practices, and the Bureau of Cooperatives, which is responsible for helping farmers to facilitate market access and collective action. These offices were responsible for the scheme management at different stages of the project, but rarely coordinated their activities.

2.1.3. Case 3. Chelekot, Tigray

Chelekot is another IFAD-supported small-scale irrigation scheme, about 18 km from Mekele town, Tigray, Ethiopia. It is a drought-prone area, with seasonal river flow, degraded upper watersheds, and notable water scarcity. Chelekot is a new irrigation scheme, where farmers have no prior irrigation experience,. The system is cereal dominated and located very close to market opportunities. It has also enjoyed strong external institutional support, in terms of training in agronomic practices, availing plant materials and overall facilitation. It has a command area of 92 ha, supporting about 240 households. It has relatively good market access, as it is located close to major towns. This is in spite of the potential competition for market and water by three nearby schemes.

The Chelekot scheme is under pressure by new upstream water users with motorized pumps, who were not considered as beneficiaries during the planning of the scheme. There was an initiative to rehabilitate the catchment area through area enclosure. Once the scheme was built, it was handed over to the local community, which did not have the capacity to begin irrigation farming and manage the scheme. The local development agents have themselves acknowledged that they lacked knowledge and experience about irrigation to pass on to farmers, but made substantial effort to make the scheme work. Salinity is also becoming a major constraint of the scheme and only a few crops are now produced.

3. Research highlights

3.1. Performance of small scale irrigation schemes

The performance of the schemes varied with the quality of the scheme design, experience of the communities in irrigation agriculture, access to reliable markets, the level of institutional support by government institutions and organizational capacity of the respective communities. In an attempt to evaluate irrigation efficiencies of small and medium scale schemes in Ethiopia, Awlachew and Ayana (2011) showed that 86.5% of the 312 irrigation schemes in Ethiopia were operational during the study period. However, not all functional schemes were operating at full capacity, i.e. serving less than the planned command areas and cropping intensity, as in the Zatta scheme. Only 74% of the command area was cultivated with irrigated crops, while 26% of the created irrigation potential was underutilized. Moreover, irrigation schemes serve only about 50% of the targeted beneficiaries (Awlachew and Ayana, 2011). Similarly, IFAD irrigation schemes were not generating the expected high economic return, partly due to excessive siltation, poor agronomic and water management practices and the failure of local institutions to sustainably mange them (Annual Progress Report for F.Y, 2012). Although the country

Table 1
Change in farming practices with irrigation interventions, in proportions of farmers interviewed in each irrigation scheme.

Management practices	Zata ($n=81$)	Burka Woldya ($n=152$)	Hizaeti Afras ($n=136$)
Practice crop rotation	61.4	70.3	99.3
Mulching	0	43.9	5.1
Intercropping	62.7	68.4	0
Contour farming	0	29.7	8.8
Physical soil conservation	19.3	54.2	21.3
Biological soil conservation	0	5.8	3.7
Other change in farm	2.4	3.2	0.7

Source: Intermediate Evaluation Survey of IFAD, 2004 (Ayele, 2004).

is committing scarce financial resources to develop irrigation with the view to ensure household food self-sufficiency and reduce poverty, the potential created is not yet effectively realized.

3.2. *Benefits from small-scale irrigation schemes*

Series of group discussions with various government institutions, including the Ministry of Water Resources, Ministry of Agriculture, Natural Resources Directorate and Regional Water Bureau revealed that the perceived benefits of small-scale irrigation are beyond drought management and higher yields. They have identified the following benefits (Amede, 2004): (1) reduced farmers' vulnerability to annual rainfall variability and associated risks; (2) increased agricultural productivity per unit of land, thereby reducing the expansion of farming to less productive hillsides and valley bottom wetlands; (3) enabled communities to develop high value commodities in homesteads and schemes; (4) strengthened collective action for broader catchment management; (5) an incentive to improve productivity of rainfed systems; and (6) a shift in farming practices (Table 1). There has been strong association between small scale irrigation and re-vegetation and protection of upper catchments through area enclosure, soil and water conservation and the enrichment of the natural vegetation (Ayele, 2004).

Despite the challenges small-scale irrigation schemes faced, as presented below, they have substantially improved household food security by minimizing drought effects, increasing crop and livestock yields and increasing income from selling high value vegetables and fruits from home gardens. There is a strong correlation between the size of irrigable land and cash income (Descheemaeker et al., 2006). Results of farmers' interviews in seven small-scale irrigation schemes revealed higher yields than in rainfed agriculture (IFAD, 2005). For instance, access to irrigation in Chelekot enabled 80% of the farmers to practise double cropping (Table 1). Crop yield under irrigation was higher than under rain fed conditions by at least 30–70%, with much higher benefit in good soils and on farms where external inputs (fertilizer, improved seeds and pesticides) were used (Amede, 2004). Farmers doubled their yield from maize, or obtained comparable yield with crops grown in good rainfall seasons. Moreover, farmers were able to produce a second crop (e.g. chickpeas) using residual moisture after maize. Similarly, farmers produced up to four times more onions, with improved access to irrigation and increased knowledge of pest management, organic manure application, and agronomic practices (Amede, 2004; Amede et al., 2011). The inclusion of seed multiplication, soil conservation and women's gardens has significantly enhanced the benefits of small-scale irrigation.

Crop diversification increased with access to irrigation, though it varies across locations (Fig. 1, Table 1). With the expansion of irrigable land and extension support in the new schemes, where traditional irrigation was not practised (e.g. Chelekot), farmers who once produced only cereals (barley, wheat and maize), began producing vegetables and spices, such as onions, potatoes and tomatoes during the off season. About 79%, 42% and 35% of the respondents across the three schemes used crop rotation, intercropping and soil conservation, respectively (Table 1). Farmers adopted improved crop varieties with access to irrigation. They also adopted intercropping and relay cropping practices, even in the mono-cropping dominated systems of the Zatta Scheme. In Zatta, about 40% of the farmers reported producing more food than before the scheme was constructed, which was particularly apparent in drought years. In agreement with our assessments, Hagos et al. (2007) reported that about 40% of the farmers achieved higher household incomes and improvements in food production.

3.3. *Major institutional and technical challenges of small-scale irrigation schemes*

The financial returns from these small-scale irrigation schemes are considered to be low, compared with other well managed schemes in Ethiopia (Awlachew and Ayana, 2011; Yami and Snyder, 2012) and beyond. Our field assessment revealed challenges in terms of reducing water loss, choosing water-efficient commodities, minimizing conveyance and drainage losses, and institutional challenges in managing and efficiently utilizing the available water. In addition, low returns from irrigated farms and competition for irrigation water between upstream and downstream users, between vegetable growers and cereal growers, between farmers with large irrigable plots and small plots, and between water users and water managers are becoming important policy and research issues. The following section highlights these observations and considers potential remedies for improving the performance of these schemes.

3.3.1. *Inadequate irrigation water management*

Irrigation schemes were mostly developed in semi-arid areas where drought is apparent, and the catchment areas were degraded by erosion, deforestation and overgrazing. Although a large investment has been spent in developing schemes, capital constraints often prevent farmers from investing in sustainable access (e.g. purchasing motor pumps), distribution and efficient use of inputs (e.g. fertilizers). Therefore, farmers do not necessarily reap maximum returns (Hagos et al., 2007). Moreover, there has been limited prior study of the hydrology of these watersheds in terms of water yield, seasonal water fluctuation and the institutional arrangements required to sustainably manage and use water resources for irrigation and other purposes. Irrigation water applied to most farmers' fields during an irrigation event was generally higher than the required depth (Hagos, 2005).

Awlachew and Ayana (2011) suggest that the most important reasons for the failure of schemes are lack of capacity for regularly maintaining the schemes and weak institutional arrangements in planning and transferring schemes to the end users, followed by sedimentation of weirs and canals. This is the case in the three case study sites (Table 2). Most of the secondary canals were not lined and hence there was a higher loss of irrigation water before reaching the fields. In research intended to quantify the water budget of small scale irrigation schemes in the Amhara region, Ethiopia, Derib et al. (2011) found that about 26% of the water in the field canals was unproductive loss, while the loss was much lower for the main and secondary canals at 4.49% and 4.00%, respectively. In other schemes, lining canals, assisting farmers to maintain field canals, and introducing night irrigation shifts improved irrigation efficiency considerably. Moreover, lined canals and cemented diversions reduced the pressure on labour with savings of about 5–8 man days per family per season, which was needed to clean and repair furrows after the main rainy seasons.

Poor crop choice and inefficient cropping systems are also reducing the efficiency of schemes, as the available water within the growing period will not be fully exploited. This is particularly apparent in schemes where dry season flow is consistent, and the main crops would not be able to efficiently utilize residual soil water. In some areas, farmers grow crops (e.g. chickpeas) using residual moisture, while in others, there is very little consideration of growing other crops (e.g. fodder grasses and

Table 2
Responses of households regarding water scarcity access to irrigation water in three IFAD schemes, in proportions of households interviewed.

Management practices	Zata ($n=81$)	Burka Woldya ($n=152$)	Hizaeti Afras ($n=136$)
Sufficient water not available	90.1	82.2	80.3
Sufficient water available	6.2	17.8	18.9
Poor management of water	3.7	0	0.8

Source: Intermediate Evaluation Survey of IFAD, 2004 (Ayele, 2004).

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legumes) unless the available water allows a second full crop. In the case study schemes, 83% of the respondents stated that sufficient water was not available to fully irrigate their farms (Amede, 2011). Preliminary studies in Tigray showed that the total depth of water applied during the irrigation season was about 128 mm for onion and 176 mm for maize. However, the net irrigation water requirement of onion and maize calculated using the CROPWAT model was about 429 mm and 571 mm, respectively (IFAD, 2005). The effect of the water deficit on the yield reduction was estimated to range from about 60% for maize to 70% for onion (IFAD, 2005). This is where agricultural intensification could be facilitated by appropriate water management interventions, including a choice of crops with suitable maturity periods to exploit residual moisture, assessing opportunities for supplementary irrigation or cultivating fast growing fodder using residual moisture for livestock feed, particularly dairy and fattening.

On the other hand, farmers intend to apply too much water during their irrigation turns, fearing there will be a long time between irrigations, as in Burka woldya. In addition to water loss, there is also a risk of nutrient loss with excess application of irrigation. In an attempt to establish the effect of frequency of irrigation on water use efficiency (crop yield per unit of irrigation water applied) in these schemes, Yenesw and Tilahun (2009) reported that applying only 25% of the full irrigation throughout the growing season resulted in the highest water use efficiency of maize (1.78 kg/m^3). All deficit irrigations increased the water use efficiency from a minimum of 5.2% in 50% deficit at the initial stage to a maximum of 72% in 75% deficit irrigation throughout the growing season.

3.3.2. *Overcoming design constraints*

Most of the modern schemes are run-of-the-river schemes whereby improvements are made to traditional schemes through building a more durable headworks. This involves replacing stone dams with concrete weirs and diversion structures, protecting the riverbanks with concrete masonry sidewalls, lining some or all of the canals and building concrete masonry gulley crossings. However, in most cases engineers in the region based their designs on the available water, irrigable area, and other physical limitations (IFAD, 2005), without considering farmers' concerns and local wisdom. Several authors (e.g. Descheemaeker et al., 2006; Awlachew and Ayana, 2011; Annual Progress Report for F.Y, 2012) showed that at least 50% of the schemes failed to give the intended returns due largely to design failures, thereby reducing the potential economic returns and negatively affecting farmers' livelihoods. After inventory of 84 small-scale irrigation schemes in Ethiopia, including the case studies we have considered above, Abate et al. (2007). indicated that the major design constraints affecting scheme performance are siltation of the main canal (100% frequency), damage of scouring (64%) and damage of secondary and tertiary canals (64%). Although designs differ, in terms of size and scheme layout, the project provided a standard package, regardless of upstream watershed covers, landscape positions and enterprise choices. This resulted in variable scheme performance and variable returns to farmers. For instance, lining an existing, but very leaky traditional primary canal could have improved scheme efficiency considerably.

One key aspect was the issue of very deep primary canals, rather than raising weir heights. Farmers, who struggle to clear the canals of silt and sand regularly, pay for this design weakness. Other design weaknesses are related to design rigidity (Annual Progress Report for F.Y, 2012). In some cases, the source points of streams were buried by faulty designs (as in Hezai Tafres scheme of Tigray) (Amede, 2004). In some schemes the weir was located in a place where the sidewall can confine the peak flood within its original course (Abate et al., 2007), while the standard practice is to locate on a spot with shallow channel depth and flat abutment. Otherwise, it would allow water loss at the edge of the wing wall, which will undermine the integrity and stability of the weir and deprive one of the main canals from water flows (Abate et al., 2007).

Given the undulated shapes of these landscapes siltation of canals is a common challenge (Yenesw and Tilahun, 2009) (Fig. 2), which demands the integration of cut-off drains into the scheme design. In general, missing cut of drains and siltation of canals (Fig. 2) has been threatening the sustainability of schemes and reducing the command area (Abate et al., 2007). These simple but critical design failures were partly due to the top-down approaches that field engineers opted to follow. Beneficiary participation was limited to discussions with the regional staff during the study phase and the contribution of labour during construction. In many cases, decisions regarding site location were made

Fig. 2. A secondary canal filled with silt, due to lack of cut-off drains (Photo: Leul Kahsay).

with only one surface flow measurements, or based on rainfall data from a distant weather station. Farmer input into scheme design was commonly minimal. In situations when farmers vocally raised concerns about the proposed design, they were not able to influence decisions. In some cases, the uppermost weir had covered springs and redirected water back underground, resulting in the rejection of the scheme by farmers (e.g. Zatta scheme in Tigray) or the amount of irrigable land substantially decreased because of upstream diversion (e.g. Chelekot). Not all engineers were top-down, however. For instance, in one small-scale irrigation scheme in Southern region, the engineers modified the design of the stop log from metal to wooden log in response to farmers' fear of theft (Kahsay, 2011).

3.3.3. *Water user associations (WUAs) and farmers' research groups (FRGs)*

Social organisation within irrigation schemes includes traditional water management structures, which include a water master, 'modern' WUAs and cooperatives. These different organisations often exist side by side. For instance, water masters and WUAs both operate in Chelekot and Zatta. Stakeholder and community perceptions of the water master's role also vary (Amede, 2004). The water master is commonly elected by the water users, and appeared to be chosen for their trustworthiness or hardworking nature. The local authorities in favour of cooperatives have however, generally ignored existing traditional water masters. Some considered water masters as one person controlling the water distribution while others consider them to follow more consensual processes. The Regional authorities claimed that the water master is merely a caretaker, whereas farmers do agree that the water master has multiple responsibilities including management of water rotation, resolution of water conflicts within the community, negotiation with neighbouring communities over water access, punishment for water theft and organisation of canal clearance.

The 'modern' WUA tends not to explicitly incorporate existing social structures, instead being established alongside them (Danert, 2004; Kahsay, 2011). Under the initial arrangements, WUAs were usually set up to mobilise the community to participate in construction. Once construction has been completed, the responsibility for WUA lied with the Cooperatives Promotion Office (CPO). However, the CPOs was focused on encouraging the communities to form market cooperatives rather than supporting WUAs. Where both WUA and cooperative exist, there was significant room for confusion (Danert, 2004). In most cases, the community was able to instruct the water master to dissolve the WUA committee. There was a recent move to upgrade the role of WUAs towards facilitating the cleaning of canals, water use allocation, and facilitating agricultural development works in collaboration with the village administration (Descheemaeker et al., 2006). However, the focus of the government institutions was to establish the WUAs without investing time and money to strengthen their capacity for management, operation and maintenance of schemes (Descheemaeker et al., 2006).

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While creating local capacity in irrigation water use and distribution is important, developing a program for regularly collecting water fees is a key strategy for enhancing local capacity and improving scheme efficiency (Molle and Berkoff, 2007). The fee could be used for operation and maintenance of the irrigation infrastructure, covering costs of water user associations and modernization of the irrigation facilities. While the current capacity of farmers in Ethiopia is weak to financially sustain the operation and maintenance of irrigation schemes and other water infrastructure, it is unsustainable to fully rely on funds emerging from the government or development partners (e.g. IFAD, ADB). This calls for strategies for alternative income sources at local level, including introduction of functional water pricing policies. Water pricing will improve irrigation efficiency, institutional performance at local and regional scales and create the sense of community ownership of water investments within the landscape.

Some development partners (e.g. IFAD) have encouraged the establishment of farmer research groups in each scheme to conduct farmer-led research on key irrigation constraints affecting the performance of schemes, including irrigation frequency, pest and disease management, spot application of chemical fertilizers, management of perishable seeds and related issues. This was best done through the support of the regional agricultural research institutions, as it was the case with Tigray Regional Agricultural Research Institute. The participatory experimentation gave farmers an opportunity to try out interventions and developed water, crop and livestock management skills. There was also a need to establish strong national and regional water institutions, with multidisciplinary teams that could regularly support and capacitate local experts at District and Kebele levels. However, the current institutional arrangements did not necessarily avail the necessary manpower and facility beyond participating in occasional workshops and management of funds.

3.3.4. Improving upstream-downstream linkages

Most of the scheme identification and development efforts were locally decided, without considering the hydrology and water budget of the catchment. Limited basin scale planning and data analysis of water resources led to insufficient water availability of target schemes during dry irrigation seasons (Yenesw and Tilahun, 2009). For instance, Chelekot, suffered from severe water shortages because of upstream water abstraction (Annual Progress Report for F.Y, 2012). There are also more beneficiaries in the respective schemes. Some schemes have also failed to satisfy current water demand (Table 2) partly because of the extreme shift of farmers from cereal-dominant to water-intensive vegetable farming, which required frequent and full season watering.

There also appears to be too many irrigators competing for the same limited resource, after witnessing farmers downstream benefiting from irrigated farms. As indicated in Case 1 above (Burka woldya) there was less water for downstream communities than ever due to the need for frequent watering of the vegetables in the upstream fields. In the traditional system, 'khat', a local stimulant with high market value was produced and it demanded watering only once a month. As such farmers used to release enough water to downstream irrigators. However, the change in cropping systems amongst upstream communities, due to the shift towards water intensive commodities (e.g. vegetables) has strained relations between upstream and downstream users. These cases became the source of conflict between upstream and downstream communities. Downstream users tended to send their water master upstream to negotiate during times of critical demand. The absence of coordinated water use rules, partly due to ineffective policy implementation often meant that abstraction rights belonged to upstream users. In this case, beneficiaries had to take matters into their own hands. The implication is that, careful consideration needs to be given to catchment planning to minimize the likelihood of water scarcity and conflict. Although these may be isolated cases, it is likely to become a greater issue in the future if more schemes are to be developed without due attention to up- and downstream water users. This emerging competition over scarce water resources could be partly resolved by improving the water productivity of the schemes and implementing rules of equitable use of resources. The lesson is that scheme planning should not only consider current beneficiaries but also future needs. Moreover, decisions on small scale irrigation development should be made after long term monitoring of water budgets and climatic variability.

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3.3.5. *Alleviating market constraints*

The most obvious disincentive for slow move towards intensification of the irrigation schemes was limited access to market infrastructure (Descheemaeker et al., 2006; Deneke et al., 2011). The case study districts, which are food insecure, overlap well with the remote districts where road infrastructure is underdeveloped, links to markets are limited and the value chain actors (traders, dealers, processors) are non-existent. Moreover, numerous schemes in Ethiopia are not accessible during the rainy season (Annual Progress Report for F.Y, 2012). This places a strain on input and output markets. Intensified cropping requires fertiliser input, while diversification requires new seeds. If farmers cannot access these inputs, impact cannot possibly be sustained. In many cases, farmers are currently entirely dependent on the Government for inputs.

Saturation of markets is affected by too many farmers producing the same crops at the same time with limited numbers of consumers and traders. There is a tendency for the same agricultural extension packages to be promoted in multiple sites. This, in conjunction with much large areas of irrigated agriculture concentrated in various schemes, can flood the market. For instance, the Chelekot scheme is in a very close proximity with Laelay Agula and Birka schemes sharing the same river. Commercial farmers also use pumps to irrigate crops in between these schemes. The consequence was that farmers of these three schemes, which are mostly growing similar crops (tomato, cabbages, potatoes, pepper, and legumes), complained of reduced prices over years as more farmers sell irrigated vegetables to the nearby markets of Wukro and Agula. Some farmers have resorted to throwing away their produces in the late afternoon of market days. For example, a farmer in Zatta scheme abandoned his 7,000 cabbages on farm. The cooperative promotion office also reported that in some seasons tomatoes were abandoned by farmers in the market places or sold for as little as 0.01 USD per kg. This calls not only for improved planning of planting dates and diversification of commodities, but also involvement of agribusinesses and processers who could facilitate the value chain and reduce farm losses. Moreover, at harvest time, inelastic staples markets and limited outlet channels create price slumps that inhibit the adoption of productivity-enhancing technologies (Hagos et al., 2009).

3.3.6. *Protecting irrigation schemes and water towers*

Given the hilly and undulated nature of the Ethiopian landscapes, improving soil and water conservation of catchment area is critically required to protect schemes from boulders, landslide and siltation. Upstream management would also increase the scheme's water yield and improve the water supply for agriculture, i.e., making sure a higher percentage of rainwater that falls in the area is available for production (Burney et al., 2013). On the other hand, the weirs and head works of the schemes were constructed without prior rehabilitation of catchments, as it was the case in all the above three case study sites. The disastrous effects of destruction of irrigation schemes by boulders and silt were observed in Chelekot and Zatta schemes, and elsewhere in the country. In some schemes the situation is so severe that periodical excavation of sediment is necessary within 2–3 years after construction (Abate et al., 2007). There have been also attempts by the regional authorities to rehabilitate upper watersheds before or during the construction of irrigation schemes through Productive Safety Net Programmes, which is designed to provide employment to food-insecure but labour availing people. Community campaigns, food for work programs and paid labour were also used. One major opportunity is that farmers are well aware of the problem and are willing to invest in sustainable land and water management interventions (Rockström, 2000) particularly in schemes where market access is visible. The long-term benefits of managing upper watershed for protecting irrigation schemes could be visible within the older irrigation schemes (e.g. Burke Woldya), whereby silting has decreased, ground water is being enriched and new springs emerging downstream (Ayele, 2004). Besides the physical structure, integrating niche compatible forages, fruit trees, and multipurpose trees in the upper watersheds was found to be an effective strategy to reduce erosion and improve the availability of biomass for feed, fuels and other multiple uses.

3.3.7. *Employing improved irrigation agronomic practices*

In most cases, low priority was given to the agricultural development plan by the respective regions (Amede et al., 2011), rather scheme development focused on the physical construction of the schemes, potentially affecting scheme performance and farmers' interest to sustainably manage and use the resource. Assumptions made by the engineers about the cropping pattern, size and layout of the tertiary units, management and operation, available labour force, etc. were mostly different from farmer's expectations (Haile et al., 2006). With the exception of Chelekot, there has been very little investment made on development plans, depriving communities from organizing themselves, experimenting on agricultural technologies, and developing capacity to build sustainable seed systems. The bias has also been reflected by the fact that the total agricultural budget used by the projects was below 2.5% for the first years of the project (Annual Progress Report for F.Y, 2012).

One other constraint affecting intensification schemes was decline in soil fertility, particularly for high value vegetable crops. In most cases, these command areas were traditionally under low input cereal based rain-fed systems, characterized by nutrient mining and soil erosion. This is particularly apparent in schemes like Chelekot, where land degradation was apparent and crop response to irrigation was low. Pests and diseases are already undermining the returns of scheme investments. An alarming build-up of pest and diseases, on major horticultural crops including garlic, potato and pepper threatened most schemes. The agricultural development plan, if any, could have followed integrated pest management principles, whereby clean seed, crop rotation, uprooting of infested plants, careful management of farm implements and pesticides are used complementarily. The ratio of break crops in the cropping pattern of studied schemes was less than 5%.

The current centralized seed system in Ethiopia did not meet the growing demands of irrigation farmers, particularly for fruits and vegetables. Farmer's sources of seeds in the schemes was about 55% own seeds, 23% government sources and 22% purchased (Amede, 2011), and there was little progress in the area of seed systems since then. There could be at least three channels of seed systems, beyond the commonly established government seed nurseries (Amede et al., 2011). These include (a) supporting elite farmers to produce and market quality seeds of crops that are of interest to the local community in the respective schemes; (b) establishing communal nurseries in the command area for own use and selling to other sister schemes on at least one ha of land, with easy access to irrigation water; and (c) establishing alternative seed sources including through traders. However, these strategies were rarely implemented in the schemes, except for the nursery plots established by the local government in Tigray. Seed storage facilities are also major incentives for farmers to produce and maintain quality seeds.

Schemes could be sustainably intensified if it integrates home gardens; providing cash and nutrition for women farmers. As most of the new schemes were placed in cereal–livestock dominated systems where home gardening is rarely practised (except schemes like Burka Woldya) it needs a proactive role in introducing and making it work. The niches for targeting home garden development includes female headed households who have access to irrigation water and land in the neighbourhood and households with access to roof water harvesting. Women farmers could also adopt home gardens with access to water harvesting ponds or cost effective ground water, and farmers with fertile homesteads enriched by compost, household refusal, night soil, sludge but also with strong market linkages.

4. Conclusion

Despite strong policy and financial support to promote irrigation in Ethiopia, the outcomes of the initiative are below expectations. However, there are many cases in which well-planned and participatory development of irrigation schemes has generated apparent benefits. The factors supporting successful scheme performance in Ethiopia are not well documented. Innovations that would allow use of improved irrigation practices are largely pragmatic: research findings indicate the need for innovations to improve adoption rates and impact (Molle and Berkoff, 2007), thus generating benefits for farmers and communities.

Building on traditional small-scale irrigation schemes could be an effective strategy to improve scheme management, but there is also a need to develop scheme-specific agricultural development plans, and to improve institutional mechanisms for addressing the many dimensions of policies and investment opportunities. In the short term, there is considerable urgency to improve the productivity of irrigation schemes and to improve farm-level responses to changes in rainfall patterns and the increasing competition for water resources. Adapting to these emerging challenges requires collective action and improved irrigation efficiency. It also requires combined strategies and institutional

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capacity, including (a) improved design, structural and infrastructural investments, such as night storage, improved weir stability, and increasing water storage capacity across landscapes; (b) technical applications, such as the introduction of high yielding, water efficient and high value crops; and (c) the improved innovative capacity of water user associations. Many farmers will benefit from programs that provide information regarding water availability, irrigation technology available, and the likely impacts on their production activities (Lam, 1996) and the prices they should expect to pay for good quality materials. Moreover, improved catchment management and reliable market linkages should support short-term investments in small-scale irrigation schemes, while enhancing understanding of the complexity of water governance and upstream–downstream linkages.

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