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An overview of extension use in irrigated agriculture and case studies in south-eastern Africa

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ABSTRACT

This study provides an overview of extension influence on the adoption of irrigation innovations in developed and developing countries, and finds that extension plays a more significant positive role in influencing soft technology adoption in developing countries. Case studies on the nature, use and availability of extension advice in six irrigation schemes in Tanzania, Mozambique and Zimbabwe are presented. The use of government extension officers varied significantly, with extension use not linked to farm outcomes. The results suggest the need to support more diverse sources of advice and to promote institutional reform in south-eastern Africa.

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Introduction

Increasing agricultural productivity on farms in countries in Africa has often been named as one of the biggest challenges for the world and one of the best ways to address future food security issues. It has also been argued that moderately increasing small-farm agricultural productivity in countries such as in Africa is more environmentally sustainable than the alternatives of greater intensification in developed countries or clearing additional land in developing countries (Hounkonnou et al., 2012; Tilman, Balzer, Hill, & Befort, 2011; World Bank, 2009). The question is how the world can best achieve this improvement in the productivity and sustainability of farms, and is there a difference between the best responses available in developed countries and in developing countries.

Irrigation development has also traditionally been presented as potentially an important pathway for African countries to manage water scarcity and develop further, though south-eastern Africa has seen mixed success in various irrigation schemes (Burney & Naylor, 2012). Once built, many irrigation schemes do not succeed because of the ongoing variable maintenance costs; farmer involvement and solvency; and institutional and other management issues (Van Rooyen, Ramshaw, & Moyo, Stirzaker and Bjornlund, 2017).

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Traditionally, there has been one major paradigm of the best way to promote agricultural development, which Hounkonnou et al. (2012) term the "technology supply push". The technology supply push involves the transfer of information and technologies via a top-down approach using a 'central source of information' model, where government-funded extension officers are the main mode of transferring information (which in the past has mainly focused on technologies) from research and policy to the farmer (Feder & Slade, 1984). The adoption and diffusion of new agricultural innovations by farmers is argued to be of prime importance for improving the techniques that farmers use and potentially improving the productivity, profitability and sustainability of their farms. Such innovations can be in any aspect of the production cycle, such as high-yielding varieties, new types of fertilizers, new practices of land and water management or new strategies of market engagement. However, this approach has traditionally focused primarily on raising yields of farmers as the most important driver of productivity, rather than concentrating on other ways of improving farm sustainability (such as changing institutions, prices, processes, networks or environmental sustainability). The adoption of technology in driving higher yield and production (and consequently lowering prices) is said to place farmers on an agricultural treadmill, where further adoption of technology and economies of scale become necessary for continued profitability. This seems to be the situation that many farmers in the US, Australia, Europe and Asia have faced (Hounkonnou et al., 2012; Wheeler, 2014).

However, the technology supply push model of agricultural development is not without its critics (Hounkonnou et al., 2012; Wheeler, 2008), especially with respect to its applicability to south-eastern Africa. Anderson, Feder, and Ganguly (2006) outlined the demise of a "training and visit" system of extension (linking researcher outputs with trained extension officers in farming villages) that had been introduced into most countries in Africa and funded by the World Bank. The programme was deemed not to produce enough benefits and to cost too much.

A different paradigm of agricultural development takes into account the wide variety of influences, from the institutional, to networks and social influences, to the economic and the way information is shared and sourced. Critics of the technology supply push paradigm point to the fact that agricultural development in countries such as the US existed within a body of institutional frameworks. These institutional frameworks included: publicly funded access to research, information and training; farmer unions; agri-business development; insurance and other market supports; infrastructure and network supports; and rules and laws minimizing corruption and enforcing property rights (Hounkonnou et al., 2012). Development took place in the presence of such frameworks. Therefore, it must be noted that any assessment of how to encourage agricultural development in south-eastern Africa must take these institutional factors into account when considering what is truly the most effective way to achieve change.

Bearing this in mind and the importance of the institutional framework around message sharing, an important determinant of the adoption of agricultural innovation is how and by whom information about it is disseminated. Information can be passed on via methods such as mass communication and interpersonal communication with peers and various other sources, such as extension officers, suppliers, buyers and NGOs (Conley & Udry, 2010; Gloy, Akridge, & Whipker, 2000; Pannell et al., 2006; Wang, Klein, Bjornlund, Zhang, & Zhang, 2015a, 2015b).

The assumption that extension officers are the best way for information on farming to be provided is obviously incorrect, as extension officers can be captured by certain viewpoints and sources, infrastructure and network support, disciplines and the extent of their own education and knowledge sources. It is often advocated that farmers should get their information and ideas from a multitude of sources, such as private industry, banks, scientists, academics, consultants and other farmers, following a 'multiple sources of information' model through many channels, including magazines, radio, Internet and mobile phones (Wheeler, 2008). Ideally, this model would go beyond information dissemination to include knowledge sharing, social learning and experimentation (van Rooyen et al., 2017).

Indeed, for innovations that have large knowledge components or are regionally specific, participatory approaches and institutional change are often promoted as the most effective. Globally, Markelova, Meinzen-Dick, Hellin, and Dohrn (2009) argue that there has been a decline in state-funded agricultural support such as extension services and subsidized inputs, and as a result many farmers find it difficult to access inputs, extension advice and training. This probably reflects the decline that took place during the 1990s in both national investments and international aid dedicated to agricultural development, as well as the fact that the traditional method of technology supply push did not work well in many countries, such as those in south-eastern Africa. In some countries the private and NGO sectors have largely offset this decline in national extension. As a result, a multitude of sources of extension advice emerged, allowing farmers to obtain information from a more diverse range of sources, in addition to government extension services.

It is beyond the scope of this article to truly understand the relationship of traditional extension support advice and outcomes in irrigated agricultural regions in south-eastern Africa (for example, the importance of institutional and network development versus the top-down approach of providing scientific advice and innovations to farmers). We seek instead to provide an overview of the findings in the literature with regard to how extension support has influenced the adoption of different types of agricultural irrigation innovations in developed versus developing countries. This article also undertakes a case-study analysis to explore the nature and availability, use and role of extension advice within six small-scale irrigation schemes in Mozambique, Tanzania and Zimbabwe.

Defining the extension role

Traditionally, the most common source of production support services are government extension officers (Van den Ban & Hawkins, 1988). This includes public- and private-sector activities that involve technology transfer, education, attitude change, human resource development, and dissemination and collection of information. Farmers need to trust extension officers before accepting their advice, which is related to the extent that officers understand and respect farmers' goals (Pannell et al., 2006). But farmers are more likely to adopt innovations if they are relevant to their needs and benefit them financially.

Most economic studies report returns to society (in other words, the entire costs and benefits resulting from an investment) of around 25–60% from agricultural research and extension investments (Van den Ban & Hawkins, 1988). Studies show a strong positive correlation between contact with extension service and adoption of new agricultural technologies. The riskier or more complex practices (which sustainable agriculture tends to use) have a higher propensity to be learned from extension, as they are harder for farmers to

adopt (Feder & Slade, 1984). Therefore, it is often argued that extension should play an even more important role in teaching and promoting sustainable farming practices (Pannell et al., 2006).

Studies have identified a range of characteristics of farmers who readily adopt innovations, including: (1) larger farm sizes (Abadi Ghadim, Pannell, & Burton, 2005; Neill & Lee, 2001; Pannell et al., 2006); (2) physical factors (e.g. soil type, rainfall); (3) proximity to other adopters; (4) regular contact with extension agents; (5) access to credit; and (6) younger age (D'Emden, Llewellyn, & Burton, 2006). However, an innovation is also more likely to be adopted when it has a high 'relative advantage' (perceived superiority to the idea or practice that it supersedes), and when it is readily trialable (easy to test and learn about before adoption) (Pannell et al., 2006). Given that most of the work on extension has been in developed countries, the following section focuses in particular on extension issues for developing countries.

Extension in developing countries

As already outlined, the adoption of agricultural innovation is argued to be especially important in developing countries, particularly in sub-Saharan Africa. Africa is the only continent where food production actually dropped during the second half of the twentieth century (Wik, Pingali, & Broca, 2008) and where food security is still a major concern and a large proportion of the population rely on subsistence farming or on agriculture as their predominant means of earning their living (Aker, 2011; Byerlee, de Janvry, & Sadoulet, 2009; Dercon, Gilligan, Hoddinott, & Woldehanna, 2009). For example, Dercon et al. (2009) investigated whether increased access to agricultural extension services led to reduced poverty and to consumption growth in rural areas of Ethiopia between 1994 and 2004. The overall effect of receiving at least one extension visit was that headcount poverty fell by 9.8% and consumption rose 7.1%. However, agricultural innovations are underused in developing countries (Byerlee et al., 2009; Masters, 2009; Suri, 2011), as the barriers to information dissemination (e.g. cost-effectiveness, spatial distance and access to information) are higher than in developed countries (Aker, 2011). There is also the argument that institutional changes matter much more in reducing poverty than in encouraging agricultural innovation adoption (Hounkonnou et al., 2012). Pamuk, Bulte, & Adekunle (2014) found that a decentralized approach to promoting innovation (where institutional change was encouraged) outperformed conventional extension approaches in a number of Central African countries.

Several studies have identified specific institutional barriers that restrict the dissemination of agricultural innovations in developing countries. Mittal, Gandhi, and Tripathi (2010) suggested that problems related to infrastructure, the availability of agricultural inputs and poor access to agricultural information represent the major restrictions on India's productivity growth. Poulton, Dorward, and Kydd (2010) suggested that a major challenge for African small farms relates to service delivery coordination and development.

Despite the barriers of distance and scarcity of peers from whom to acquire or share information, it seems that interpersonal information networks are useful for the diffusion of new agricultural technologies in developing countries, especially in Africa (Conley & Udry, 2010; Foster & Rosenzweig, 2010). The use of fertilizer on crops has often been encouraged in Africa (Morris, 2007), along with changing crops to improve income (e.g. Sinclair, Marrou, Soltani, Vadez, & Chandolu, 2014) and enlarging irrigated area (Cassman & Grassini, 2013), though with limited success.

Water resource development in developing countries is often promoted to replace the reliance on rainfed farming to improve food production and security, reduce poverty, increase employment and stimulate economic growth (Giordano & de Fraiture, 2014; Hussain, 2007; Namara, Hope, Sarpong, De Fraiture, & Owusu, 2014; Smith, 2004; Turral, Svendsen, & Faures, 2010). Namara et al. (2014) studied constraints on the use of water-lifting technologies (such as small motorized pumps) in Ghana. They found that this technology was primarily accessible to better-off farmers and that the main constraints on wider adoption were supply chains, lack of access to financing, high operating and maintenance costs, high price risks and lack of institutional support. Other research on irrigation in African countries has identified that women and resource-poor farmers have difficulty accessing irrigation technologies (Giordano & de Fraiture, 2014). Xie, You, Wielgosz, and Ringler (2014) suggested that there is a large potential for the profitable expansion of smallholder irrigation in south-eastern Africa using motor pumps, treadle pumps, communal river diversion and small reservoirs.

Aker (2011) reviewed agricultural extension in developing countries and found that mobile phone coverage is increasing and that their use is relatively cheap and can greatly assist in the transfer of information on transport, market prices, weather, cultivation techniques, pest and disease management, and agricultural innovations. The other benefits of mobile phones are convenience and that the information can be customized to individual farmers. As a result, Aker suggested that the uptake of agricultural innovation could be improved through information and communication technologies–based extension programmes. Greater use of mobile phones to transfer information was also encouraged by Mittal et al. (2010) in India. However, they suggest that, to reach the full potential of mobile phone and information services, improvements need to be made to the existing infrastructure as well as capacity building among farmers.

Many studies (Anandajayasekeram, Davis, & Workneh, 2007; Quizon, Feder, & Murgai, 2001; Rejesus et al., 2012; Van den Berg & Jiggins, 2007) have examined the use of farmer field schools as a vehicle for delivery of extension in Africa and Asia. These schools involve an intensive participatory training programme led by a facilitator to encourage integrated pest management and improved crop cultivation through learning, interaction and experimentation. The programmes train a small number of local farmers, who then help train others. Overall, evidence of the success of farmer field schools has been inconclusive (e.g. Anandajayasekeram et al., 2007; Quizon et al., 2001; Rejesus et al., 2012; Tripp, Wijeratne, & Piyadasa, 2005; Van den Berg & Jiggins, 2007).

Dissatisfaction with the traditional technology supply push and the lack of agricultural development in south-eastern Africa has led to a push for a more inclusive development approach, including a larger group of stakeholders for information sharing and learning, problem identification and process-oriented strategies. This is often called an 'agricultural innovation platform' approach. Pamuk, Bulte, and Adekunle (2014) describe the development of agricultural innovation platforms in Africa, while Van Rooyen et al., 2017 describe their application in irrigated areas in south-eastern Africa. The following section further disentangles the importance of extension in irrigated agriculture.

Literature review of the impact of extension on irrigated-agriculture adoption

It is important to establish (a) whether extension plays a more important role in developing than in developed countries (especially given the argument that the technology supply

Table 1. An overview of the impact of extension on the adoption of irrigation innovations by farmers ($n = 53$; % in parentheses).

	Positive, significant	Negative, significant	Not significant	Total
Hard technology (e.g. irrigation infrastructure systems, new crops, new farm irrigation technology)				
Developed	6 (75)	1 (13)	1 (13)	8 (100)
Developing	13 (62)	2 (10)	6 (29)	21 (100)
Soft technology (e.g. soil and water practices, timing, crop management changes)				
Developed	1 (33)	0 (0)	2 (67)	3 (100)
Developing	12 (57)	0 (0)	9 (43)	21 (100)
Both technologies				
Developed	7 (64)	1 (9)	3 (27)	11 (100)
Developing	25 (60)	2 (5)	15 (36)	42 (100)
All	32 (60)	3 (6)	18 (34)	53 (100)

push model seems applicable only to developed countries), and (b) whether extension's impact depends on the type of innovation. For example, irrigation innovations can be divided into two broad types: those that are 'hard' in nature (e.g. infrastructure adoption); and those that require a change in skills and management (e.g. alternate wetting and drying techniques) and hence are 'soft' in nature.

The literature search results (53 studies in total) on the impact of extension on the adoption of irrigation innovations are displayed in Table 1. The studies were categorized by hard or soft agricultural irrigation innovations and whether they were undertaken in developed or developing countries. Furthermore, the results were categorized according to whether extension was found to have a significant positive, significant negative or non-significant effect on innovation adoption.

First, Table 1 identifies more studies in developing than in developed countries (42 versus 11). When the results for hard and soft technologies are examined separately, extension services have been less likely to have a positive effect on adoption of hard technology in developing than in developed countries (62% versus 75%). In addition, the provision of extension support was more likely to be found insignificant (29% versus 13%) (and hence unimportant) in developing than in developed country studies. As suggested by the technology supply push argument highlighted earlier, it seems that extension is more relevant for developed countries. But there is some evidence that extension services have been more likely to have a positive effect on soft technology irrigation innovations (such as changing the way farmers manage resources) in developing than in developed countries (57% versus 33%). When both hard and soft technologies are examined together, extension services have been slightly more likely to have a positive effect in developed than in developing countries (64% versus 60%). Finally, when all of the studies are examined together (both developed and developing countries, and both hard and soft technologies), most (60%) indicated that extension has a positive effect on adoption, a smaller number (34%) found no significant effect, and only three studies (6%) indicated that extension had a negative effect.

This article further investigates the role extension plays in irrigation in regions in south-eastern Africa through detailed case studies.

Data, methodology and case study information

The analysis in this study is based on farm household surveys (semi-structured interviews with the key household decision maker). Data collection was undertaken in six irrigation

schemes, in Tanzania (Kiwere and Magozi, in the Iringa District), Mozambique (Khanimambo and 25 de Setembro, in Magude and Boane Districts, respectively) and Zimbabwe (Mkoba and Silalatshani, in Vungu and Insiza Districts, respectively) from May to July 2014. For a discussion of the data collection process in the respective schemes, see Moyo, Van Rooyen, Moyo, Chivenge and Bjornlund (2017), Mdemu, Mziray and Bjornlund (2017), and de Sousa et al., (2017).

There were a total of 402 valid responses. The average age of the household head was 52; 73% of the household heads were currently married; 72% of households were headed by males; 21% had more than primary school education, 48% primary school only, and 31% less than primary school. The findings section reports a range of statistics and significance tests to test (1) any differences in extension use amongst the three countries; (2) differences between extension use and other information sources; and (3) associations between extension use and various innovation adoptions and key characteristics of the farm household head.

In Zimbabwe, extension advice is provided by two divisions within the Ministry of Agriculture, Mechanisation and Irrigation Development: the Irrigation Development Division provides water management advice; and the Agricultural Technical and Extension Service provides agronomic advice. According to Moyo et al. (2017), extension officers are readily available in the schemes; they are the most important source of advice, and farmers generally trust them. However, they also find that with today's complex agricultural systems it is not realistic than one extension officer is qualified in all aspects of irrigated agriculture.

In Tanzania, extension support is theoretically provided by the District Council, with one officer attached to each village. In the two schemes in this study, there should therefore be two and three extension officers, respectively. However, only one officer is attached to Kiwere, and in Magozi only two. The officers are overworked, as they also provide advice to dry-land farmers and livestock keepers and occasionally act as village executives. As a result, contact between farmers and extension officers is infrequent. Mdemu et al. (2017) find that while extension officers are still reported as the most frequent source of farmer advice, farmers find it inadequate (based on the frequency of extension officers' visits to them). They also find that advice on fertilizer application is based on outdated soil analyses and that the extension officers lack training on the most recent research. As a result, farmers tend to rely on their own knowledge.

In Mozambique, the local District Services of Economic Activity should make extension officers available for farmers in each scheme. As in Tanzania, the number of extension officers is limited, and they have to cover both rainfed and irrigated systems. de Sousa et al. (2017) find that extension officers are largely absent due to poor pay and working conditions. Government extension officers are paid about one-tenth of what they are paid in the private or NGO sector. Hence, extension officers also often work elsewhere. As of mid-2015 there was no extension officer left in 25 de Setembro. However, the government of Mozambique is in the process of approving the extension officer's career legal framework, which will help differentiate irrigated from rain-fed systems.

Findings

Table 2 displays the main information sources used when households make decisions about their farms. Extension service is indicated as the main source of information. For example,

Table 2. Main information sources for making farm decisions across all countries (number of households, with % in parentheses).

		Extension service	Buyers of crop/ live-stock, sellers of farm input	Farmer group	Irriga-tion assoc./ NGOs/ research	Other farmers	Media	Own knowl-edge	Total
Rainfed crops	What to grow	225 (76)	3 (1)	9 (3)	8 (3)	18 (6)	15 (5)	18 (6)	296
	How to manage	245 (77)	6 (2)	6 (2)	11 (3)	19 (6)	15 (5)	18 (6)	320
	Where to sell	190 (63)	36 (12)	13 (4)	14 (4)	20 (7)	18 (6)	13 (4)	304
Irrigated crops	What to grow	247 (71)	6 (2)	11 (3)	27 (8)	13 (4)	21 (6)	22 (6)	347
	How to manage	270 (72)	12 (3)	8 (2)	28 (7)	17 (5)	19 (5)	23 (6)	377
	Where to sell	211 (58)	48 (13)	14 (4)	18 (5)	23 (6)	22 (6)	24 (7)	362
Livestock	What to grow	193 (78)	8 (3)	2 (1)	4 (2)	15 (6)	14 (6)	13 (5)	249
	How to manage	227 (79)	15 (5)	3 (1)	6 (2)	14 (5)	11 (4)	11 (4)	287
	Where to sell	200 (72)	32 (12)	4 (1)	4 (1)	13 (5)	12 (4)	12 (4)	277

Table 3. Use of extension service for irrigated crops by country (number of households, with % in parentheses).

		Extension services	Other sources
What crops/feed to grow	Tanzania	80 (55)	66 (45)
	Mozambique	4 (12)	29 (88)
	Zimbabwe	163 (97)	5 (3)
	Pearson chi-squared test		129.9***
How to manage the crops/livestock	Tanzania	102 (57)	77 (43)
	Mozambique	5 (17)	25 (83)
	Zimbabwe	163 (97)	5 (3)
	Pearson chi-squared test		116.8***
Where to sell the outputs	Tanzania	62 (35)	117 (65)
	Mozambique	1 (4)	23 (96)
	Zimbabwe	148 (93)	11 (7)
	Pearson chi-squared test		149.3***

***$p < .01$; **$p < .05$; *$p < .1$.

79% of the households report using extension services for livestock management. In general, households use extension services more for decisions about the type of crops to grow and their management, than for decisions concerning markets (though extension is still a significant source of information on where to sell). Around 12% of the households obtain information on markets from buyers and sellers of farm inputs. Information sources such as irrigation associations, NGOs, researchers, other farmers, media and own knowledge generally are each used by less than 10% of households. Only advice on where to sell produce is sought from another source (namely from buyers of their produce) by more than 10%.

Table 3 presents the differences in information sources across countries with respect to three farm management aspects: what crop to grow; how to manage the crop/livestock; and where to sell the output. Irrigators in the three countries differ significantly in their reliance on extension services, which seem to be used most often in Zimbabwe (up to 97%), regularly in Tanzania (up to 57%), and least often in Mozambique (up to 17%), while other services are used far more frequently in Tanzania and Mozambique.

These differences reflect the level and condition of access to extension officers provided in the three countries. Access to extension in the two schemes in Mozambique is very poor. As discussed by de Sousa et al. (2017), extension officers in Mozambique tend to come and go due to poor working conditions, and they lack capacity to offer advice on irrigation and dry-land systems. Extension officers are paid as little as USD 100 per month, which is inadequate to maintain a family. It is suggested that better extension officers are attracted to the private and NGO sector, which pays about USD 1000 per month. In Tanzania, there is one extension officer available in one of the schemes and two officers in the other, but they are overcommitted with responsibilities. As result, extension officers are not able to properly plan visits to farmers, and sometimes farmers need to contribute to their transportation costs, reducing incentives to use the officers (Mdemu et al., 2017). In Zimbabwe, extension officers are more readily available, and farmers trust their advice (Moyo et al., 2017), but they are almost entirely trained in crop production, with little or no emphasis on livestock issues. In no country are the extension officers trained to provide advice on market issues (although they are still used as a source).

Since close to 100% of Zimbabwean farmers use extension services, and since in Mozambique the sample size is so small, it is not meaningful to look at how those who do not use them differ from those who do in terms of farming practices, farm income or socio-economic differences. Therefore, we present these findings only for Tanzania, where extension services were used by around half of the farmers.

Table 4 displays the links between extension service use and innovation adoption by irrigators in Tanzania. The table breaks down the three types of extension service use by different types of hard technology (a combination of pumping surface water, pumping

Table 4. Use of extension service for irrigated crops by technology/practice adoption in Tanzania (%).

		What to grow	How to manage	Where to sell
Hard technology innovations				
Pumping surface-water, pumping groundwater, water buckets or other devices, run-off harvesting	Adoption	57	63	43
	Non-adoption	53	52	28
Two-sample test of equal proportions (*Z*-score)		0.40	1.51	1.99**
Soft technology innovations				
Growing cover crops	Adoption	46	49	43
	Non-adoption	64	65	26
Two-sample test of equal proportions (*Z*-score)		2.18**	2.07**	2.35**
Mulching	Adoption	50	53	44
	Non-adoption	55	58	34
Two-sample test of equal proportions (*Z*-score)		0.41	0.41	0.92
Crop rotation	Adoption	49	50	33
	Non-adoption	59	62	35
Two-sample test of equal proportions (*Z*-score)		1.15	1.55	0.29
Other natural resources access (e.g. wood, charcoal, fish)	Adoption	69	71	44
	Non-adoption	41	44	27
Two-sample test of equal proportions (*Z*-score)		3.36***	3.67***	2.40**
Planting leguminous crops	Adoption	53	56	36
	Non-adoption	58	59	33
Two-sample test of equal proportions (*Z*-score)		0.61	0.39	0.55
Alternate crop mix/varieties	Adoption	49	53	39
	Non-adoption	59	60	32
Two-sample test of equal proportions (*Z*-score)		1.12	0.97	0.96

***$p < .01$; **$p < .05$; *$p < .1$.

groundwater, water buckets or other devices, and runoff harvesting) and soft technology (six different management innovations). Farmers adopting hard-technology innovations are slightly more associated with using extension services than farmers not adopting. For soft-technology innovations, there were only two types where extension usage differed significantly. First, farmers growing cover crops were significantly less likely to be associated with using extension services than farmers who did not. However, farmers who accessed other natural resources (e.g. wood, charcoal, fish, etc.) were significantly more likely to use extension services than those who did not. There was no significant difference in extension service usage between farmers who do and do not adopt mulching, leguminous crops, crop rotation or alternative crop mix/varieties.

Table 5 presents on-farm income comparison between farmers who use extension services and other sources of information in Tanzania. The mean (*t*-test), median (chi-squared test) and distribution (Kolmogorov-Smirnov test) of on-farm income for the two sample groups were tested. Although the mean and median incomes for farmers using extension services are higher, the difference is not significant.

Table 6 breaks down household characteristics of gender, education and marital status by their use of extension services in Tanzania. Although a larger share of female farmers use extension services, the difference is significant only with respect to where to sell the outputs. Married household heads are significantly more likely than non-married household heads to use extension services (for all three categories). In terms of education, farmers with primary education or less are significantly more likely to use extension to obtain advice on what to grow and how to manage their crop/livestock (with no significant difference in where to sell). There was no significant difference in household head's age between the two groups (extension use versus non-use).

Table 5. On-farm income comparison by use of extension services in Tanzania (USD).

		Mean	Median	Distribution function
What crops/feed to grow	Extension service use	2,063.8	900.5	
	Other sources	1,305.0	674.6	
	Equality test	0.91[1]	0.71[2]	0.19[3]
How to manage the crops/livestock	Extension service use	1995.2	856.6	
	Other sources	1,176.2	629.1	
	Equality test	1.17[1]	1.89[2]	0.19[3]
Where to sell the outputs	Extension service use	2,234.0	866.0	
	Other sources	1,316.3	753.1	
	Equality test	1.25[1]	0.41[2]	0.10[3]

Note: None of the above tests were significant at the 0.1 level.
[1]Two-sample mean *t*-test.
[2]Two-sample median chi-squared test.
[3]Two-sample distribution Kolmogorov-Smirnov test.

Table 6. Gender, education and marital status by use of extension services in Tanzania (%).

	Gender		Education			Married	
	Male	Female	Less than primary	Primary	More than primary	Yes	No
What crops/feed to grow	54%	62%	55%*	59%*	25*	61%***	30%***
How to manage the crops/livestock	57%	58%	51%**	63%**	27**	62%**	38%**
Where to sell the outputs	32%**	52%**	39%	36%	14%	38%*	22%*

***$p < .01$; **$p < .05$; *$p < .1$ (Pearson chi-squared test).

This study used a range of statistics and tests to evaluate the difference in the use of extension services, its impact and broad relationships with a variety of factors in six irrigation schemes in three south-eastern African countries. Although the results indicate that extension is one of the main sources of information used by farmers, and that it is an important source of information for both hard and soft irrigation innovations, it is not possible to conclude any causality from our comparisons. Further work on understanding the drivers of on-farm income, while controlling for a variety of influences such as farm/country/farmer/regional characteristics, will need to be undertaken in future research. Only then will it be possible to discern the relative impact of extension in the three countries.

Discussion

Agricultural extension is often presented as one of the most important influences on the adoption of agricultural innovations, especially from the point of view of the technology supply push theory. This is because extension can help farmers overcome barriers or constraints to achieving their goals. Also, it has been shown that the more extension is accountable, works with farmers, is a two-way relationship, and provides technical knowledge and information that is needed, the more it is successful. But it has also been shown that for some innovations other sources of information are more important, and reforming institutions and networks may be more critical for agricultural development (Hounkonnou et al., 2012). This article's review of 53 irrigation innovation adoption studies of hard (e.g. irrigation infrastructure) and soft technology (e.g. irrigation management and skills) found that extension services were more likely to have a positive effect on adoption of hard technology in developed than in developing countries. This supports the argument that the technology supply push theory seems more applicable in developed than in developing countries. But extension seems more important in supporting soft-technology adoption in developing than in developed countries. If innovation adoption is associated with increased farm income, then this may indicate that farmers who access extension services are better-off than those who do not. However, there are many spatial and time influences on farm income and production which need to be controlled for (e.g. farm/farmer socio-economics, regional characteristics, market access) in evaluating this; hence it cannot be assumed that extension is always going to have a positive impact.

This article explored the extension question using 402 farm household surveys from 2014 in six irrigation schemes in Mozambique, Tanzania and Zimbabwe (see Tables 2–3). More detailed analysis was only possible for the Tanzanian data, because that was the only scheme that had a diversity of extension use. Access to extension was quite different across all three countries (Table 2). In Zimbabwe, extension officers are the trusted source of advice for nearly all famers. In Tanzania, farmers' access to extension service is infrequent, and thus it is used by only half the farmers. Access to extension officers is also infrequent in Mozambique, with less than one-fifth of farmers using the service. In both Tanzania and Mozambique the low level of use is clearly associated with access and a lack of resources. In Tanzania there are relatively few officers, due to resource constraints, and they are burdened by many other responsibilities; farmers have to pay for their transportion if they want them to visit. In Mozambique, extension officers are very poorly paid, and therefore they leave for better jobs in the private or NGO sectors at the first opportunity. Although our literature review suggests that there may be a positive impact from extension, it is clear from our six case

studies in three south-eastern African countries that regional, institutional and country factors may override the positive outcomes of extension.

Although extension is used the most in Zimbabwe, farmers there are not performing better than farmers in Tanzania and Mozambique. The two schemes in Zimbabwe (Mkoba and Silalatshani) have by far the greatest amount of underutilized irrigated land, high livestock mortality rates, low yields and low farm income. Hence, other influences such as market access and distortions play a much larger role. The absence of extension officers in Tanzania and Mozambique has led to irrigators' seeking advice elsewhere, and despite the lack of extension access, they perform at least as well as Zimbabwean irrigators. This suggests that the 'centralized source of information' model used in Zimbabwe, with an almost sole reliance on extension officers trained in cropping rather than livestock and marketing, might be a shortcoming. An active effort is needed to encourage institutional reform and support a 'multi-source information model' with a more complex set of advice sources.

Nevertheless, extension officers are the main source of advice for the majority of irrigators, in particular on how to manage the farm (rather than where to sell commodities). The breakdown of demographic factors by the use of extension suggests that female farmers are more likely to seek extension advice on where to sell their produce, and married farmers are more likely to use extension for advice on all three types of farm decisions. This could suggest that stable farm families, with both a husband and wife involved in farming, are making better-informed decisions. The finding that the least-educated farmers are most likely to seek extension advice is contrary to general literature findings. It does suggest that better-educated farmers might perceive that extension officers are poorly trained and inadequately informed and that they have alternative sources not so readily available to others. In-depth interviews and focus groups conducted in Tanzania suggest that there is a need for continual retraining of extension officers to ensure that up-to-date information and analyses are used. This again goes back to the issue of officer trust, which is fundamental in creating a positive environment in which extension advice is received.

Conclusion

This article finds support for the argument that a centralized one-source extension service and the application of the technology supply push model is inappropriate for the three studied African countries (Zimbabwe, Tanzania and Mozambique). In particular, the meta-review of existing studies emphasizes that extension service advice and provision has played a more positive and significant role in irrigation innovation adoption in developed countries than in developing countries. The case study analysis of extension provision in three African countries in this article (which focused primarily on Tanzania, where there was a diversity of extension use by farmers) indicated a clear need for continual institutional reform, supporting a multi-source information approach, where governments, private businesses and NGOs are active in providing advice on a broader range of issues, from crop and livestock production to market opportunities. For this to happen, multiple sources of information will need to be integrated into the value chain, and the agricultural innovation platform approach might be a viable way of doing this. Further work on discerning the relative impact of extension on on-farm income in south-eastern Africa will need to be undertaken, controlling for a variety of other influences, such as farmer/farm/country and regional characteristics.

These are important lessons for government or donors to contemplate when investing in improving small irrigation schemes or developing new ones. Failing to ensure integration as part of the planning and development process, and failing to encourage continual institutional reform, will result in a repetition of the past, with underperforming schemes as are prevalent throughout south-eastern Africa.

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