

# Diffusion of small-scale pumped irrigation technologies and their association with farmer-led irrigation development in Malawi

Jean Kamwamba-Mtethiwa<sup>1&2\*</sup> Kenneth Wiyo<sup>1\*k</sup> Jerry Knox<sup>2\*j</sup> and Keith Weatherhead<sup>2\*w</sup>

<sup>1</sup> Lilongwe University of Agriculture and Natural Resources, Malawi (LUANAR)

<sup>2</sup>School of Water, Energy and Environment, Cranfield University, Bedford MK43 0AL, UK

## Abstract

Adoption of small-scale pumped irrigation technologies were evaluated using field surveys in Malawi. Four pumped systems were identified, distinguished by ownership (group vs individual) and technology (treadle vs motorized). Farmer access to pumps was either through organizational support (incentivised) or privately (self-motivated) with progression depending on the mode of access and farmers attributes. Self-motivated farmers had better socio-economic status and access to knowledge supporting the pumps' continued-use. Conversely, incentives drive the uptake of other pumps and the provision of continued external support reinforced their continued-use. Farmers need to be supported beyond affordability by safeguarding the availability and maintenance of pumps.

**Keywords:** adoption; agriculture; Malawi; pump; sustainability;

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\* Corresponding Author: Jean Mtethiwa, LUANAR-NRC Campus, P.O. Box 143, Lilongwe. Email: [jmtethiwa@gmail.com](mailto:jmtethiwa@gmail.com)

\*k Email: [wiyoengineering@gmail.com](mailto:wiyoengineering@gmail.com)

\*j Email: [j.knox@cranfield.ac.uk](mailto:j.knox@cranfield.ac.uk)

\*w Email: [k.weatherhead@cranfield.ac.uk](mailto:k.weatherhead@cranfield.ac.uk)

## **Introduction**

More than 70% of Africa's poor live in rural areas and depend on rain-fed agriculture for their livelihoods (You et al., 2011), yet they face significant challenges associated with population growth and climate change (Knox et al., 2012). Irrigation development is considered a key option to increase agricultural production and build resilience to climate change in sub Saharan Africa (SSA). For example, the first of the four pillars of the Comprehensive Africa Agriculture Development Plan, advocated by the New Partnership for Africa's Development (NEPAD, 2003) is land and water development with a specific focus on irrigation development. Evidence from Asia shows that success in improving food security and tackling poverty has largely been through provision of irrigation infrastructure (Fujiie et al., 2011). In many SSA countries, small-scale irrigation is a fundamentally important component of agricultural development underpinning initiatives to increase food crop production, supporting livelihoods, household incomes and food security. Small-scale irrigation is typically characterized by the uptake of less formal and simple technologies often dependent on manual labour (Fujiie et al., 2011). Recently, there is evidence emerging of small-scale irrigation commonly termed farmer-led irrigation development. According to SAFI (2018), Farmer-led irrigation is a process in which small-scale farmers drive the establishment, improvement and/or expansion of irrigated agriculture, often in interaction with external actors. In farmer-led irrigation, farmers initiate and control the process of irrigation development having been convinced of its usefulness. Farmers do not wait for external assistance to provide technologies; instead they acquire the technology convinced that it has some utility.

In Malawi, agriculture accounts for about 37% of Gross Domestic Product and employs over 80% of the rural population. Most agricultural production is rain-fed (Chirwa et al., 2008) given the low level of irrigation infrastructure (less than 150,000 ha). Rain-fed production has failed to meet the food demands of the population which was reported to be increasing at +3.2% per annum (Chirwa et al., 2008). In Malawi, the frequency of droughts has been increasing suggesting that rain-fed agricultural systems may not be sustainable (Chidanti, 2011). To redress the situation, Malawi has been promoting small scale irrigation technologies (Wiyo and Mtethiwa, 2014; Kamwamba-Mtethiwa et al., 2016).

Irrigation development is a government priority to support food security, raise incomes and reduce poverty (Government of Malawi, 2011). Small-scale pump irrigation systems such as treadle and motorized pumps are among the technologies being widely promoted. In 1994, the Malawi Department of Irrigation introduced ‘Rope and Washer’ pumps to farmers in the wetlands. These were manual irrigation water-lifting devices intended for lifts of up to 5m and offered at a subsidised price. According to Wiyo (2002), the programme was phased out within a few months of inception because farmers lacked interest. In the late 1990s, the Department of Irrigation introduced small motorized pumps (5 and 7 horsepower (hp)) which were donated by the Taiwanese and Japanese governments (Government of Malawi, 2010). These were distributed freely to farmer groups. However, by the end of 1999 almost all pumps were abandoned due to high operating (fuel) and maintenance costs (Wiyo et al., 2002).

Despite reported failures, the Malawian government procured about 2,000 10 hp motorized diesel pumps from India (Government of Malawi, 2010) and distributed these free to farmer groups and on loan to selected civil servants. Furthermore, although treadle pumps had been widely used, in 2000 the government intensified the programme by distributing free treadle pumps to increase production and improve the livelihoods of resource-poor farmers (Mangisoni, 2008). In 2004, the distribution of treadle and group motorized pumps was extended such that Members of Parliament were distributing the pumps to farmers in their constituencies. This led to the distribution of approximately 60,000 treadle pumps to farmers between 2002 and 2005 (Government of Malawi, 2010; Kamwamba-Mtethiwa et al., 2012). Despite concerns regarding the appropriateness of these pumps (Joseph and Yamikani, 2011; Kadyampakeni et al., 2012), the government and other organizations continued to promote small-scale pump irrigation in various forms.

Studies have indicated that the potential area for irrigation expansion in Malawi is about 407,862 ha, which represents 15% of the arable cultivable area (Government of Malawi, 2015). However, by 2013/14, only 97,932 ha had been developed out of which 49,116 ha (50%) was under small-scale irrigation the remainder was under private estates (Government of Malawi, 2014). Over a third of that area was reported to be using small-scale pump irrigation technologies (Government of Malawi, 2014), highlighting its importance for agricultural production. However, there were concerns regarding small-

scale pump irrigation as these were considered expensive, and often promoted by aid agencies with gender-biases as some small-scale pump were not easily operated by women (Shah et al., 2002).

In Malawi, various initiatives including the Green Belt Initiative, Malawi Growth and Development Strategies and Agricultural Sector Wide Approach have been established to increase smallholder irrigated areas with small-scale pump irrigation being strongly promoted (Wiyo and Mtethiwa, 2014). However, it is not clear whether increased support towards small-scale pump adoption contributes to sustainable irrigation development. Sustainability is considered here in terms of whether farmers continue using and/or build upon the pumps they have adopted. This research focuses on providing new evidence to inform policies on the factors that influence the uptake of small-scale pump irrigation. Specifically, the research explored the opinions of stakeholders including farmers in selected districts of Malawi using the diffusion of innovation theory (Rogers, 2003) as one of the relevant theoretical frameworks. The results of this study are relevant to the many SSA (e.g. Ghana, Kenya) and Asian countries that are promoting small-scale pump irrigation as one way of improving crop production, livelihoods and food security.

## **Conceptual framework and methodology**

### ***Rogers (2003) diffusion of innovation framework***

A review of literature on technology adoption informed the selection of a model for designing this research. Technology adoption refers to “*the choice of acquiring and using a new invention or innovation*”; while diffusion is considered as “*the process by which something new spreads throughout a population*” (Hall and Khan, 2002 pg. 1). Contributions from new technology can only be realized if they are widely diffused and used. Diffusion is realized from a group of individuals’ decisions to start using the new technology. In making the decisions, individuals tend to compare the uncertain cost of adopting a new invention with its uncertain benefits (Hall and Khan, 2002). This implies that understanding factors affecting the decision choice is important for those investigating the growth or success of a technology. Garforth and Usher (1997) highlighted that numerous models relating to technology adoption exist in the literature and a comprehensive review may not be possible and hence

selected models were reviewed. However, the central insight of most of these theories is the recognition that human practices are built on various interrelated elements including norms, physical activities, mental activities, technology use, knowledge and meanings; these form their everyday actions and behaviour (Morris, et.al., 2012). The review showed that interpretation of adoption processes differ. In some models adoption is successful when a critical mass starts to use a new innovation whereas in others is considered to extend beyond taking the decision to use the technology and includes continued-use and/or discontinuance. To explore the sustainability of small-scale pump irrigation adoption process, Rogers (2003) diffusion of innovations model was selected as a suitable model to structure this research since it provides a comprehensive process for understanding adoption beyond taking the decision to use the technology.

Figure 1 about here

The theory of diffusion (Figure 1), considers innovation as an agent of behavioural change whereby both the attributes of an innovation and the characteristics of adopters ultimately determine the rate of adoption. Four main elements are recognised (Rogers, 2003): the innovation itself, communication channels, time and the social system. The Rogers model perceives that different communication channels have specific impacts on diffusion of innovations, and there are different roles that mass media and interpersonal communication channels play in influencing diffusion of innovation. The model perceives interpersonal communication channels as being more effective for persuading actual adoption. It also perceives that “social systems shape the boundaries around the diffusion such that communication is more effective among individuals with similar attributes (e.g. education, social status, values)” (Rogers, 2003). The model considers innovation as an agent of behavioural change and that both the attributes of an innovation and the characteristics of adopters determine the rate of adoption. Behaviour will change more rapidly if the innovation is considered as being better than previous options (relative advantage), it is consistent with existing values, experiences and needs of the potential adopters (compatibility), it is easy to understand (complexity) and able to be tested (trialability) and visible (observability). Hence, the diffusion pathway, which leads to the decision to either adopt or reject an innovation, occurs through five discrete stages, namely knowledge, persuasion, decision,

implementation and confirmation. This study analysed farmer and stakeholder responses and mapped these onto these five stages.

Criticisms of the model identified by Morris et al., (2000) include pro-innovation bias whereby the model perceives that an innovation should be diffused and adopted by all individuals in the social system. It also assumes that innovations should not be re-invented or rejected. This is considered as being prescriptive suggesting a prearranged, predictable and linear progression from awareness through to adoption. However these concerns have been addressed (Rogers, 2003). For example, the model relies on respondents to remember when a new idea was adopted suggesting potential for obtaining data that is inaccurate; this was resolved by triangulation in this study. Despite criticism, the diffusion of innovations model is useful for explaining adoption and diffusion of agricultural technologies (Morris et al., 2000). For example, Otte (2014) compared the motivation for adoption of solar cookers in developing countries and was able to establish the pre-requisites for adoption such as economic savings. In Malaysia, Sail and Hamad (1994) used the model to determine the level of technology adoption among smallholder rubber producers.

## **Methodology**

This study evaluated stakeholder perceptions and attitudes to factors affecting adoption of small-scale pump irrigation in Malawi. We used purposive sampling to select respondents and triangulation to assess the quantitative results. Multiple data sources included interviews, informal observations and organizational documents (e.g. annual reports, project documents). Selection of respondents was based on information provided by government officials. To select respondents from other stakeholders, the chief executives of the respective organisations were contacted to suggest potential respondents and interviews then scheduled. Farmer selection was guided by government extension workers relying heavily on their local knowledge about communities. To increase the sample size, snowballing was used whereby farmers were asked if they knew other individual farmers and/or farmer groups using the pumps in the surrounding areas.

Two field surveys involving semi-structured interviews with 212 farmers (201 pump adopters (Table 1) and 11 non-adopters) and 25 other stakeholders (including 10 from government departments, 9 from local and international Non-Governmental Organizations, 2 from the pump commercial distributors, 2 from the donors and 2 academic institutions) were undertaken in 3 districts between 2013 and 2014 (Lilongwe, Ntcheu and Mchinji) (Figure 2). These districts were chosen to represent the major agro-ecological zones where small-scale pump irrigation systems were potentially applicable. Lilongwe and Mchinji represent mid-altitude warm plain zones (760-1300m) whilst Ntcheu represents both the middle and low-altitude (200-760m), and a hot and dry agro ecological zone. Within each district, selection of the study sites was limited to an Extension Planning Areas with a large number of irrigation pumps. Formulation of the farmer and stakeholder questionnaires was guided by findings from a systematic review (Kamwamba-Mtethiwa et al., 2016).

Figure 2 about here

The systematic review revealed that technical and socio-economic factors are key drivers in performance of small-scale pump irrigation. Both surveys used similar processes. In general the farmers' questionnaires included the farmers' socio-economic history, pump characteristics, the adoption process in which the questions included farmers previous irrigation methods and reasons for adopting the pumps, the pump adoption profiles (pump types, operational status, crops grown, irrigated areas sizes, farmers' perception on labour demand, repair and maintenance, water supply, inputs for capital, continuity and discontinuity contributing factors), farmers membership in the cooperative societies and farmers' preferences and future prospects on the pumps. For pump non-adopters, their views on the pumps were sought; this included their knowledge about pumps, the reasons for not using a pump; any intention to use pumps in future, and their reasoning for the type of pump anticipated.

For other stakeholders, the questions were the same as the farmer questionnaire. This was to ensure triangulation of data gathered. In addition, it included the respondents' organization history and types pumps associated, the type of support provided, expected benefits, comparisons of the pumps, perceptions and future prospects. For informal observations, since most interviews with farmers were carried out right in their irrigation fields whilst irrigation activities were taking place, this provided an

opportunity to supplement the data by taking field notes on the processes taking place as the farmers were irrigating.

Given the nature of the research questions and the unequal sample sizes, descriptive statistical analysis using percentages and Chi Square tests were used to describe the profiles of small -scale pump irrigation currently adopted in Malawi. The responses from open-ended questions were analysed using content analysis techniques (Krippendorff, 2003).

## **Results and Discussion**

### ***Descriptive characteristics of pumps and adopters***

Four distinct pumped systems, comprising two pump types (treadle and motorized) and two ownership modes (group and individual) were identified (Table 1). For group treadle pumps, the average number of members sharing a pump was 10 (range 9-23); these were used on individual fields. For group-motorized pumps, average membership was 21 (range 12-38); these pumps were used on communal land usually provided by either the chiefs or one of the group members under agreed conditions. About half the group-treadle pumps were provided to farmers free while over a third were subsidised. Most individual-treadle pumps were obtained via subsidies; about a quarter were obtained privately at full cost. All group-motorized pumps were provided free whilst most individual-motorized pumps were sourced at full cost. Farmers relying on support from organisations were referred as ‘incentivised’ whilst those using their own private initiatives were called ‘self-motivated’.

[Table 1 about here](#)

Treadle pumps use human energy as their source of power; their capacity depending on the amount of energy applied by the farmers. Treadle pumps were either made from galvanized iron (Money Maker) or steel and timber (Advaith) (Njuki et al., 2014). Most group farmers were likely to use the Advaith pumps while most individuals used Money Maker pumps ( $p < 0.001$ ). This could be because the government only distributed the Advaith pumps to groups of farmers. However, farmers were generally in favour of the Money Maker pump as Advaith pumps were harder and heavier to operate. Advaith treadle pumps weigh 35-40 kg and have a high discharge ( $3 \text{ m}^3/\text{hr}$ ) compared to the Money Maker (15-

20kg; discharge 1.44- 4.32 m<sup>3</sup>/hr). For motorized pumps, two capacities (6 and 10 hp) were used. Most group farmers used the 10 hp pumps. The engine capacities for individual motorized pumps ranged between 3 and 10 hp with the most common size being 5.5 hp.

There was a significant difference ( $p < 0.001$ ) between group and individual ownership, in terms of whether the pumps were still used or not. The majority of group-treadle and motorized pumps were not used. In contrast, most individual treadle and motorized pumps were still in use. Similarly, most pumps acquired by the self-motivated farmers were likely to be operational compared to those acquired by incentivised farmers ( $p < 0.001$ ). The characteristics of both the group treadle pumps and motorized pumps may have contributed to them being non-operational. However there was no significant difference between treadle and motorised pumps in terms of whether the pumps were still in use or not.

Most treadle and group-motorized pump farmers used traditional irrigation methods (watering cans) prior to adopting the pumps. Considering that most of these pumps were either provided free or subsidized, it is likely that farmers were partly persuaded to adopt pumps by incentives. In contrast, most individual-motorized pumps farmers had previously used treadle pumps, suggesting that these had prior experiences with pumps. The results showed significant differences between treadle and motorized pump farmers in terms of the type of water sources used. A higher proportion of those using private wells used treadle pumps. None of the group-motorized pumps used shallow wells as their water source, possibly due to their larger water discharge.

Over 90 percent of farmers grew maize, the main staple food in the area. About a third, especially those with individual pumps, also grew vegetable crops including tomatoes, potatoes and onions for local sale. Most respondents were male (Table 1), middle aged (36-50 years), educated at least up to primary school level and with an average of six household members; a higher proportion of those educated to secondary school level were the self-motivated farmers ( $p < 0.05$ ) suggesting these had better knowledge than the incentivised farmers. Most of these had retired from paid work and settled in the rural areas. The dominance of men among the respondents could also be due to their flexibility and knowledge to respond to irrigation technology issues. In general, most farmers adopting the pumps had increased their irrigated areas. However, most incentivised farmers owned irrigated areas that were significantly ( $p < 0.001$ )

smaller (0.04-0.2 ha) compared to irrigated area for self-motivated farmers. Across all pump categories, farmers owned various household assets such as radios, mobile phones and bicycles (Table 1). In addition, of the very few farmers that owned larger-value assets (e.g. televisions, motorcycles, oxcarts and motor vehicles), the majority were the individual-motorized pump farmers indicating better access to financial resources currently or in the past. Furthermore, more farmers with the individual owned pumps (particularly those with motorized pumps) were likely ( $p < 0.000$ ) to belong to some community groups within their societies such as political, religious and socio-developments whereby most of them served as leaders in those groupings. For groups, very few farmers belonged to some community groups or some cooperatives within their communities.

Statistical analyses showed there was a significant difference ( $p < 0.000$ ) between groups and individual farmers in terms of 'ownership' and 'pump capacity'. Smaller pump capacity was more likely to be owned by individual farmers who had more positive socio-economic conditions compared to the group farmers who mostly owned larger capacity pumps. The farmers' pump adoption routes also were analysed; most farmers that started with group treadle and motorized pumps discontinued using the pumps while others reverted to traditional irrigation methods such as watering cans. In contrast, most farmers that started with individual treadle and motorized pumps continued using pumps for a longer period. Of these, about half of the individual treadle pump farmers switched to using individual motorized pumps. Most individual motorized pump farmers started with treadle pumps as a start-up irrigation technology.

### ***Mapping adoption of pumped systems onto Rogers diffusion theory***

The field survey results were mapped onto the five-stage decision-making process including the prior-conditions and knowledge, persuasion, decision, confirmation and implementation, in order to assess the relevance of Rogers (2003) diffusion theory to small-scale pump irrigation adoption.

Prior-conditions and knowledge: Most farmers agreed that it was the capacity of the pumps to increase their irrigated areas that motivated them to adopt, and that they could not increase their irrigated areas

with their previous irrigation methods. For example, treadle pump farmers claimed that watering cans demanded more labour. Similarly, motorized pump farmers who previously used treadle pumps claimed that treadle pumps were too demanding in terms of energy and provided lower water flow such that they could not increase their irrigated area. Most farmers also mentioned that the distance from the water source to their fields strongly influenced their decision to adopt pumps.

The results showed that the self-motivated farmers had more positive conditions prior to adoption of pumps than the incentivised farmers. Their attributes included good education, large irrigated areas, more capital assets, leadership skills and experiences in pump irrigation. This indicates that the conditions of the self-motivated farmers are consistent with the prior conditions advocated by Rogers (2003). Kamwamba-Mtethiwa et al. (2012) reported that relatively wealthy farmers had a significantly higher probability of adopting treadle pumps than their poorer counterparts. These results confirm that socio-economic attributes of self-motivated farmers play an important role in influencing farmer decisions to adopt pumps and that farmer-led irrigation is practiced mainly by those farmers who are more financially and socio-economically secure. This may also explain some of the reasons linked to gender disparities under farmer-led irrigation.

For incentivised farmers, except for the age and household size, most were only educated to primary school level, lacked leadership skills, owned small irrigated areas, lacked capital assets and were not innovative. These attributes show that these farmers were not fully prepared to adopt the pumps but rather external incentives influenced their decisions. This implies that the quality performance, progression towards adoption and positive feelings about the pumps may have been lower for these farmers (Herath, 2010). In South Africa, Fanadzo (2012) noted that weak institutions and poor technical skills of farmers were the major factors leading to under-performance in most small-scale irrigation systems.

Knowledge stage commences when an individual is exposed to an innovation's existence and gains an understanding of how it functions. For self-motivated farmers, pump knowledge was via friends who used similar pumps. Farmers either borrowed or rented pumps before making the decision to adopt. Similar observations were reported among farmer-led irrigation farmers (SAFI, 2018) who had the

opportunity to test the pumps before making their decision. On the other hand, most incentivised farmers learnt about the pumps through organisations (e.g. government, Non-Governmental Organisations) that promoted them. These organisations had different criteria for disseminating the pumps, which likely affected the farmers' exposure to information about small-scale pump irrigation. For example, the government indicated that their initial stage for disseminating the group-motorized pumps was to assess the feasibility of potential pump sites. This included checking the water supply, land availability and topography. Thereafter, farmers were approached for pump adoption suggesting that perhaps the government overlooked the aspects of farmers' technology exposure for successful adoption. For treadle pumps, one Non-Governmental Organizations indicated that it sets targets for its extension workers (e.g. number of pumps to be distributed within a specific period).

Given these approaches, it is likely that most incentivised farmers received pumps before fully understanding their function and related benefits. Group motorized pumps were completely new to farmers and the only source of the information was through the government. Furthermore, these pumps were only available in selected communities. This likely reduced the farmers' exposure to the pumps, thereby increasing their uncertainty towards them. This may support the importance of 'technology observability' in the adoption process (Morris et al., 2000; Rogers, 2003) and could explain some of the reasons for the consistent treadle pump adoption routes and patterns.

Persuasion: Here farmers seek information to reduce their uncertainty about the expected benefits. We explored how both the positive and negative attributes of the four pump types influenced the decision of farmers to adopt through the farmers opinions. The results showed that the attributes of most pumps adopted by the self-motivated farmers were often more compatible to the existing conditions of farmers than the pumps adopted by incentivised farmers (Table 1). Most pumps adopted by the self-motivated farmers were portable, could be used on farmers' small irrigated plots and could easily be tried by other farmers within the community, suggesting these pumps were consistent with most of the innovation attributes advocated by Rogers (2003). For incentivised farmers, the situation was different. The pumps were often heavier, required a water source with large volumes and were not portable while most farmers typically owned smaller irrigated areas and accessed smaller and undeveloped water sources (Table 1).

In addition, some pumps required resources for fuel and maintenance costs while most incentivised farmers had limited access to capital. This suggests that adoption of pumps by the incentivised farmers was not influenced by the innovation attributes but rather because the pumps were free or subsidised suggesting that the innovation attributes did not influence the farmers' decision to adopt.

Decision and implementation: Farmers sought confirmation of the earlier information regarding pump attributes (e.g. ability to reduce labour, increase water flow and increase irrigated area) as to whether their expectations prior to adoption were genuine. We explored this by assessing whether the expectations that farmers expected before pump adoption were indeed what they experienced. The results showed that adoption of the pumps created new challenges such as increased labour demand (for treadle pumps), high operational, repair and maintenance costs and the need for modified or alternative water sources (for motorized pumps). Farmers required additional resources, access to labour and technical knowledge to successfully adopt and continue using these pumps.

Farmers addressed these challenges differently with most self-motivated farmers using improvised strategies. For example; farmers replaced pump spare parts with locally available materials (e.g. replacing treadle pumps valves with parts from bicycle tyres) because they were innovative; some hired mechanics for pump repair and maintenance because they had access to financial resources; others received support from colleagues using similar pumps because they were influential within their communities. Based on Rogers (2003), the creation of these strategies can be understood as innovation re-invention which signifies technology acceptance. We argue here that the creativity of self-motivated farmers to cope with new demands by pumps supported their decisions to adopt the pumps and hence contributed to the increased pump adoption and continued-use.

For incentivised farmers, they struggled to fully understand how the pumps continued to function after adoption. For example, treadle pump farmers struggled to mobilise resources such as high labour demand, repair and maintenance. Group motorized pump farmers struggled to access resources such as operating costs (fuel) and developing water sources. Most incentivised farmers expected further support on operational costs, pump repairs and maintenance services from the promoting organisations. Although not all the organisations provided ongoing support, it included the provision of spare parts,

fuel, irrigation inputs (fertilizers, seeds and herbicides), and training and extension services. Of the farmers that received support, over half switched to using private individual-motorized pumps, about a third continued using the pumps, while only a very few abandoned the pumps after support was discontinued. This supports Chancellor (2000) who argued that poor farmers in SSA cannot afford to use small irrigated pumps which may explain the reasons for low uptake and discontinued use of most of the pumps acquired through incentives.

Confirmation (continued or discontinued pump use): In this stage farmers seek reinforcement for their innovation decision to adopt the pumps and are likely to reverse the decision if exposed to conflicting messages (Rogers, 2003). We explored farmer pump preferences if given a choice and whether they intended to use the same pumps over the next decade. The results showed that most farmers preferred individual-motorized pumps. However, none of the organisations promoted these pumps. Farmers provided various reasons including the ability for the pump to increase the irrigated area, being easy and simple to operate, and the freedom to use the pump. Several farmers preferred treadle pumps; mostly these were group-motorized pump users. The main reason was that the treadle pumps do not require fuel; supporting the argument that group-motorized pumps were possibly not compatible with farmers' financial status. Very few farmers preferred group-motorized pumps and none preferred group-treadle pumps. Regarding whether the farmers expected to use the same pumps over the next decade, the majority of individual-motorized pump farmers indicated 'yes' while most treadle and group motorized pump farmers indicated 'no'. Most treadle pump farmers indicated that they would change to individual-motorized pumps while the group-motorized pump farmers indicated that they would be using individual-treadle pumps. These farmers' choices agree with farmer-led irrigation findings by the Studying African Farmer-led irrigation (2018) that private motorized pump irrigation is increasingly rolling out in SSA.

The findings showed that not all the paths that lead to the farmers' decisions to adopt the small pumps are necessarily consistent with the five stages of the diffusion of innovation model (Rogers, 2003). However, self-motivated farmers were consistent with the stages of the model. Incentivised farmers tend to ignore the other stages (principally knowledge and persuasion). These farmers decide to adopt the

pumps (decision stage) before they get to proceed to ‘prior-conditions’, ‘knowledge’ and ‘persuasion’ stages in diffusion of innovation. The implication is these farmers would thus have little experience with pumps and be more likely to abandon them as in the case of group owned pumps. However, despite not fully complying with all stages of Rogers (2003) framework, adoption of other pumps such as individual-treadle pumps showed that most farmers continued to use them. These farmers also received continued external support from the pump promoting organisations such as extension, trainings and inputs. The provision of external support may thus have reinforced continued pump use. It was also believed that pump adoption followed a different adoption trajectory referred to here as the ‘incentivised’. The restructuring of Rogers (2003) conceptual framework to include an ‘incentivised pathway’ could support future policies in developing appropriate strategies to promote the uptake of technologies initiated by incentives. Furthermore, there is scope to evaluate other theoretical frameworks such as the Coward Hydraulic Property Theory in the small-scale pump irrigation adoption process.

### ***Research implications***

Malawi is one of the poorest countries in SSA and the pump adopters in this study represent typical rural farmers who rely on irrigation in many SSA countries. The findings show that there are differences on progression of the small-scale pump irrigation systems between the adopters, and these appear to emanate mostly from whether the pumps were adopted by the self-motivated farmers or the incentivised farmers. The mode in which the pumps were accessed appears to have implications on the characteristics of the farmers, their knowledge prior to adoption and the factors that persuaded the farmers to adopt the various pumped systems. Decision-making in technology adoption is a complex process and requires an adopter to select from series of choices. According to Rogers (2003), these choices are based on the socio-economic status of the potential adopters and the information available about the technology attributes. Whilst Rogers (2003) diffusion theory did not fit all stages of the adoption process, it does provide valuable insights for policy makers to base decisions on small-scale pump irrigation both in Malawi and SSA. For small-scale pump irrigation farmers, these choices are constrained by inadequate income to purchase pumps, have relatively small-irrigated areas and inadequate information on which

to base their decisions. These constraints can be worse when the pumped systems have related requirements including the need for technical skills, operating (fuel) costs, repairs and maintenance services. These affect the decision-making process.

In this study, farmers with better access to capital assets were found to have better access to information about pumps since they were innovative. Conversely, farmers with limited capital assets had poor access to the information. This suggests that the choices on the small-scale pump irrigation for those farmers with limited resource bases (financial, physical and social), were also restricted (DFID, 1999; Oni et al., 2011; Fanadzo, 2012). This could explain the reasons for small-scale pump irrigation discontinued-use among the lower socio-economic status farmers although they were provided with free/subsidised pumps.

The findings showed that not all the paths that lead to the farmers' decisions to adopt the small pumps are necessarily consistent with the five stages of the diffusion of innovation model (Rogers, 2003). However, self-motivated farmers were consistent with the stages of the model. The decision to adopt the pumps by the self-motivated farmers was based on their socio-economic status and understanding on the attributes of the pumps which is consistent with the diffusion of innovation theory (Rogers, 2003). These farmers had better attributes (e.g. good education, large irrigated areas, capital assets, leadership skills and relevant experience) that supported their decisions to adopt and continue using the small-scale pump irrigation. Continued or discontinued use of pumps will depend on farmers' satisfaction with the pumps in meeting their expectations. In order to promote uptake, policies promoting small-scale pump irrigation need to recognise the consequences of how different adoption pathways (self-motivated or incentivised) can impact on pump use and to offer solutions that will ensure sustainable adoption processes. In addition, the rapid adoption of the individual-motorized pumps by the self-motivated farmers could also be attributed to pump availability. The markets in Malawi are flooded with cheap Chinese-manufactured petrol water pumps, which are entitled to VAT exemption (World Bank, 2011). Trends observed elsewhere across SSA (Colenbrander and van Koppen, 2012; Namara et al., 2013; De Fraiture et al., 2014; Giordano and de Fraiture, 2014; Woodhouse, 2016) have shown that emerging

irrigation systems e.g. private petrol motorized pumps were increasing due to the import of cheaper Chinese-manufactured water pumps into the market.

In contrast, incentivised farmers tend to decide to adopt the pumps (decision stage) before they get to proceed to 'prior-conditions', 'knowledge' and 'persuasion' stages in diffusion of innovation. The implication is these farmers would thus have little experience with pumps and be more likely to abandon them as in the case of group owned pumps. Furthermore, these farmers lacked better socio-economic attributes which increased their uncertainty towards the pumps. However, despite not fully complying with all stages of Rogers (2003) framework, adoption of other pumps such as individual-treadle pumps showed that most farmers continued to use them. Other factors such as the provision of continued external support, their availability within the communities (which provided an opportunity to the farmers to test the pumps) and their ability to fit in the existing farmers' conditions such as the water sources, supported the adoption process and sustainability. These farmers received continued external support from the pump promoting organisations such as extension, trainings and inputs. The provision of external support may thus have reinforced continued pump use allowing them to survive the 'learning curve' (Burney and Naylor, 2012). This shows that the initial conditions leading to continued or discontinued-use of the pumps are significant in the adoption process.

In their study on the motivations and adoption of solar cookers, Otte et al. (2014) considered a personal motivation of a decision maker as significant if a small problem that occurred with the solar cookers was fixed by the adopters. Where the personal motivation was low, the smallest problem with the new technology led to discontinuance. This study supports this observation; most group pumps were discontinued because the farmers were not motivated sufficiently to adopt the pumps. However, researchers exploring adoption due to incentives should apply the Rogers (2003) model with caution. The study also revealed that among incentivised farmers, treadle pump farmers received continued external support compared to other pump categories. These findings are consistent with previous studies that reported treadle pumps were heavily supported by many organisations (Kamwamba-Mtethiwa et al., 2012) in Malawi. This could explain why there was a steady adoption rate of individual-treadle

pumps over time and a gradual change of a higher proportion of the adopters to the individual-motorized pumps.

According to Burney et al. (2012) and Carter et al. (1999) providing continued support to technologies such as treadle pumps helps ensure sustainability and reduces the possibility of adopters going back to their previous technologies. Policies that consider the capacity of the potential pump adopters to operate, repair, maintain and obtain the spare parts of the pumps may therefore be necessary for sustaining adoption. It may be that there are strong political, ethical and other reasons for supporting the poorer farmers, but these farmers are likely to need more and continuing support, which needs to be included in the strategies to sustain the adoption (Burney and Naylor, 2012; Djagba et al., 2014; Muchara et al., 2014). Previous studies argued that it does not help to provide physical capital such as pumps without addressing social or capital needs of the adopters (DFID, 1999; Djagba et al., 2014; Muchara et al., 2014). These findings have relevance to countries in Africa and Asia where small-scale farmer-led irrigation development is being widely promoted.

The study hypothesised that farmers without pump experience can effectively adopt individual motorized pumps. Evidence showed that such farmers might be supported by their socio-economic attributes to sustainably manage the pumps. However, these farmers lack technical skills, and in order sustainably promote adoption, there is a need to build-up their technical competences on pumps. This may include the provisions of technically competent extension workers, well-trained local artisans, clear information on pump operation and maintenance and easy access to spare parts. Alternatively, sustainability for these pumps can be ensured if policies promoting the pumps can emulate and apply 'servitizations' principles. According to Baines et al, (2009), servitization is defined as the innovation of organization's capabilities and processes to better create mutual value through a shift from selling product to selling product service systems. This implies integrating promotion of the small-scale pump irrigation with services and solutions that complement the adoption processes. For example, promotion of cheap pumps can be combined with services that ensure availability of pump spare parts. Finally, for sustainable adoption, our study proposes that policies promoting the uptake of incentivised pumps should consider supporting the potential adopters beyond affordability concepts whilst policies that

create an enabling environment and apply servitization principles such as allowing the inflow of cheap pumps and spare parts could be an alternative option for supporting self-motivated farmers.

This study revealed that pumps adopted through incentives are not clearly recognised by the diffusion of innovations model as an alternative pathway leading to adoption. A consideration of these discrepancies led to the need to clearly define success in adoption of small-scale pump irrigation. There is no common approach for identifying success for small-scale irrigation systems (Burney and Naylor, 2012; Hussain and Hanjra, 2004; Kamwamba-Mtethiwa et al., 2015). For example, most theories for technology adoption are concerned with the uptake and diffusion of new innovations (Garforth and Usher, 1997). In these theories, ‘success’ in technology adoption is often based on the number or proportion of adopters initially accepting the innovation. Rogers (2003) however attempted to include other stages (implementation and confirmation) beyond the acceptance, suggesting that innovations can be continued or discontinued even after the decision to adopt has been taken. This perspective suggests that continued-use can be used as a measure for success in adoption. Burney and Naylor (2012) recognised success in small-scale irrigation projects as when “the adopter realizes significant efficiencies and is able to reinvest in subsequent labour and cost savings, starting up the ladder of increasing investment and asset accumulation”. This suggests that successful adoption is beyond innovation continued-use and hence the need to re-define ‘success’ in small-scale pump irrigation adoption.

### ***Successful adoption and conditions for continued use***

Findings from field surveys agreed with most evidence in the literature on the success elements for small-scale pump irrigation. The results showed increased adoption trends, continued-use and change in the socio-economic status (e.g. accumulation of assets and reinvestment in labour saving technologies) in several pump types. Continued-use here is considered as when farmers used the pumps for a minimum period of six months or full irrigation season. Based on the analytical understanding, those pumps could be categorized as successful by using any of the success definitions. However, a reflection on conditions which contributed to these successes provided a new insight on how ‘success’ in the adoption process should be recognised. The analysis revealed that some pumps were adopted

through incentives. Anand (2014) argued that this does not necessarily mean that the adopters who have embraced a technology by incentives will continue using it but rather have honoured the idea as good and are likely to include it in their current agenda. The implications is that counting the number of adopters accepting the pumps as a success measure for adoption could be misleading especially with the incentive farmers.

The field results also showed differences in the conditions that supported the continued-use of small-scale pump irrigation between the incentive and self-motivated farmers. The provision of continued external support to the incentive farmers reinforced the continued-use of the pumps. For self-motivated farmers, their initial conditions such as previous experiences, exposure and better socio-economic status facilitated their continued-use. These differences suggest that the conditions leading to either the continued or discontinued-use of pumps are significant and should be incorporated in the adoption processes adopted through incentives. The results also found that most treadle pump farmers advanced to better pumps (individual private motorized pumps) and that success can be recognised beyond continued-use and by increasing investment as advocated by Burney and Naylor, (2012). These results seem to agree with the argument that there is a need for better understanding of ‘success’ in adoption of small-scale pump irrigation. We therefore propose that success in small-scale pump irrigation adoption can be realized when adopters have accepted the pumps, continue using them and are able to increase household investments and grow.

## **Conclusions**

This study evaluated the adoption of the small-scale pump irrigation systems in Malawi guided by Rogers (2003) theory of diffusion. We found that not all the small pumps adopted are consistent with Rogers (2003) diffusion of innovation decision-making stages. Four pumped systems, group treadle, group motorized, individual treadle and individual motorized pumps were identified and farmers with different characteristics and access to knowledge adopt these pumps. The study found that the pump adoption choices for farmers with limited resource bases, access to knowledge and exposure are narrow. The study linked this to the increase in the adopters’ uncertainty towards the pumps and argued that the

higher the adopters' uncertainty about the pumps, the higher the probability of the pumps being discontinued.

The study identified technical factors such as less labour demand and increased irrigated area as major enablers for motivating farmers to adopt small-scale pump irrigation; while both technical (e.g. repair and maintenance) as well as socio-economic (e.g. lack of capital for inputs and/or fuel costs) factors are the major reasons limiting adoption. However, not all the organizations that promote incentivised pumps consider the farmers' technical and socio-economical requirements and hence such pumps are less likely to be continued-use. Successful adoption can be supported with policies that integrate small-scale pump irrigation promotion with services and solutions that provide technical as well as socio-economic support.

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## **Diffusion of small-scale pumped irrigation technologies and their association with farmer-led irrigation development in Malawi**

**Kamwamba-Mtethiwa, Jean; Wiyo, Kenneth; Knox, Jerry W.; Weatherhead, E. Keith**

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