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Technical considerations affecting adoption of drip irrigation in sub-Saharan Africa

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ABSTRACT

Global water supplies are limited and will be increasingly strained as a result of global warming and increased agricultural demands. Drip irrigation can reliably provide increased yield and water use efficiency, yet its adoption in many food-insecure countries is negligible or less than 1% of total cultivated land. Failed technology transfer attempts are especially apparent in many African countries, despite a variety of promotion efforts. We explore the factors that influence successful drip irrigation adoption. Unlike previous studies, we focus on technical malfunctions and the array of difficulties that farmers may experience with their drip systems and their responses to these problems. By considering different farm types and four countries together, our results offer a broad perspective on the general trends and common problems among African drip users. We interviewed 61 drip irrigation adopters and analyzed their responses for statistically significant association with successful adoption. All respondents experienced a wide variety of technical difficulties with their systems. We also found that certain, very specific difficulties were good predictors of future drip irrigation abandonment. These include, water storage problems and problems with destructive wildlife. We make the following recommendations to drip irrigation promoters. (1) Redesign drip systems to help prevent common problems. (2) Invest in clear education for adopters, focusing on maintenance and repairs. (3) Encourage the adoption of complementary technologies to support the functioning of drip systems, such as water storage, purification and delivery systems, and defenses against animals.

1. Introduction

In spite of major gains in agricultural technology and per-capita global food production during the past two decades, agricultural production in sub-Saharan Africa has remained steady or declined (FAO, 2012). The introduction of low-cost or cooperatively managed modern agricultural technology has been shown to increase food security and improve livelihoods in developing countries (Polak and Yoder, 2006; Burney et al., 2010; Woltering et al., 2011).

Drip irrigation, in particular, can sustainably provide commercial farmers with improved yields and irrigation efficiency (Goldberg et al., 1976; Keller and Blisner, 1990; Blum, 1991; Postel, 1999; Ibragimov et al., 2007). In spite of these advantages, drip irrigation accounts for only about 4% of total global irrigation (ICID, 2012). Meanwhile, after decades of development aid, less than 5% of the arable land in the whole of Africa is irrigated at all, and drip irrigation is only a small fraction (<1%) of this (ICID, 2012). Improved farming technology, in particular irrigation technology, has been shown to enable African farmers to grow more and healthier food varieties (Burney et al., 2010). Singh et al. (2009) showed, however, that African smallholders cannot afford to consistently purchase the inputs required for using advanced irrigation techniques. In addition, once farmers purchase advanced technological systems for their farms, there is no guarantee of continued use or even future benefit to the farmer and the surrounding community (Cornish, 1998; Kulecho and Weatherhead, 2006a; Belder et al., 2007). The agricultural development literature is shifting to focus on the technology users' experience. It is hoped that this approach, which we have adopted in this article, can shed light on what might be done to encourage the successful adoption of innovative technologies and why many previous attempts have not been successful.

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We explore technical factors that may influence successful adoption and we examine farmer-reported problems with drip systems. We have interviewed African farmers who currently or recently used drip irrigation. Specifically, we compare the survey responses of current African drip users to the responses of disadopters. Our objectives are not to assess the relative levels of adoption of drip irrigation on a national or community scale, or to compare the approaches of various organizations and commercial entities to the promotion of drip irrigation use in Africa. Rather, our goal is to understand the problems that farmers report, and their responses to those problems, to understand how certain problems or farmer responses might influence adoption or abandonment. We explore the differences between the experiences of successful drip users and those of disadopters in a variety of African countries and contexts. Our findings highlight some potential causes of unsuccessful adoption, and offer possible solutions to the technical problems faced by drip irrigation users in Africa.

2. Methodology

We designed our approach as a semi-structured, open-ended survey. This approach is similar to that used by Kulecho and Weatherhead (2005, 2006a,b), Hussain (2007a,b) and Belder et al. (2007). Our questions reflect issues previously found to be important for the successful adoption of drip irrigation in Africa. We chose the open-ended survey design to encourage farmers to speak freely about their experience. Interviews typically lasted for 30–45 min. The survey focused on four fundamental areas:

(1) The type (e.g., commercial, subsistence, etc.) of agriculture practiced on the farm;
(2) Technical problems experienced by the drip irrigation adopter;
(3) Responses to problems (e.g., repairs, replacements, etc.); and
(4) Any observed benefits of drip irrigation.

We surveyed farmers in the sub-Saharan African countries of Ethiopia, Malawi, Senegal and Zambia during the months of August–September 2009 (Ethiopia and Malawi) and again from February to March in 2010 (Senegal, Zambia and Ethiopia). The survey was administered in face-to-face interviews with drip irrigation users in both English and the local language, through the use of a translator. Because most Zambian farmers spoke English well enough to be interviewed directly, translation services were not required there.

2.1. Selection of survey regions

We chose the four focus countries in this study because of the organizations that promote drip irrigation in each of them (supplemental material). Contacts within each of these organizations helped us to locate and interview drip irrigation adopters.

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.agwat.2013.04.014.

In addition, by choosing Ethiopia, Malawi, Senegal and Zambia we examine a variety of geographic locations and climates (Table 1). These countries are representative of several climatic zones and thus provide a good sense of the success of drip irrigation adoption across climate regions in sub-Saharan Africa.

Within the countries selected for field visits, the regions in which farmers were interviewed were largely constrained by the resources and information available. For example, because local NGOs, government, and aid agencies facilitated most of our interviews, our study contains a majority of successful drip irrigation adopters. This bias skews our results away from those of other similar studies (e.g., Kulecho and Weatherhead, 2005) in which the majority of farmers stopped using drip irrigation shortly after adopting it, making most respondents disadopters. Resource constraints also required us to interview farmers only in urban or peri-urban areas, within a day's journey of the nearest city. Urban and peri-urban farmers have been shown to have higher rates of successful drip adoption. This is due to a variety of factors, including proximity to technical support, the ease with which field agents can reach them, generally increased economic status, and relatively enhanced educational levels, along with better access to credit (Woltering et al., 2011). Despite these advantages, we found that 36% (22 of 61) of our respondents classified as disadopters.

2.2. Classifying successful drip irrigation adopters

Technological adoption does not lend itself to binary distinctions. During our fieldwork we observed that drip irrigation users exist on a spectrum between fully enthusiastic adoption and complete abandonment. For the purposes of statistical analysis, however, we distinguish between successful (adopters) and unsuccessful (disadopters) drip irrigation users. This distinction was defined by characterizing continuous, long-term drip use as successful adoption. Long-term use is essential for new technologies to have a sustained effect on the prosperity of the user (farmer) and the surrounding population (Andersson, 2005; Belder et al., 2007; Woltering et al., 2011). The spectrum of use that we observed during our fieldwork encompassed total abandonment, regular seasonal use and continuous use. We defined both regular seasonal and continuous use as adoption.

Kulecho and Weatherhead (2005) found that 78% of the Kenyan adopters interviewed in their study stopped using drip within a period of less than two years. Belder et al. (2007) reported a similar figure, with 62.8% of the Zimbabwean farmers in their study abandoning the system within one or two years. Our classifciation of successful adoption thus also includes a parameter for the length of time each farmer has used drip irrigation. To be considered a successful adopter, a farmer must have used drip irrigation for at least one complete growing season.

Any interviewed drip irrigation users not meeting the above qualifications were classified as disadopters. The classification of unsuccessful adopter thus includes farmers who previously used drip irrigation but have stopped, either intentionally or as a result of outside events, such as the destruction or loss of the system. This category also includes farmers who have not used drip irrigation long enough to be classified as successful adopters, which may contribute to some statistical bias, though such farmers only account for 4 of 61 interviews. The disadopter category also includes any farmer who – during the interview process – expressed an intention to stop using drip irrigation, even if that farmer otherwise met the qualifications for classification as a successful adopter.

2.3. Definition of farm type

We classified each of the farms in this study into one of four types based on the following definitions.

(1) Subsistence farms, which are claimed as the primary source of household food;
(2) Commercial farms, on which all produce is grown to be sold, either locally or via export;
(3) Development projects, which are established by NGOs or development agencies;
(4) Government farms, which are established and maintained by the government or a government agency. The Mwembeshi

Table 1
Climate characteristics, precipitation averages and agricultural market statistics in survey regions of selected countries.

Country	Region	Climate	Precipitation (mm/year) in survey regions	Agriculture as % GDP	Subsistence agriculture as % total population	Common crops	Irrigated land as % arable land
Ethiopia	East African highland – Rift valley	Tropical, subtropical and temperate	500–750	41 (2011)[a]	85 (2010)[c]	Coffee, cereals (t'eff), pulses[a]	0.5 (2009)[b]
Malawi	Southeast African tropics	Tropical	750–1250	30.3 (2011)[a]	40 (2010)[f]	Tobacco, coffee, tea, corn, Sorghum[a]	0.8 (2008)[b]
Senegal	Sahel	Semi-arid	250–500	15.9 (2011)[a]	75 (2007)[e]	Fish, peanuts, Sorghum, cotton, flowers[a]	0.7 (2006)[b]
Zambia	Central African tropics	Tropical	500–1250	21.5 (2011)[a]	55 (2009)[d]	Corn, Sorghum, rice, fruit, vegetables, coffee, soy[a]	0.0 (2010)[b]

Sources:
[a] https://www.cia.gov/library/publications/the-world-factbook.
[b] http://data.worldbank.org/indicator/AG.LND.IRIG.AG.ZS.
[c] Chanyalew et al. (2010).
[d] http://www.ifdc.org.
[e] Ndiaye (2007).
[f] http://faostat.fao.org.

Prison Farm outside of Lusaka, Zambia is the only government farm included in this study.

2.4. Statistical tests

Farmer responses were recorded on-site and transferred into the JMP 9.0 statistical analysis software. We then performed descriptive and contingency statistical analyses to search for patterns among the farmers' responses.

We used two statistical tests to determine the association of various technical problems with failed adoption. The first was the measure of relative risk (Goodman, 1969) and the second was the Fisher's exact test.

Relative risk measures the likelihood (i.e., "Risk Ratio," RR) of a subject being classified in a certain category, given that subject's classification in other, related categories. In this case, relative risk is used to examine a farmer's chance of being categorized as a disadopter, based on the presence or absence of certain events (problems, reported benefits, repairs or replacements) in the farmer's experience with drip irrigation. Relative risk values equal to 1 indicate neither an increased nor a decreased probability of failed adoption. Relative risk values greater than 1 indicate an increased risk of failed adoption (the greater the value, the greater the risk).

The Fisher's exact test is a measure of the statistical significance of count distributions among categories in a 2×2 contingency table (i.e., the probability that any given 2×2 contingency table will occur by chance). Fisher's exact test results reveal whether the number of subjects falling into a given set of overlapping categories is within the bounds of expected statistical variability. In this case, the Fisher's exact test shows whether the number of farmers both experiencing a specific problem and also falling into the disadopter cohort was statistically unlikely. The smaller the "p-value" (p), the less likely the result is, and thus the more significant the finding. Fisher's exact test resembles the Chi-square analysis of counts, but can be accurately applied to populations less than five (Zar, 2010). We applied a significance cutoff of $p = 0.05$ (De Veaux et al., 2008).

3. Results and discussion

3.1. Response rate and classification of respondents

After applying the definition of successful drip irrigation adoption, given above, the ratio of successful to unsuccessful drip irrigation users was 39–22 farmers, or 64% successful drip irrigation adopters. We observed that disadopters are difficult to find without direct connections to drip dissemination programs (e.g., Kulecho and Weatherhead, 2005). Organizations that promote drip irrigation are not eager to share failures with outside researchers. This creates an inherent bias. Nonetheless, the numbers of farmers are large enough in each category that comparisons can be made between the two populations (Goodman, 1969). Our 100% response rate results from the fact that respondents were primarily contacts provided by the local NGOs, government, and aid agencies who helped facilitate interviews.

Our statistical test results show that adopters in Ethiopia (RR = 3.6, $p = 0.0005$) are at a greater risk of failure than those in other countries. We cannot draw firm conclusions from these results, however, because there may be artifacts of sampling bias. Farm types are not distributed evenly among the four focus countries, which makes standard statistical comparison difficult (Fig. 1). Ethiopia also has the highest proportion of subsistence farms with 19 of 26 farmers, or 73%. In addition, our interview sample from Malawi contains no disadopters, which may contribute to the relative significance of our finding on Ethiopia.

Contingency analyses of successful adoption with respect to farm-type indicate that subsistence farmers have an elevated, but not significant risk of failure (RR = 2.0, $p = 0.1$). In contrast, commercial farmers have a slightly reduced, but also insignificant risk of failure (RR = 0.4, $p = 0.3$). We conducted the majority (33 of 61, 54%) of our interviews with subsistence farmers. Therefore these data encompass more potential outcomes than those for other farm types. The bias in favor of subsistence farms arises from the fact that most of the organizations that assisted with this research target smallholder households. It also reflects the economic reality in three of our four survey regions in which a majority of the population is engaged in subsistence agriculture (Table 1). These results support previous studies of drip adoption, in which poverty has been shown to be a good indicator of failed adoption (e.g., Namara et al., 2007). Subsistence farmers, in particular, have been found to be impatient with new technologies and unable to absorb risk (Belder et al., 2007; Kulecho and Weatherhead, 2005).

3.2. Major problems associated with drip irrigation adoption

Farmers were asked to report specific problems they encountered with drip irrigation. We divided the reported problems into two categories, problems reported about specific components of

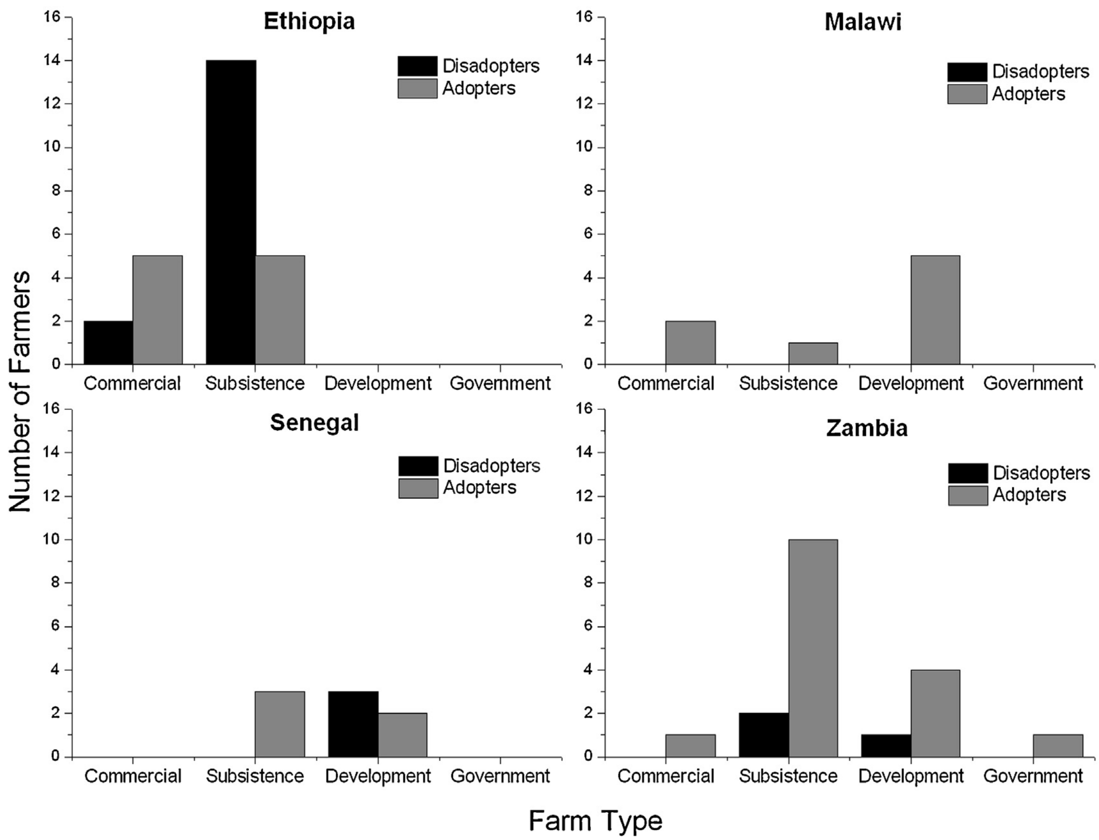

Fig. 1. Distribution of adopters and disadopters by farm type, subdivided by country. Ethiopia has the greatest number of disadopters (RR = 3.6, p = 0.0005).

the system (Fig. 2a) and problems reported by general type (Fig. 2b). Many farmers reported more than one problem, thus the total number of reported problems does not sum to the number of farmers interviewed.

The four most commonly reported problems were blockages, wear, problems with driplines and problems with filters. Successful adopters reported a wider variety of more complicated problems

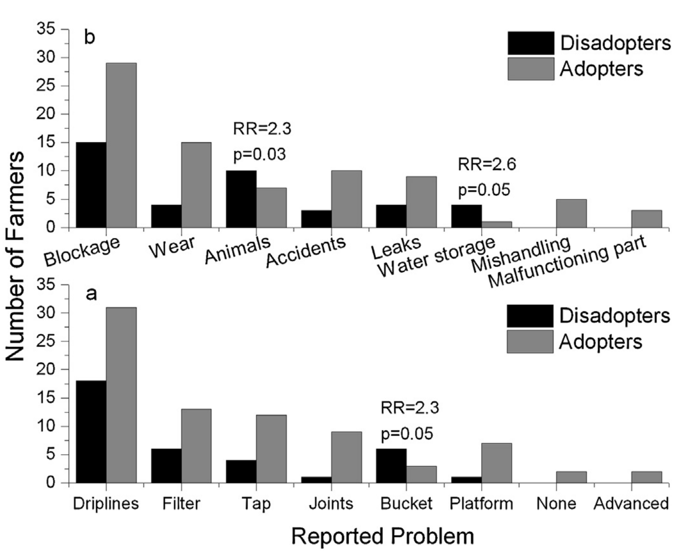

Fig. 2. Distribution of adopters and disadopters reporting problems with various system parts (a) and of various types (b). Displayed RR and p-values correspond to problems significantly associated with disadoption. 'Advanced' refers to computers and other high-tech components.

than disadopters. Only commercial farmers reported problems with advanced (computers or high-tech) parts, or no problems at all (Fig. 3).

The only component significantly associated with disadoption is the bucket – a generic name for the variety of water storage containers we observed in the field (RR = 2.3, p = 0.05). Logically, farmers reporting water storage problems have a risk of failure comparable to that of those reporting problems with their buckets (RR = 2.6, p = 0.05). Our results support previous findings that water storage and supply problems undermine sustained drip adoption (e.g., Kulecho and Weatherhead, 2005 and Belder et al., 2007).

The second most common problem (10 reports) for disadopters is damage caused by destructive animals (Fig. 2b). Reported animal problems include everything from absolute system destruction by marauding elephants, to system hardware loss after chewing by vermin (rats and other rodents) or hyenas, and are significantly associated with disadoption (RR = 2.3, p = 0.03). Subsistence farmers make up the majority of farmers reporting animal problems (82%). This may reflect the fact that subsistence farmers lack the resources to invest in adequately defending their fields from animals, or it may reflect the fact that poor farmers tend to own land further away from major population centers, where the likelihood of animal interactions is increased. The majority (54%) of subsistence farmers reporting problems with animals, however, continued to use drip irrigation and were classified as successful adopters. In contrast, the two commercial farmers and two development project farmers who reported problems with destructive animals, also reported that this led to their disadoption of drip irrigation.

This finding is compelling for two reasons. First, despite having been frequently reported by farmers surveyed in this study, we have not found any previous references to this issue in the

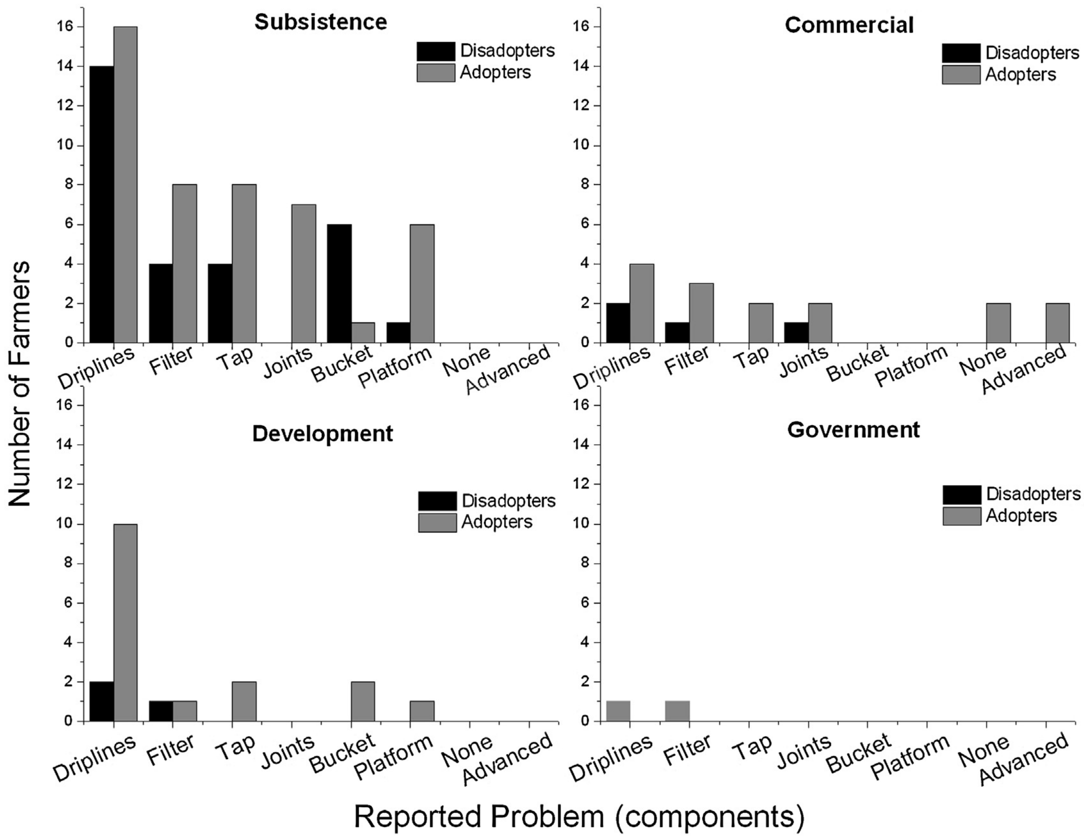

Fig. 3. Distribution of adopters and disadopters reporting problems with system parts, subdivided by farm type. As in Fig. 2, 'Advanced' refers to computers and other high-tech components.

literature. Second, although animals inflict damage most frequently on poorly guarded – usually poor and rural – farms, problems with animals can be devastating to any farmer and may lead to drip irrigation system loss and disadoption. Adding animal defense methods to farmer installation training is a straightforward way to address a common problem that significantly contributes to disadoption.

Although blockage and dripline problems were not significantly associated with failure, most (72% and 80%, respectively) of the farmers interviewed report one or both of these problems. In addition, farmers on all four farm-types report dripline problems (Fig. 3). Subsistence farmers had the highest rates of reported dripline (86%) and blockage (80%) problems. This may reflect the lower-quality, low-cost drip irrigation systems provided to or purchased by subsistence farmers. However, 40% of commercial farmers also report problems with blockage and 60% report problems with their driplines. Farmers using drip irrigation through participation in a development project also frequently reported problems with their driplines (80%) and blockage (73%). This indicates a common problem, irrespective of farm-type, which should be addressed to improve the chances of successful drip adoption in sub-Saharan Africa.

Theft can be a common problem for owners of drip irrigation systems in urban and peri-urban areas (the majority of our sample), however, only four of the interviewed farmers mentioned theft as an active concern. These farmers have a heightened risk of disadoption (RR = 2.25), but this risk is not significant ($p = 0.1$).

Our results reveal new trends indicating that drip adoption in sub-Saharan Africa would benefit from responses to the problems of water storage and damage by destructive animals. In addition, drip systems should be redesigned to address the common problem of dripline blockage.

3.3. Benefits associated with adoption of drip irrigation systems

Every interviewed farmer reported at least one benefit from the use of drip irrigation and many farmers reported more than one. Adopters reported the same number of benefits as disadopters and we found no benefits that significantly associated with either successful or failed adoption. These findings contradict our hypothesis that farmers experiencing many benefits from drip irrigation become successful adopters.

Successful drip adopters most frequently report that their system saves labor, closely followed by improves water use efficiency (WUE) (Fig. 4). Disadopters most commonly report that the system saves time. We differentiate saving labor from saving time by defining responses about making work easier as saving labor and those about making work faster as saving time. Farmers reporting that the system made work 'easier' (labor-saving) are more likely (RR = 1.4) to be successful adopters than those reporting that it made work 'faster' (time-saving) (RR = 0.8), but this is not statistically significant ($p = 0.2$ and $p = 0.3$, respectively). The trend, however, may reflect farmers valuing labor over time, or early adopters failing to commit to drip if they perceive it as more difficult to use than traditional irrigation methods.

Higher yield is one of the most frequently cited advantages of drip irrigation (e.g., Goldberg et al., 1976; Shoji, 1977; Howell et al., 1981; Bucks et al., 1982; Davis and Bucks, 1983; Phene et al., 1987; Keller and Blisner, 1990; Blum, 1991; Postel, 1999; Ibragimov et al., 2007). Yet fewer than half of our respondents cited increased yield as a benefit. This may reflect a lack of availability of additional agricultural inputs, advice and extension services. As Maisiri et al. (2005) showed, yields achieved with drip irrigation, without fertilizer, are not appreciably higher than those achieved with surface irrigation.

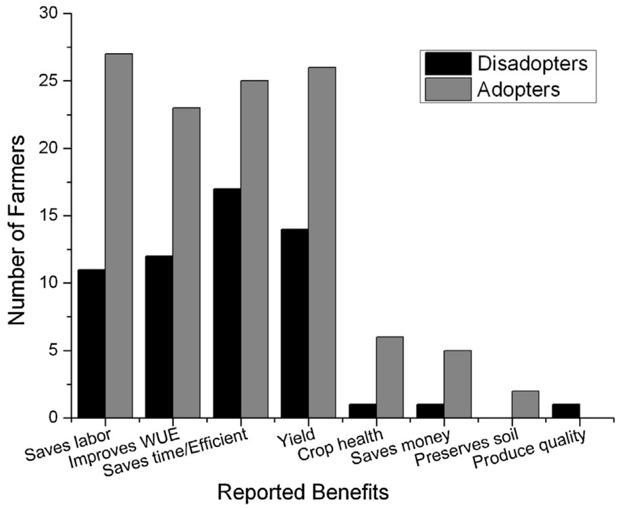

Fig. 4. Distribution of adopters and disadopters reporting various benefits of their drip irrigation systems.

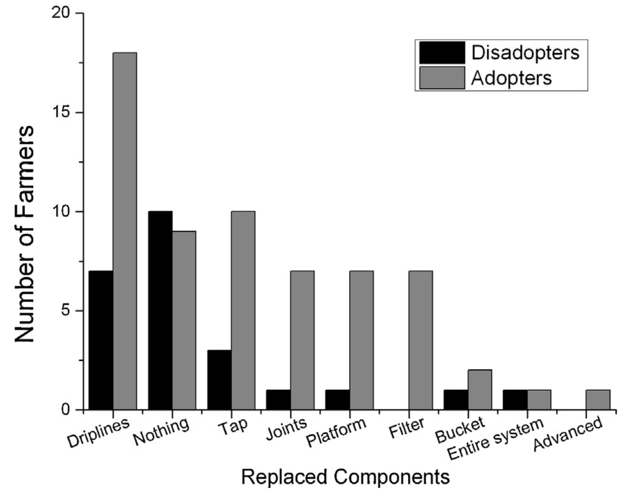

Fig. 6. Distribution of adopters and disadopters replacing certain parts of their drip irrigation systems. As in Fig. 2, 'Advanced' refers to computers and other high-tech components.

Belder et al. (2007) report that farmers often describe the virtues of new agricultural technologies in the hope of receiving aid. Our survey is probably sensitive to this source of bias. We observed disadopters describing benefits they received in great detail. This bias probably contributes to our finding that no specific benefit associates significantly with either adoption or disadoption.

Some of our respondents claimed that their drip systems were too small to observe full benefits. Despite this, we found no correlation for non-commercial farmers between the size of the drip system (shown in log-scale to better display the variation in size among small-scale farms) and the length of time a farmer uses drip irrigation (Fig. 5). However, it may be advantageous for adopters if providers were to help farmers organize into groups to purchase better quality systems. This approach is similar to that practiced by TIPA in West Africa (Woltering et al., 2011) and may allow poor farmers to take advantage of economies of scale to invest in more durable technology. Such technology is generally not available at the small scales required by individual subsistence farmers. During our fieldwork, we observed general complaints that small-scale, low-cost systems are not sufficiently durable.

Another example of the need for additional agricultural inputs is reflected in our finding that only one farmer (a disadopter) (Fig. 4) reported experiencing the benefit of improved produce quality. This finding supports the work of Belder et al. (2007) and Woltering et al. (2011) who demonstrate that drip irrigation is only viable as part of a long-term, comprehensive agricultural development plan.

3.4. Maintenance and repairs of drip irrigation systems

We asked farmers whether and what types of repairs or replacements they make to their systems. Most farmers (91.8%) reported making repairs, and 67.2% reported making replacements. Only three farmers reported making neither repairs nor replacements.

Repairs and replacements are not significantly associated with successful drip irrigation adoption. This fails to support our hypothesis that farmers who are better able to respond to problems are more likely to be successful adopters. However, farmers reporting making replacements are slightly more likely to be successful adopters (RR = 1.5, $p = 0.08$) than those who do not report making replacements. Farmers who make regular replacements have the economic resources to continue investing in their systems and this supports their adoption of drip.

Although replacements overall are weakly associated with successful adoption, there is no association between the replacement of a particular part of the system and successful adoption (Fig. 6). However, adopters report replacing more and a wider range of

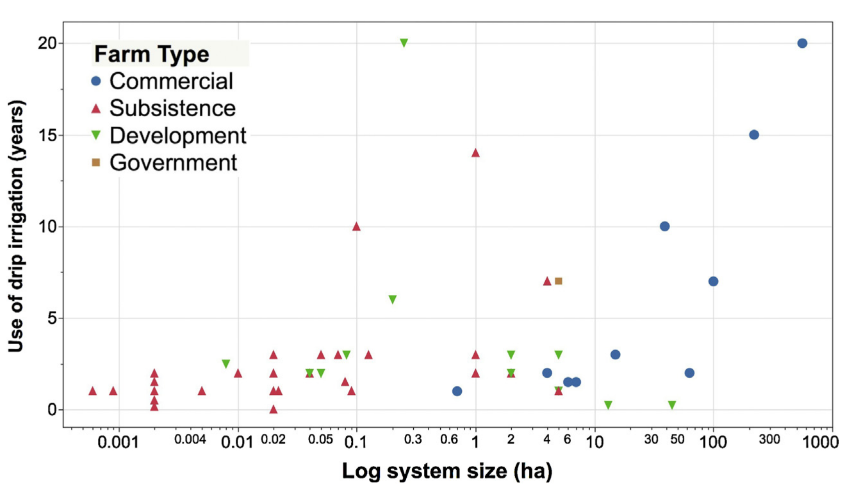

Fig. 5. Plot showing the correlation between log-scale drip irrigation system size and the length of time a farmer claims to have used drip irrigation (in years). There is a low-quality correlation ($r^2 = 0.373$) including commercial farms and no correlation excluding them. We plotted these data in log-scale to better display the distribution of sizes among small-scale farms.

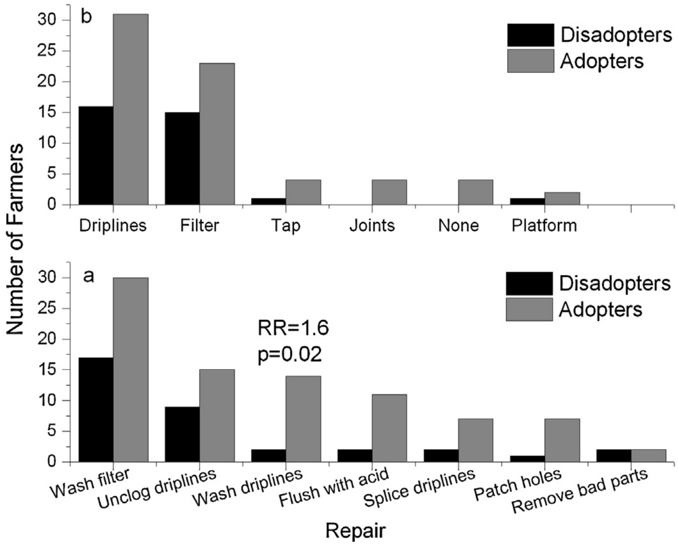

Fig. 7. Distribution of successful and unsuccessful adopters making repairs of various types (a) and repairs to various parts (b) of their drip irrigation systems. Displayed RR and p-values correspond to repairs significantly associated with successful adoption.

parts than disadopters. This further supports the conclusion that an ability to make replacements is actually a proxy for economic status.

In contrast, farmers who report washing their driplines were found to be significantly more likely (RR = 1.6, $p = 0.02$) to be successful adopters than those who did not report making this type of repair (Fig. 7a). This repair helps prevent blockage, which was the most frequently reported problem with drip systems (Fig. 2b). This finding suggests that proactive maintenance efforts and the corresponding work ethic are a good proxy for adoption. Farmers taught washing techniques can mitigate common problems on their own. Some drip irrigation providers (e.g., IDE, Netafim, TIPA) train farmers in the care of their systems, as indicated by the two most commonly reported repairs among successful adopters: washing the filter and unclogging driplines. Future investment in training programs should be supported to encourage successful adoption and prevent common problems.

As expected, driplines are the most commonly repaired component (Fig. 7b) and also the most frequently replaced (Fig. 6). Interestingly, we found no correlation between farm type and the time required to obtain replacement parts for the drip system (Fig. 8). We expected that development farms and commercial farms would be able to obtain replacement parts quickly as a result of government connections and economic status. Our results, however, show that obtaining replacement parts can take from 1 week to 15 weeks, and that farm type does not affect this timing.

Both successful adopters and failed adopters report making repairs and replacements to their drip systems. This may reflect inaccuracy by survey respondents attempting to provide perceived correct answers, or may indicate that even disadopters attempted to responsibly care for and maintain their drip systems before discontinuing.

During our fieldwork, we observed creative repairs practiced by innovative farmers. Most of these repairs were simple variations of washing or unclogging the driplines. Providing opportunities for farmers to teach each other repair methods will help spread effective maintenance and allow farmers to share information and experience. We recommend that drip irrigation providers consider making group-learning a part of regular maintenance and extension services.

4. Conclusions

Contrary to much of the literature on agricultural development, we found that only a few notable technical problems are strongly associated with drip irrigation disadoption. These include difficulty with water storage and damage by animals. Water availability, quality and storage are problems that are commonly associated with drip irrigation adoption and have been previously discussed in the literature (Kulecho and Weatherhead, 2005, 2006a,b). Problems with animal destruction, however, have not been previously reported and form an important part of this paper's contribution to the discourse about agricultural development and drip irrigation adoption. Destructive animals affect a much greater proportion of subsistence farms than commercial farms or development projects. These problems, however, can lead to disadoption regardless of farm type. During our fieldwork, one successful adopter mentioned that simple actions – such as, providing water for hyenas to prevent them from chewing driplines in the dry season – can mitigate or prevent the negative impact of animals. The efficacy of these and other possible animal defense actions should be tested by drip irrigation providers, and effective measures promoted during farmer training at installation.

The impact of very common problems such as dripline blockage on adoption is difficult to assess. Specific problems, however, can be corrected, and addressing them may make a significant difference in success or failure. Both successful and unsuccessful adopters report many technical problems. Thus, it may not be these problems

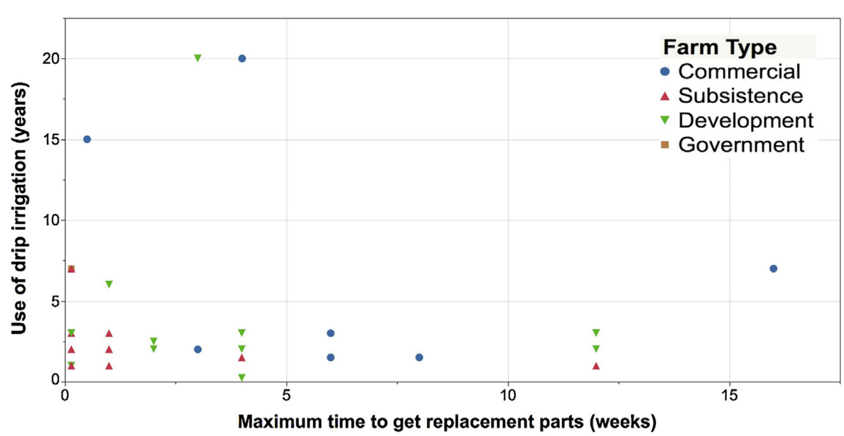

Fig. 8. Plot showing the correlation of the length of time farmers reported waiting for replacement parts and length of time they claimed to have used drip irrigation. We did not find any correlation between these variables, regardless of farm-type. We also see a wide range of wait-times irrespective of farm-type. This implies that commercial and development-project farmers do not necessarily have an easier time securing replacement parts for their systems.

alone that drive potential adopters to abandon drip irrigation, but additional problems or even macro-situtational factors (economic policies or market accessability). By asking individual farmers about their experience with drip irrigation, providers can target individual problems and help farmers obtain the right advice to meet their needs.

During interviews, disadopters reported many justifications for discontinuing their use of drip irrigation. Three farmers reported that they had discontinued use as a result of the destruction of their systems. These farmers claimed they could not afford to replace their systems, but if given the opportunity to start over, they would continue using drip irrigation. Twenty percent of disadopters reported that dismantling, storing and reinstalling their systems at the start, during and end of every rainy season was too difficult or time-consuming for them to continue. Most disadopters did not offer a specific reason, simply saying that they did not think the technology offered significant benefits over traditional methods.

It is not possible to assign any one problem or farmer experience a causal link with disadoption; in part because it is not possible to eliminate user preference, diligence, error and personality. Our results reveal, however, the importance for drip irrigation providers of encouraging farmers to invest in additional technologies to support their systems (water delivery and filtering technologies, fences and other animal defenses), and also the importance of asking farmers about their individual experience, as this can reveal new and potentially important issues.

Drip irrigation is not a panacea, but it can be highly effective at improving health and livelihoods if successfully adopted and correctly implemented (Burney et al., 2010). Unexpected technical problems can sometimes have large impacts on adoption success or failure. Common problems do not strongly correlate with either failed or successful adoption. Thus the reasons ordinarily given for disadoption may not be appropriate considerations for all farmers. To discover what new adopters need to be successful, we advise drip promoters in Africa to invest in frequent, direct interactions with adopters and to couple these interactions with training. This, along with greater user investments in complementary technologies, would significantly improve the probability of successful drip irrigation adoption in sub-Saharan Africa.

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