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Motor Pump Revolution in Ethiopia: Promises at a Crossroads

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ABSTRACT: In sub-Saharan Africa, motor pump irrigation is at an earlier stage than in Asia but is growing rapidly in many countries. The focus of both policy and research in Africa to date has been on facilitating supply chains to make pumps available at a reasonable price. In Africa, pump irrigation is mainly based on two sources: shallow groundwater aquifers and small streams and rivers. Both usually have limited and variable yields. We present a case study from Ethiopia where pump irrigation based on small rivers and streams is expanding rapidly, and draw parallels to experiences in Asia and other African countries. We show that while farmers understand the social nature of community-managed irrigation, they share with policymakers a narrow understanding of pump irrigation as being primarily 'technical'. They perceive pumps as liberating them from the 'social' limitations of traditional communal irrigation. However, the rapid expansion of pump irrigation is leading to increasing competition and conflict over the limited water resource. We analyse the wider implications for Africa of this blindness to the social dimension of pump irrigation and offer suggestions on future policy and applied research to address the problem before it becomes a widespread crisis.

KEYWORDS: Community-managed irrigation, motor pump irrigation, sub-Saharan Africa, Asia, Fogera, Ethiopia

INTRODUCTION

In the past few decades in Asia and more recently in Africa, an 'irrigation revolution' has led to large numbers of farmers investing in small motorized pumps. These pumps have enabled smallholders to diversify their farming systems and grow high-value crops for urban and even international markets. The benefits have contributed to a 'snowball' effect – neighbouring farmers see the potential and also invest in pumps. Pump irrigation now dominates the irrigation scene in South Asia and North China (Mukherji et al., 2009). It also constitutes the fastest growing irrigation sector in sub-Saharan Africa (Burney and Naylor, 2012; Giordano and de Fraiture, 2014). However, the social and institutional context and framework for governing pump irrigation has been largely ignored, especially in sub-Saharan Africa. This is leading to growing competition for scarce water supplies, conflicts among farmers, and mining of small rivers, streams and aquifers.

While agreeing that this growth in private pump-based irrigation is a welcome development in sub-Saharan Africa (SSA), we argue that sustainable private pump-based irrigated agriculture requires no less social cooperation and collective action than community-managed irrigation. However, the kind of cooperation required for pump irrigation is more complex and less amenable to direct government support. The necessity of cooperation – the incentive to cooperate – for management of communally managed schemes is relatively clear: if farmers fail to work together for scheme maintenance and sharing water, they will all be harmed as no one will receive water. However, in the case of multiple farmers with their own pumps extracting water from an 'invisible' aquifer or from a river, the incentive itself is invisible: each farmer will respond to growing shortages by increasing his or her rate of pumping, rather than cooperating for sustained management of the shared resource. Yet, such a trajectory may not necessarily be a result of lack of capacity for collective action. It may occur even in a situation where local people already have effective institutional arrangements for managing shared natural resources including traditional irrigation use and management. This calls for understanding whether there are ways to facilitate local people to build on their social cooperation traditions to manage the negative outcomes (externalities) of the expansion of motor pump irrigation or whether there are other arrangements that can facilitate sustainable motor pump irrigation.

The skewed technological orientation among most actors regarding the conception, planning, diffusion and implementation of motor pump irrigation exacerbates the problem. In particular, policy makers and development agencies' studies and investment programs focus primarily on developing the 'value chain' needed for a sustainable and successful pump-based irrigation economy, i.e. the provision of low-cost pumps, spare parts, servicing, etc.; as well as output markets to profit from pump-based irrigation. There is an emphasis on investments and policies to expand privately owned and managed irrigation, calling on governments, donors and NGOs to improve the supply chain of motor pumps to accelerate private irrigation (Burney et al., 2013; Colenbrander and Koppen, 2013). There is a tendency to think pump irrigation based on shallow aquifers or small rivers and streams does not require attention to collective action in the way community-managed irrigation does. However, this leaves a huge gap that threatens the sustainability of pump irrigation.

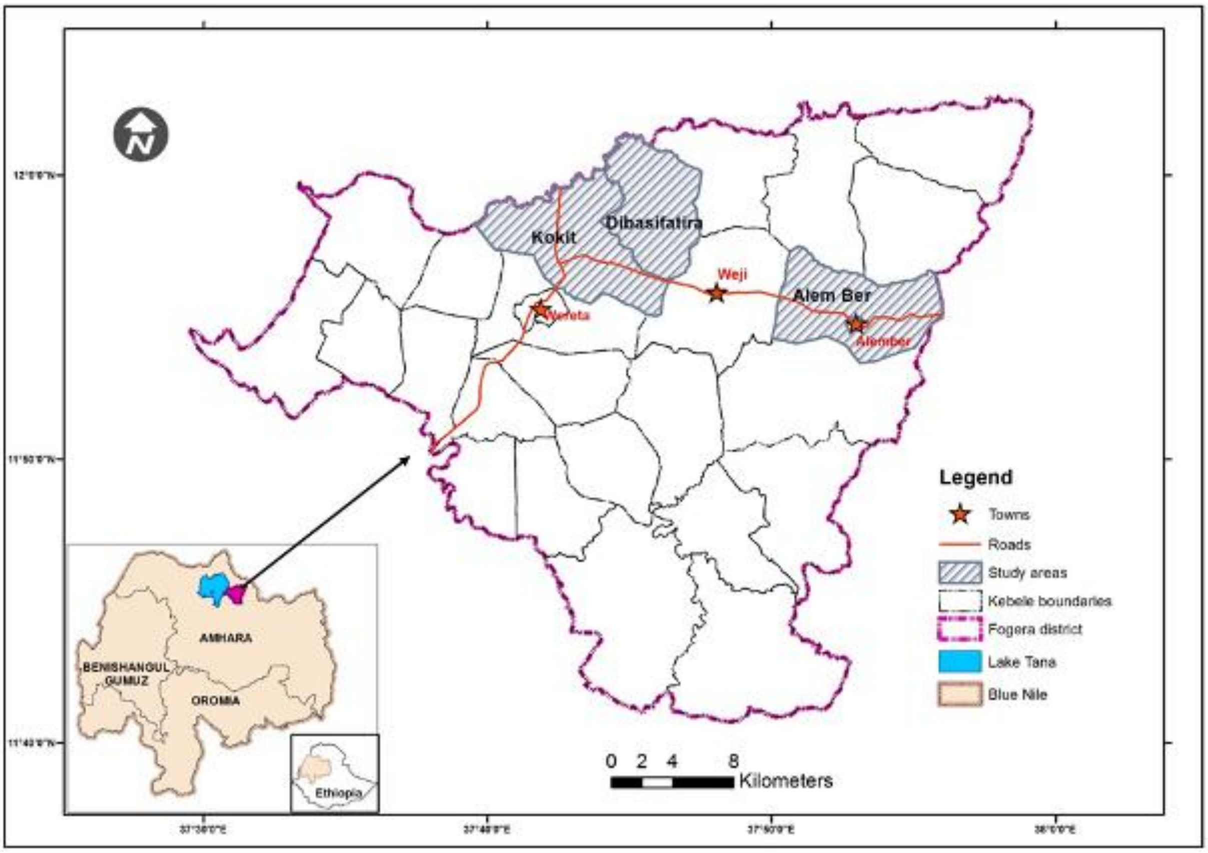
The use of individually-owned small pumps has grown exponentially in parts of Asia, bringing huge benefits to smallholders as well as consumers, but also posing difficult challenges, including aquifer depletion and unsustainable electricity costs, during the past decade. In Africa, the pump revolution is at an earlier stage than in Asia, and in most places, is taking place in a different agro-ecological context: farmers are largely exploiting relatively small rivers, streams and shallow aquifers on small to medium-sized watersheds. The potential yield of these sources of water is limited. Growing exploitation using pumps is therefore a potentially serious threat. This article uses data from field research on a small watershed in Ethiopia, and draws parallels to experiences in other African countries. The institutional mechanisms that enable these Ethiopian farmers to cooperate on small communal schemes contrast with the lack of such means to address growing competition among pump users. The paper examines the roots of the problem, proposes some ideas on how social cooperation and institutional arrangements could contribute to the sustained productive use of these water sources, and identifies further research that could contribute to sustained motor pump irrigation agriculture and livelihood benefits in Africa.

METHODS

This article is based on a case study in Fogera, a small watershed located in the Blue Nile Basin of Ethiopia. Fogera is a *woreda* (district) in South Gonder zone within the Amhara National Regional State of Ethiopia (see Figure 1). This map was prepared with the support of Yenenesh Abebe, a GIS expert at the International Water Management Institute, Addis Ababa.

Qualitative field research was carried out in successive years in three selected *kebele*s (sub-districts) of Fogera District, namely Alember, Dibasifatira and Kokit. While these represent differing landscape features – upland, midland and lowland respectively – they also constitute interconnected landscape units in terms of natural resources use and management. Initial fieldwork was done in 2012 under the Nile Basin Development Challenge (NBDC). NBDC was part of a larger multi-disciplinary research for development program aimed at finding ways to improve the management of rainwater and resilience of rural livelihoods in a landscape framework.[1] Subsequent fieldwork on small-scale irrigation was carried out in 2013. This was followed up with fieldwork conducted in 2014 for a wider study on livelihoods, landscapes and decision-making about land use.

Figure 1. Map showing the location of Fogera.



The research employed a combination of qualitative and participatory methods of data collection, including formal and informal interviews, semi-structured interviews, key informant interviews, observations, focus group discussions, and participatory problem identification. The use of a combination of different techniques facilitated data triangulation and validation. Sources of data included a range of community members such as men, women, youth and elders, as well as extension agents and agricultural professionals. Relevant written information was also gathered from *kebele* and *woreda* agriculture offices. We pursued a continuous process of data analysis and interpretation through the processes of data collection and write-up. We employed descriptive, topic and analytic coding, and proceeded with building categories, themes, patterns and relationships vis-à-vis the topic of our investigation. The study also involved comparative analysis of other small-scale irrigation experiences from Asia and Africa.

[1] http://nilebdc.org/ accessed 13 August 2014.

THE SOCIAL DIMENSION OF IRRIGATION

Our approach to the social dimension of motorized pump irrigation is based on several related conceptual trends in the analysis of agriculture and natural resource management. First, we view irrigation as a socio-technical system (Mollinga, 2003; Veldwisch et al., 2009). This approach emphasizes that the social dimensions of irrigation are as important as the technical dimensions. Social dimensions entail a range of interrelated factors including the organization of water use and management as well as issues of participation, equity, conflict resolution, collective action and institutions. The persistent perspective among technically-trained implementing agencies that irrigation is largely an engineering problem underlies the disappointing outcomes of irrigation investments. This paradigm does not adequately address the extent to which irrigated agriculture is embedded in larger agro-ecological systems.

Researchers have come to recognize the importance of engaging with farmers to encourage innovation and of embedding this work in a wider conceptual social-ecological framework variously characterized in recent literature as 'integrated agricultural research for development', 'sustainability science' or 'integrated landscape initiatives' (e.g. Sayer and Cassman, 2013; Sayer et al., 2013; Milder et al., 2014). There is no universally agreed definition of landscape approaches, but most agree that they involve an attempt to approach agricultural intensification within a systems perspective that recognizes there are multiple interactions and trade-offs with other uses and users or resources. Sayer et al. (2013) identify ten 'principles' of the landscape approach, which include a strong emphasis on participation, continued learning, transparent communication, adaptive management, and strengthening stakeholder capacities.

This study focuses primarily on the social dimensions of irrigation, which we approach from an innovation systems and institutional creativity perspective. Institutions play a critical role in enabling communities not only to cope with problems they face but in transforming this ability into a more creative and sustainable capacity to adapt to change (Berman et al., 2012). Institutions are defined as "the rules of the game in society" (North 1990: 1) by institutional economists; but it is important to understand that these rules embody values, often deeply and subconsciously held, that are interpreted differently by different people, and are dynamic and contested (Merrey and Cook, 2012). Therefore, although institutional arrangements for collective management of shared resources are characterized by a set of 'principles' (e.g. Ostrom, 1992), this does not mean they are amenable to being applied in the same way as the principles of physics are applied in designing and constructing physical infrastructure: 'social engineering' does not work (Merrey et al., 2007).

We therefore follow the lead of Francis Cleaver in adopting an approach to institutions she refers to as "critical institutional thinking" (Cleaver, 2012). The basic idea of this approach is that humans are motivated by a complex set of perspectives, values, and interests, some consciously held but many unconscious, which are derived from their social milieu. Institutional change and innovation is ultimately a creative process involving the engagement of local change agents with the institutions shaping and being shaped by the process. She refers to this creative process as 'institutional bricolage' (Cleaver, 2012; Merrey and Cook, 2012). These institutions are neither completely new nor completely traditional but rather a dynamic hybrid combining elements of 'modern', 'traditional', and the 'formal' and 'informal' (Cleaver, 2012). We return to the implications of this perspective for motor pump irrigation later.

The Green Revolution of the 1960s-1970s bolstered the importance of irrigation as an essential agricultural input. The Green Revolution involved intensive use of irrigation combined with improved varieties of seeds and chemical fertilizers. It has been remarked that "the Green Revolution was as much a story of water as it was of modern crop technology" (Burney et al., 2013). Small-scale as well as large irrigation systems have been developed, expanded and 'modernized' by governments and donors for decades (Pinstrup-Andersen and Hazell, 1985; Borlaug, 2000; Burney et al., 2013). In the wake of the

Green Revolution, orientations that primarily associate agricultural development with technological advancement seem to have been strengthened, providing the impetus for a growing focus on technological solutions.

A related subsequent call envisaged a 'Blue Revolution', where technology would lead the way toward higher water use productivity (e.g. Borlaug, 2000). This particularly focuses on sub-Saharan Africa (SSA), which is seen as having failed to benefit from modern irrigation. In recent years, new initiatives that call for a 'uniquely African Green Revolution' or 'New Green Revolution in Africa' are responding to that vision. New inter-institutional alliances for agricultural development, involving governments, private foundations, United Nations organizations and transnational collaborative agricultural research programs and corporations have emerged (Burney et al., 2013; Dano, 2007). Irrigation constitutes the most capital-intensive component of these initiatives; but the model also envisions farmers purchasing expensive high-yielding seeds accompanied by fertilizers and pesticides. To facilitate this input-intensive model of agriculture, there is a growing interest in expanding irrigation in SSA. African governments have recently placed particular emphasis on irrigation expansion as an important strategy to enhancing food security and securing livelihoods (World Bank, 2007; Karina and Mwaniki, 2011; Lankford, 2003). The Comprehensive Africa Agricultural Development Programme (CAADP) promoted by the African Union’s Nepad Planning and Coordination Agency (NPCA) gives very high priority to expanding irrigation as a basis for transforming African agriculture (Bwalaya et al., 2009).

In Africa, the development of new small-scale irrigation schemes with government and donor support continues to be biased towards the technological dimension of irrigation and its exaggerated benefits (e.g. Yami, 2013). This is so in spite of the rhetoric on farmer participation. It reflects what is described as a 'persistent mindset' prevalent among interveners that emphasizes modern irrigation technology as the essential route to modernizing agriculture (Veldwisch et al., 2009). Innovations and improvements achieved in the technical aspects of irrigation, without considering social factors, will not necessarily guarantee successful irrigation experiences (Montaña et al., 2009).

Irrigation involves multiple stakeholders with varying interests. We emphasize the importance of carefully considering the context of users' participation in water use. 'Participation' is often understood in terms of the actors and stakeholders using water and their involvement in water governance (Montaña et al., 2009). It generally implies empowering users to varying degrees to take responsibility for their scheme. While agreeing with this general notion of participation, the call for considering the broader context of users' participation in water use refers to understanding the embedded power dynamics and social categories of resource users as well as the various uses of water in a landscape perspective.

Water sources used for irrigation largely belong to the public and their use affects a wide range of local stakeholders. How different categories of people participate in water use has significant implications in terms of their social relationships over resource use. It is critical to consider the multiple uses and users of water as well as the included and excluded actors (van Koppen et al., 2009). The conception and practices of irrigation should pay attention to the multiple dimensions of water uses and users, and their interactions for and impacts on successful resource use.

Inequitable access to water and differential water use and benefits are often sources of conflicts over water. Conflicts may arise out of competition for scarce water and disagreements over its use. Such conflicts need to be managed for sustainable water use. Natural resource management involves competing interests; it is a "form of conflict management" (Castro and Nielsen, 2003). Elinor Ostrom argues that irrigation systems are among the most important forms of common-pool resources; they require conflict resolution mechanisms to resolve conflicts among users (Ostrom, 1990, 1992, 1999). Appropriate institutional arrangements are essential to facilitate and coordinate collective action and cooperation required for successful irrigation.

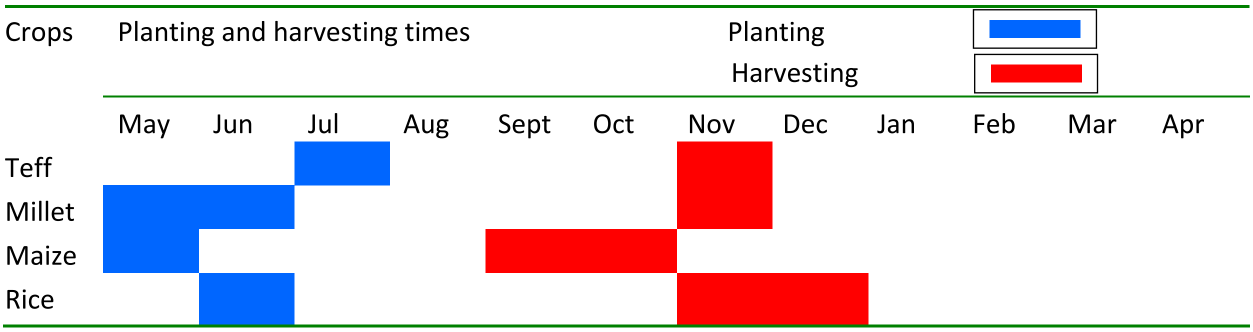
How to promote or create effective institutions is a complex issue. A package of institutional designs imposed from outside is unlikely to fit the multi-dimensional conditions of irrigation schemes in diverse social, cultural and economic contexts. Where institutional innovations are needed, they should build on existing or potential institutional arrangements. This requires a careful examination of these relationships and exploration of spheres of complementary relationships for natural resource management (Dessalegn, 2009). The search for enabling institutional arrangements must also consider multiple options. This process can be characterized as 'facilitated institutional bricolage', promoting and facilitating the creation of institutions from a diverse range of sources (Merrey and Cook, 2012; Cleaver, 2012). Such a locally-driven but possibly externally facilitated process is more likely to lead to effective legitimate institutional arrangements than structures imposed from outside.

The discussion of irrigation as a socio-technical phenomenon and the need to encourage local institutional solutions applies to small-scale private irrigation technologies as well, though it has received very little attention. The potential solutions to the social side of community-managed irrigation are fairly well understood. However, the equally critical importance of addressing the social dimensions of private small-scale irrigation is not well recognized, and the possible solutions are not clear.

SMALL-SCALE IRRIGATION IN FOGERA: MOTOR PUMP EXPANSION[2]

Rural people in Fogera depend on agriculture for their livelihoods. They practice plough agriculture using oxen. Most agricultural activities depend on the *kremit* rainy season from June to September (MoARD, 2007). The major wet season crops include *teff*, maize, millet and rice. The agricultural calendar, i.e. planting and harvesting, starts in May/June and ends by December, depending on the type of crop (see Table 1). Dry season crops which depend on access to irrigation include emmer wheat, chickpea, grass pea, lentils, onion and tomato.

Table 1. Reported planting and harvesting times for wet season crops.



Source: Interviews with farmers

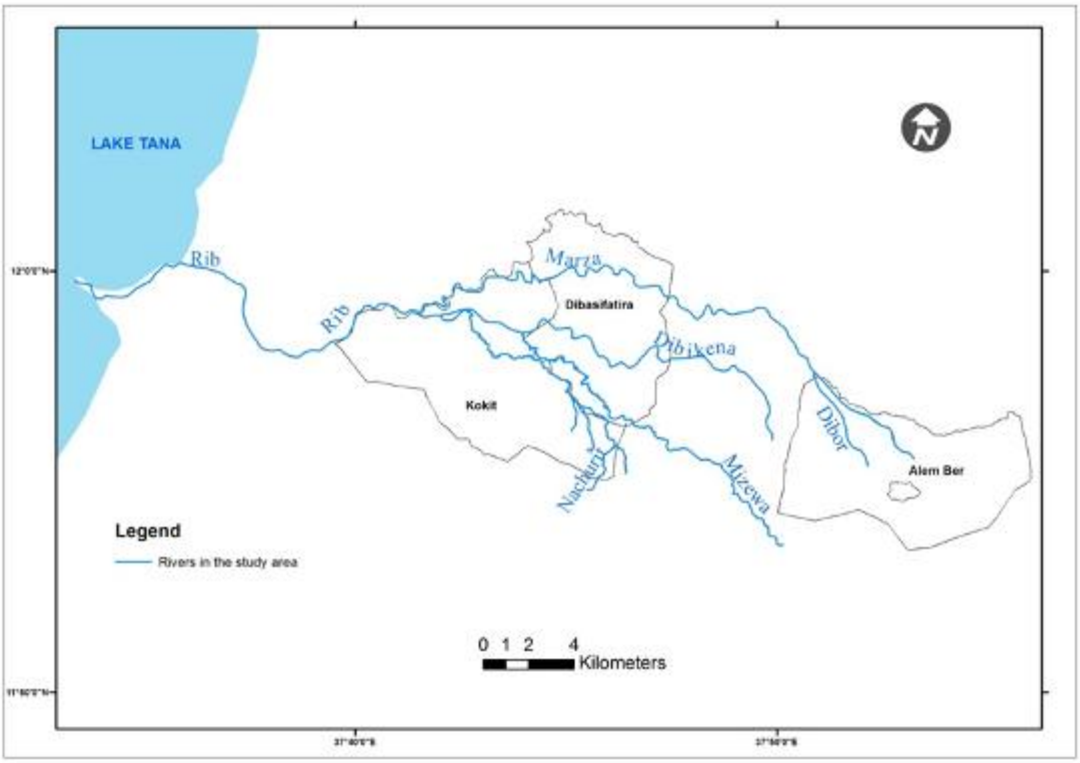
Agriculture is the mainstay of the Ethiopian and Fogera economy. It is largely based on smallholder rainfed farming. However, the reliance on rainfed agriculture is often problematic. It is vulnerable to rainfall uncertainties, i.e. erratic rainfall and drought. Therefore, in recent years, small-scale irrigation has expanded in Fogera. Farmers practice both motor pump irrigation and traditional irrigation. Other observers have also noted the diversity of small-scale irrigation in the Blue Nile Basin of Ethiopia (e.g. Eguavoen et al., 2012). Pumps are owned and used by individual farmers; 'traditional' irrigation invariably involves groups of farmers jointly managing and using infrastructure to bring water to their fields.

[2] See Dessalegn and Merrey (2014) for a more detailed presentation of the case study data.

There has also been a growing interest within the government and its partners in expanding irrigation at the national level. Recently, the Ethiopian government has ranked irrigation development as a high priority part of its agricultural and rural development agenda. Irrigation is addressed in key government policy documents including a Plan for Accelerated and Sustained Development to End Poverty (PASDEP) and the more recent Growth and Transformation Plan (GTP), where irrigation is identified as a key instrument to enhance agricultural production, food security and economic growth (FDRE, 2006; FDRE, 2010). The government is promoting large as well as small-scale irrigation; the latter includes modernizing and expanding 'traditional' irrigation schemes as well as encouraging private small-scale irrigation.

In Fogera, farmers using irrigation recognise its benefits, emphasizing that they have been able to shift from producing only rainy season crops to production in both the rainy and dry seasons. The rivers used for irrigation include Rib, Alemayehu, Marza, Mizawa, Dibekena, Nachurit, Diber and Bastkwa (see Figure 2). The use of motor pumps has expanded irrigated agriculture beyond the scope of traditional irrigation. In Fogera District at large, 27,141 ha are irrigated, accounting for 47% of the total cultivated land (57,444 ha) (FWARDO, 2013). In the three study *kebele*s, data obtained from their centres indicates that 4,682 ha of land are irrigated, accounting for over 50% of the total cultivated land (8131 ha). A careful examination of district level figures (FWARDO, 2013) indicated that in Fogera 12,405 ha are pump irrigated. This may represent 45% of the total irrigated land (27,141 ha). However, reported figures largely focus on irrigated land in general, without distinguishing pump-irrigation from other types.

Figure 2. Map showing rivers in the study areas.



Note: This map was prepared with the support of Yenenesh Abebe, a GIS expert at the International Water Management Institute, Addis Ababa.

The use of motor pumps has been expanding rapidly in Fogera. Important enabling factors have facilitated the dissemination of the technology. Credit to buy motor pumps is now available through the Amhara Credit and Saving Institution in conjunction with the *woreda* agriculture office. While the latter delivers the motor pumps, the former provides the credit to buy them. A total of 20,916 pumps were reportedly distributed in the region at end of 2009 alone (Namara et al., 2013). This figure is likely to have risen in the subsequent years.

Motor pump use has expanded through local arrangements as well. Farmers have extended traditional sharecropping arrangements to motor pump irrigation. Farmers who have no motor pump engage in sharecropping arrangements with motor pump owners. In this arrangement, the former contribute land and labour, while the latter provide the motor with fuel and seed, and they share the harvest equally. In addition, the use of motor pumps has expanded through rentals which generate income for farmers owning motor pumps while enabling others to irrigate. Motor pumps rent for 12-15 birr/hour (about US$0.80) plus covering the cost of fuel.

Motor pump irrigation provides significant income opportunities. Farmers as well as agricultural extension officers emphasized that irrigated onion has become an important source of cash. Another study (Teshome et al., 2009) also indicated that in Fogera, onion production has been increasing and the area has become a source of onion seed for other areas of the region.

Local conceptions: 'Motor' versus *mesno*

Pump technology is being implemented without social cooperation and institutional arrangements for sharing of the common resource, the small rivers and aquifers. This situation differs from the joint responsibilities required for successful traditional irrigation use and management. As shown in Table 2, traditional irrigation schemes in Fogera differ in terms of the size of users' groups and irrigated areas, but they invariably involve social cooperation from the onset of planning the scheme through water use and irrigation schedules. Local users pool their labour, ideas and commitments to work on irrigation facilities, i.e. river diversion, dam construction and the preparation of water channels. Water usage is regulated by using water use turns and irrigation schedules depending on water availability, and this is coordinated by 'water judges' and 'water committees'.

Table 2. Selected traditional irrigation schemes in the study areas.

Locality of scheme	River used for irrigation	Group size (No. of households)	irrigated area (ha)
Kero	Mizawa	70	40
Billa	Nachurit	60	30
Mikael/Wendegere	Bastkwa	50	15
Tilik-mesk	Aguwa/Diber	12	5

Source: Interviews and discussions with farmers and extension officers, and *kebele* documents

In contrast, there are no institutional arrangements guiding motor pump irrigation. This is perpetuated through conceptions of irrigation that differentiate motor pump irrigation from traditional irrigation. The local term for irrigation is *mesno*. Key informants described its features in terms of water using turns, schedules and other forms of collaboration related to utilizing river water for irrigated agriculture. We followed up such explanations with queries regarding how such forms of collaboration relate to motor pump use. Key informants clearly distinguished *mesno* from motor pumps. The notion that motor pump irrigation is differentiated from traditional irrigation is reflected in other descriptions as well. In villages where both motor pump and traditional irrigation is practiced, informants described collaborative irrigation use in relation to *mesno*. In areas where only motor pumps are used, informants responding to queries regarding cooperation for utilizing river water tended to emphasize that they do not practice *mesno*. During a participatory mapping exercise with groups of farmers, participants classified crop cultivation as crops grown with rain and crops grown with river. When asked about whether the latter refers to *mesno*, they explained that it is not *mesno* but 'motor'.

Farmers clearly emphasized that motor pump irrigation practices lack mechanisms for water allocation and irrigation scheduling. For instance, a key informant in Dibasifatira stated that "There is no water use turn with motor pump use. Water is used as one wants to use [it]. People stop when the water stops". Similarly, a key informant in Kokit indicated that, "Motor pump use has no water committee. It has no turn. It is possible for everyone to irrigate as they would like to". Such explanations were widely shared among local people contacted during fieldwork and in focus group discussions. Observations of motor pump irrigation practices during fieldwork and interviews with such pump users also reflected this situation. Irrigation using a motor pump is an individualized undertaking, with no coordination and restrictions.

Why farmers do not think of motor pump irrigation in the same way that they think about traditional irrigation has a lot to do with incentives to cooperate. It may be that the critical missing ingredient or 'trigger' for cooperation is that while for *mesno*, cooperation is necessary to divert water from the source and bring it to the fields, for pump irrigation, no such cooperation is required at the initial stage. Pumps can easily be acquired and used without cooperating with one’s neighbours. Therefore there is no 'driver' necessitating cooperation as there is with *mesno* irrigation. This interpretation follows Coward (1986), who argued (and demonstrated) the process of creating 'hydraulic property' (shared irrigation facilities) provides the basis for their social action. He suggested that creating irrigation facilities through cooperative action establishes the social basis for collective action to utilize and sustain community-managed irrigation facilities (Coward, 1986).

Our examination of motor pump irrigation in Fogera suggests that priority is given to acquiring and using motor pumps. Government institutions and affiliated development personnel have been keen to facilitate the use of the technology at the local level. These efforts have focused on facilitating credit arrangements and delivering the motor pump. At the global level as well, the focus is largely on promoting the expansion of individualistic irrigation through improving the supply chain of motor pumps (Burney et al., 2013; Colenbrander and Koppen, 2013; Merrey and Sally, 2008). Indeed, the use of motor pumps is a significant and welcome development of small-scale irrigation. However, we argue that the emphasis placed on motor pumps for improved irrigation performance should move beyond the sole focus on acquiring the technology and disseminating its use.

Emerging competition and conflicts over water

Pump-based individualistic irrigation practices based on small rivers and streams, without effective institutional arrangements and collective action for managing the shared resource, has counterproductive implications. Information obtained through interviews and discussions with farmers in Fogera revealed the emerging problems. It is creating destructive competition and conflicts over water.

Unregulated and uncoordinated use of motor pumps is threatening the sustainable use and management of shared water resources. Motor pump users have become concerned with the increasing competition for water use, limiting the duration of water availability and creating water shortages. Irrigation users in Tachawa said that the water they use from the Rib River does not easily come to their area due to many motor users in upper areas. A woman farmer in Kokit described this situation as 'frustrating' and emphatically stated that "Now that the motors are randomly placed in every direction there is shortage of water". Such concerns were widely shared by other people as well.

Another recent study also reported that communities around the Mizewa River complained about water shortages due to upstream pumping of water (Zemadim et al., 2013).

Shortage of water was identified as a growing problem during interviews and focus group discussions conducted with farmers. They indicated that the amount of water available for irrigation is decreasing. Rivers are getting 'weaker' and drying up before their regular seasonal period. For instance, during a group discussion, farmers in Dibasifatira indicated that, "[t]here are so many motor pumps now that the Marza River has dried earlier than its season. We were using it from October to February. Now it has stopped at the start of January". Farmers pumping water from Mizewa River also remarked that the amount of water available for irrigation has decreased. While motor pump use has facilitated cash crop cultivation, it has reduced the amount of water available to other users. As a middle-aged farmer indicated, "[b]efore increased *chat* (cash crop) cultivation by pumping the water, the water that comes to our area would last until March or April. However, now it has become weak just in February". A study that involved a participatory approach to hydro-meteorological monitoring (Zemadim et al., 2013) also stated that pumping of water for irrigation reportedly resulted in one of the main tributaries of the Mizewa River going dry in the dry season.

Farmers pumping water from the downstream portions of streams insist that users in the upper part always use the water as they want, depriving downstream farmers of their share. They complain about the lack of any mechanism to check and deal with water blocking or over-pumping. A government extension officer in one of the study *kebele*s explained such problems of irrigation use, emphasizing that "[t]here are too many motor pumps now. It is difficult to follow up. If we would try to follow up in our *kebele*, it would be difficult for us to follow up things in another *kebele*". This situation reveals not just the lack of inter-village coordination for water use; it also indicates how the gap in social cooperation and linked problems cross cut *kebele* boundaries.

Shortage of water is becoming a big influence on irrigated onion production. The profitability of onion cultivation has been one of the most important factors spurring farmers' enthusiasm for motor pump use. Reduced water availability and its impact on the feasibility of onion cultivation can affect sustained motor pump use and benefits. Motor pump users are very concerned about this situation. They shared the concern of a farmer who said,

> we have benefited from the cultivation of onion for some three years. Now there are many motors and the water has become smaller. So, we have abandoned the onion. In the past, the water used to serve us from October to February. But now, utmost it serves until December. If the water is not available through February it is useless for onion.

One emerging response to declining water availability is changes in cropping patterns. Farmers we interviewed indicated that many people are getting involved in *aja* (emmer wheat) cultivation. A rural *kebele* official explained:

> competition for pumping out river water from here and there has reduced water availability. This has hindered the cultivation of onion. So, this year farmers have shifted to cultivating *aja* (emmer wheat); it consumes a smaller amount of water. Onion needs to be irrigated 6-7 times. But, regarding *aja*, it will be enough if it is irrigated three times.

Further investigation is needed to understand the scope and implications of such responses. If confirmed, this trend is particularly concerning when considering that onion is far more profitable than *aja* cultivation.

The expansion of motor pump use has been without cooperation and coordination arrangements to facilitate shared use of water resources for irrigation. This is creating inequitable use of water among users of shared rivers, particularly affecting traditional schemes. For instance, farmers who practice traditional irrigation in the downstream portions of Alemayehu River insist that the expansion of motor pump use in the upper areas has reduced the flow of water to their area, thereby jeopardizing their *mesno* irrigation. In Alember, farmers who irrigate by diverting water from the Aguwa-Diber River described a case of conflict between motor pump use and *mesno* whereby motor pumpers are alleged to be blocking water and stopping its flow to the *mesno* waterway. In Dibasifatira as well, farmers using *mesno* by diverting the Nachurit River stated that some motor pump users surreptitiously remove weir structures and redirect water to the river so that more water flows through the stream branch from which they pump water and irrigate fields.

The competition between motor pump use and traditional irrigation becomes even more complex at the ground-level where a farmer who owns a motor pump may also be involved in traditional irrigation. A traditional irrigation scheme is normally used by traditional irrigators, i.e. those not using pumps. Some farmers may have access to motor pumps but do not use them within the traditional scheme. However, a key informant in Dibasifatira indicated that at times some of these users resort to using their motor pumps covertly within traditional schemes. Such motor pump owners consider motor pumps as a means of 'avoiding' the 'inconvenience' of traditional irrigation. For instance, an irrigation user in Billa stated that, "*mesno* is less convenient because we use it by *worefa* (water use turns). When *worefa* becomes longer, I prefer to use motor". Similarly, another irrigation user said, "If you get motor, you do not expect to wait for *worefa* to get water. You will have easy access to water by using the motor".

Thus, pump irrigation has led to increasing competition for water even within *mesno*s, potentially undermining their institutional arrangements. The growing shortage of water threatens their sustainability. Competition and conflict are increasing between motor pump and traditional irrigation. The end result is becoming a lose-lose situation for users of both types of irrigation. We anticipate the situation will worsen and become more widespread over time, if unabated.

There are important government institutional and policy contexts that recognize the importance of appropriate water resource use and management. A key government policy document, the GTP, has emphasized the importance of irrigation development and improved water utilization, as well as building the capacities of farmers and government support structures. Key documents of the Ministry of Water Resources such as the Water Resources Management Policy (MoWR, 1998) and Water Sector Strategy (MoWR, 2001) have also identified the importance of developing irrigation and appropriate institutional structures for the implementation and management of irrigated agriculture. In 2014, the government issued a Proclamation on Irrigation Water Users' Associations (Federal Negarit Gazette, 2014). Such institutional and policy provisions and enactments can have their own implications in terms of facilitating a context for the creation of local institutional solutions for pump-based irrigation. There is also a wider government-initiated institutional context whereby rural people have been mobilized for watershed management activities. Farmers in Fogera have been engaged in collective soil and water conservation activities through *woreda* and *kebele* structures, and watershed management task forces which are organized from village through *kebele* levels.[3]

Nevertheless, to date there has been little institutional response at the *kebele* level in terms of institutional arrangements to guide motor pump irrigation and ensure its sustainability. Indeed, so far there has been little direct official response to the growing shortages of water in small rivers resulting from the expansion of pump irrigation. It is also remarkable that to date farmers have not drawn on their own long-standing repertoire of institutional solutions to competition for water. As noted above, it may be that the critical missing ingredient or 'trigger' for cooperation is the need for co-investment: because pumps can easily be acquired and used without cooperating with one’s neighbours, there is no 'driver' necessitating cooperation as there is with *mesno* irrigation, which requires that farmers work together to construct, operate, and maintain the infrastructure. There is therefore an institutional gap,

[3] These watershed management programs are characterized by the use of participatory terminology but in reality are driven largely by quotas imposed from above; see Ludi et al., 2013.

which will need to be filled to avoid scenarios such as elite capture of the water source or serious conflicts, or both.

Reflections from Asia and Africa

In Asia, Africa and the Americas, rural people have long-standing irrigation traditions. Communities having well-established 'irrigation cultures' continue today. For example, in Bali, Indonesia, traditional irrigation has existed for over a thousand years, and Balinese farmers continue to use a complex system of canals managed through associated temple complexes to grow rice (Lansing, 1991; Lansing and Kremer, 1993; Lansing et. al., 2009). Many studies have documented indigenous irrigation systems in other parts of Asia including Nepal, India, Philippines and Sri Lanka, as well as in the Andes region of Latin America and in SSA (e.g. Sharma et al., 2009; Ostrom et al., 2011 for Nepal; Engberg-Pedersen, 2011; Leach, 1961 for Sri Lanka; and Fleuret 1985 for Kenya). Such traditional irrigation schemes require effective collective action to construct, reconstruct and maintain canals and weirs, and to share scarce resources. These experiences indicate the efficacy of farmer-managed irrigation schemes in terms of facilitating irrigation use and management.

Until recently, irrigation investments in Asia and Africa consisted almost entirely of public investments. Although farmers did invest in small-scale individual and community-managed schemes, these investments were invisible to governments. Colonial and post-colonial governments invested in large-scale schemes based on canals, barrages and dams, especially in South Asia, Sudan, West Africa, and South Africa. The main exception was public support for rehabilitation of small community-managed 'traditional' schemes in Asia. These types of investments continued in the post-colonial period, and were scaled up in conjunction with the Green Revolution in Asia.

In the early years of government and donor investments in irrigation, the focus was on introducing more 'modern' technology in traditional community-managed schemes, and designing and constructing new schemes with little or no reference to the social and cultural dimensions of irrigation. These investments were largely in infrastructure, with little attention to ensuring that the institutional capacity and framework, including resource governance, will be in place to manage schemes. There has been increasing attention over time to organizing farmers in the form of water user associations (WUAs) and promoting irrigation management transfer (IMT) on larger schemes. However, the focus of such reforms is usually too limited; for example IMT has largely sought to transfer governments' financial burdens to farmers (Merrey et al., 2007).

Interventions that contradicted or ignored existing functional patterns of social relationships around water use involved unintended and undesirable effects on access to water. For instance, Lankford (2004) found that an irrigation improvement project in Tanzania affected the long-standing equity of water distribution among small farmer-managed schemes sharing a river, leading to inequitable access to water: with the introduction of 'modern' off takes, upstream users greatly benefited while reducing tail-enders' water supply. Existing social arrangements for sharing water along the river also broke down as upstream farmers asserted a 'right' to their enhanced supply (for which they paid a fee). Similarly, in Bangladesh water resource development projects that mainly focused on promoting the intensive use of water for irrigation have created inequity in the distribution and allocation of water resources among different stakeholders (Rasul and Chowdhury, 2010). There are other examples from Asia, some of them documented many years ago; in one case in the Philippines the donor and irrigation agency initially ignored existing community-managed irrigation schemes and proposed to build entirely new ones that would have obliterated them (Yabes, 1994; Siy, 1982). It is clear that promotion of water management technologies that disrupt existing patterns of water resource sharing is not new.

Since the 1980s, public and private dissatisfaction with the performance of public irrigation has grown. Individual farmers in India, Pakistan, Bangladesh, and elsewhere began investing in pumps. A report on treadle pumps published in 2000 was an eye-opener with its title, Pedaling out of Poverty

(Shah et al., 2000). But it soon became clear that the real story was not treadle pumps so much as the low-cost portable pumps that came onto the market in the 1990s. Initially these were mostly powered by petrol or diesel; more recently with rural electrification, electric pumps became more common in Asia; and most recently, solar pumps are coming onto the market in South Asia and at least experimentally West Africa (Shah et al., 2007; Tewari, 2012; Burney et al., 2010).

In recent years, small scale private individualized irrigation technologies have taken off, first in Asia, and more recently in Sub-Saharan Africa. This is due to a combination of factors including increased availability of low-cost pumps, sprayers and drip systems, and urbanization that creates local markets for high-value products and in some cases global markets (Giordano et al., 2012; de Fraiture and Giordano 2014; Burney et al., 2013; Namara et.al, 2011). Although there are exceptions, for example the *fadama* projects in Nigeria and the private irrigation projects in Niger (both supported by the World Bank; see Abric et al., 2011), in Africa much of this development has occurred with no formal government investments or even policy attention.

By the mid-2000s, the area under private irrigation constituted over 60% of India's irrigation, exceeding the area under public schemes despite continued public investments (Mukherji et al., 2009). In sub-Saharan Africa (SSA) pump irrigation got off to a slower start but is now also growing rapidly in many countries (Shah et al., 2013). In some African countries, for example Ghana, the area under private small scale irrigation now greatly exceeds the area under public irrigation (Villholth, 2013). African governments have become interested in supporting this expansion: private pump-based irrigation does not require long lead times and huge outlays of public funds; it mobilizes significant private investment; and it is making important contributions to the food supply of growing cities as well as to agricultural exports.

Policy makers, donors and even researchers perceive promotion of private small-scale irrigation as an alternative to collective schemes with their high transaction costs and need for social cooperation. There is an assumption that getting the markets and value chain set up and putting in place more encouraging policies (e.g. favourable exchange rates, taxes etc) is sufficient on the 'institutional' side (e.g. Colenbrander and van Koppen, 2012). In addition, farmers too are likely to see pump irrigation as a way of escaping the often onerous transaction costs associated with collective management. The result is insufficient attention by all parties – government, donors, farmers – to the need for institutional arrangements to manage water resources which are still 'shared' even if 'invisible'. This refers to both small streams and rivers and to groundwater, which is coming to be recognized as a potentially significant source of water for irrigation as well as other uses in Africa (e.g. Pavelic et al., 2013; Villholth, 2013).

The significant impacts of pump-based irrigation in terms of poverty reduction and higher agricultural productivity are impressive in both Asia and Africa (e.g. Shah et al., 2007, 2013; Mukherji et al., 2009; Burney and Naylor, 2012; de Fraiture and Giordano, 2014). However, the rise of individually owned pump-based irrigation has led to new problems. In parts of western and southern India, northern China and North America, over-pumping of groundwater has led to serious depletion of both shallow and deeper aquifers. In some areas in South India it has also resulted in depletion of ancient collectively managed small reservoirs ('tanks') by pumping groundwater that is dependent on the tanks (Shah et al., 2007; Kajisa et al., 2007). Recent research in SSA finds that groundwater remains an under-exploited resource in most places; but there is growing evidence of over-exploitation, degradation and conflict over groundwater (e.g. Villholth, 2013).

In addition to groundwater, vast areas of the semiarid and humid tropics zones of SSA are characterized by the existence of multiple small streams and rivers. In the driest areas these are ephemeral; in nearly all of them, their flows vary dramatically between the wet and dry seasons. With a few possible local exceptions, data on the locations and flows of these streams are non-existent. Indeed, recent estimates on the potential for motor pump irrigation focus entirely on groundwater and ignore the potential for pumping from small streams (e.g. Namara et al., 2013). As pump irrigation expands in SSA, it seems highly likely that competition for water from small streams and rivers as well as aquifers will become increasingly serious. There are also less well-documented cases of over-pumping from small rivers and streams leading to conflict.[4] This problem will require creative solutions at local levels.

Promoting institutional arrangements to enable large numbers of smallholders to manage groundwater is especially problematic as the resource is 'invisible'. Interdependencies among users are not immediately obvious or are easily ignored by individuals. Shared use of small streams and rivers presents a similar problem. Increased pumping upstream reduces the water supply downstream. Even though the interconnections may be more 'visible', establishing and enforcing water sharing agreements are difficult. Traditional diversion technologies using locally available material are less efficient at capturing water and more visible than pumps. The necessity for groups of farmers to cooperate to construct the diversion and canals and to maintain them creates a strong incentive to cooperate; there is no such necessity of incentive for pumps. Therefore, the challenges of achieving cooperation for sharing a common water resource among pump users on both aquifers and small streams are fundamentally the same.

India, China and North America have experimented with institutional and technological approaches for managing the problem of aquifer mining. In North America, the Ogallala Aquifer Initiative supports a range of measures to reduce depletion of a major source of agriculture water, including encouraging conservation agriculture, more efficient irrigation, and changes in cropping patterns.[5] Other measures include systems of enforceable permits for water extraction and spacing of pumps, pump metering, promoting community-based and even larger scale groundwater recharging (e.g. Gujarat, India), and reconfiguration of rural electricity systems that separate supplies for domestic and industrial purposes and supplies using dedicated lines to agricultural pumps. In the latter case, electric supply for agriculture is highly reliable but rationed (Shah et al., 2004, 2008; Mukherji et al., 2009). However, indirect control of pumping through electricity supply is not an option in much of SSA, where pumps are diesel operated.

African and South Asian countries need to be cautious about adopting solutions that work under different conditions. Shah and van Koppen (2006) have argued that the promotion of integrated water resources management models borrowed from wealthier countries with more developed economies and institutions has done more harm than good in countries where the vast majority of water users are very small scale and operate in an informal economic and institutional context. In other words, it is important to understand "what works on the ground and what does not, and devise indirect policy instruments to encourage or compel private institutional arrangements to meet public policy goals" (ibid) Their argument is basically an evolutionary one: in countries where most water management arrangements are local and informal, governments have a limited capacity to influence these; they should therefore try to create a policy environment that encourages the evolution of effective local institutional arrangements but focus direct interventions only on large-scale water users. Their argument is also cautionary: we cannot assume that direct interventions – social engineering – by government or NGOs are feasible responses to the problems created by the pump revolution in Africa.

CONCLUSION

Pump irrigation is beginning to revolutionize irrigated agriculture and rural development in sub-Saharan Africa in much the same ways as it has in Asia. As in Asia, it is enabling millions of smallholder farmers

[4] For example, the second author has observed two such cases based on expansion of treadle pumps in Kenya and Malawi.

[5] www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/programs/?cid=stelprdb1048809, accessed 3 December 2013.

to create wealth and move out of poverty while also contributing to nonfarm rural development as well as national economic growth. It has also created a new generation of problems related to management of scarce water resources and equitable access. This is still an emerging issue in SSA, though it is already taking shape in some localized areas, including Fogera in Ethiopia. We have argued that the root of the problem is that while traditional community-managed irrigation is perceived by both farmers and governments as having both technical and social dimensions, pump irrigation is viewed largely as a technological innovation. This narrow focus on technology repeats an earlier error committed by governments and donors wishing to promote small scale irrigation. Researchers and governments have focused on one institutional dimension, the need for effective supply chains for pumps, spare parts and maintenance services; and markets for agricultural products. But the need for institutional measures to guide pump-based irrigation and manage a common water resource, such as aquifers and small rivers and streams, remains a blind spot.

Local users' involvement and accomplishments in traditional irrigation reveal their experiences with collective action and their understanding of traditional irrigation as a social undertaking. The events unfolding following the spread of motor pump irrigation is a result of over-reliance on a technological perspective, disregarding the social requirements of irrigation. If governments and farmers continue along this path, it will generate increasingly serious and intractable conflicts among users, concentration of resources in the hands of the more powerful local elites, and ultimately serious degradation of a valuable resource. The impacts will go beyond agriculture and food security: shallow aquifers and small streams are a major source of domestic water in rural Africa, and indeed some governments including Ethiopia's encourage 'self-supply' of domestic water using pumps as an alternative to community-managed water supplies (Butterworth et al., 2013).

What can be done? We view the problem as a socio-technical problem in an integrated landscape context. There is growing evidence of positive outcomes of integrated landscape initiatives in SSA and elsewhere (Milder et al., 2014). While we are sceptical of the efficacy of direct government intervention in such complex local issues, there is considerable evidence that people can find creative institutional solutions for local resource management problems with facilitation and policy support from government and NGOs (e.g. Komakech and van der Zaag, 2011; Komakech, 2013; Merrey and Cook, 2012). More specifically, the promotion and facilitation of 'innovation platforms', forums that include a wide range of stakeholders with shared interests, can enable people to identify a problem and potential solutions, test the possible solutions and implement them more widely if they work (Nederlof et al., 2011; Tenywa et al., 2011; CPWF, 2013; Kilelu et al., 2013; Duncan, 2011). In this case, such a platform might include the farmers pumping water from a shared stream or aquifer, local water and agricultural officials, agricultural product wholesalers, and pump suppliers. All of these parties have a strong interest in sustainable management of the common resource. Facilitators (who may be local extension agents or NGO representatives for example) can introduce solutions that have been tried elsewhere and encourage discussion of how to share the limited water resource sustainably and equitably while also maximizing its productivity. This approach is an example of facilitated institutional bricolage: enabling local communities to develop solutions to shared problems.

The viability of an alternative structure for pump use depends on specific local and operational contexts. Recommending specific institutional arrangements is not feasible and may be counter-productive. Based on 'critical institutional thinking', we argue that what is important is to support and facilitate a creative problem-solving process at local levels. For example, Coward (1986) emphasized the importance of assisting local people making investments to create their own hydraulic property relationships, a position consistent with that of Cleaver's (2012) 'institutional bricolage' concept.

Encouraging the adaptation of institutional arrangements already used in other contexts to this new problem may also be effective. Transparent participatory monitoring of pumping and stream flows or aquifer levels can inject needed information on the scale of the problem and trends over time. Depending on local conditions, local governments or community-based organizations can play a critical role in this process of monitoring, raising awareness and proposing solutions. Effective solutions will be context-specific: what works well in one country or even watershed in the same country may not be the best solution in another. Some governments may be tempted to try to limit the number of pumps through licensing or regulations regarding their location and capacity. There is very little evidence from developing countries that such direct interventions will be successful, though where local governments are effective and have adequate resources this may work. In the future, as rural electrification expands, more opportunities may arise to use electricity management as a means of rationing pumping as is done in Gujarat, India. We recommend governments should play a leading role in raising awareness among pumpers and facilitating local problem solving.

Further research can contribute greatly to promoting and sustaining motor pump irrigated agriculture and its benefits in SSA. First, there is an urgent need to carry out more localized and detailed assessments of both aquifers and small streams: their locations, estimated flows or yields, aquifer recharge rates, water quality, and both threats and opportunities affecting their sustained use. Second, we suggest that researchers carry out detailed multi-disciplinary case studies in areas where motor pumping is expanding rapidly to identify emerging problems and responses, complemented by more extensive comparative studies in order to understand the scale of over-use of common water resources is becoming. Evidence on the scale of the problem is critical to get the attention of policy makers. Countries also should collect thorough irrigation data that is well differentiated by source and type of technology. These data could be used by policy makers to focus on areas where there is an emerging problem. Third, returning to our 'institutional creativity' theme, we would encourage participatory action-oriented research and experimentation in places like Fogera to identify how external agents can best facilitate the emergence of local social arrangements or adaptation of existing institutional arrangements to address a new problem. Solutions cannot be imposed; they must emerge from recognition of the problem and agreeing to test solutions on the ground. Further research should also look for examples where groups extracting surface water sources deal with externalities that challenge their water source both from internal members and non-members.

Finally, we understand that this article seems to be generalizing from one case study to an entire continent. However, we believe that the situation described for Fogera, Ethiopia, is being replicated in many areas in SSA. It applies to both groundwater and surface water from small streams and rivers. There is a lag between the emergence of what may become a serious issue and research in most of the continent. If we are correct, then it is important to gain a full understanding of this emerging threat to small scale irrigation and begin to facilitate solutions before too much damage is done.

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