CRANFIELD UNIVERSITY

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Sustainable irrigation development: The adoption of small-scale pumped irrigation in Malawi

School of Energy, Environment and Agrifood (SEEA)
Cranfield Water Science Institute (CWSI)

PhD
Academic Year: 2012 - 2015

Supervisors: Professor Keith Weatherhead & Dr Jerry Knox

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ABSTRACT

There has been an increased interest on small-scale pumped irrigation (SSPI) in Sub Saharan Africa (SSA), however little is known on the adoption processes behind this technology. Moreover, the conditions for successful SSPI adoption remain largely unexplored. This research aims to achieve a deeper understanding of the present adoption processes to inform future policy. The thesis was framed around the diffusion of innovations model (Rogers 2003), using the systematic review methodology and field surveys. Interviews involving 212 farmers and 25 other stakeholders were conducted between 2013 and 2014 within 3 districts in Malawi. The responses were analysed using descriptive statistics and content analysis.

The systematic review revealed that evidence relating to pump performance in SSA was limited, lacked standards and confined within particular regions. The field surveys identified that four different pumped systems have been adopted by farmers in Malawi; group treadle, individual treadle, group motorized and individual motorized. Farmers generally prefer individually managed pumps that are easy to operate and fit in with their existing farming practices. Adoption is driven either by the attributes of self-motivated farmers or by incentives such as free or subsidized pumps. While adoption by self-motivated farmers is consistent with Rogers (2003) model, adoption due to incentives shows differences.

The research proposes a modification to the Rogers (2003) model and a revised definition of success in SSPI adoption, leading to a new framework showing pathways of success. This framework identifies the routes taken by farmers who successfully adopt or discontinue using pumps. Incentive farmers are typically the poorer; these need continued external support to survive the learning curve. For self-motivated farmers, their higher socio-economic status supports successful adoption. To ensure sustainability, SSPI promoters need to offer continued support to incentive farmers and/or reduce barriers to accessing the pumps for self-motivated farmers.

Keywords: farmers, diffusion of innovations, incentives, technology, Africa

DEDICATION

This work is dedicated to:

My little son, ***Comfort*** *…*

For your perseverance during my 3 years of absence

and

My late lovely father, ***Mr Hastings E. Kamwamba****,*

Who could not see the end of this journey…

'Dad, you will always be my Hero!!'

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I thank the Almighty God for His unconditional love....'*Your Grace for me is Sufficient'*, and '*Indeed with You, the Almighty God, everything is possible….*'

LIST OF PUBLICATIONS

The following articles have been derived from this PhD study so far.

Peer-reviewed papers:

Kamwamba-Mtethiwa, J. Weatherhead, K. Knox, J.W. (in press) 'Assessing performance of small-scale pumped irrigation systems in Sub Saharan Africa: Evidence from a systematic review, *Irrigation and Drainage*. Paper accepted on 11th May 2015. DOI: 10.1002/ird.1950.

Upcoming papers:

Kamwamba-Mtethiwa, J. Weatherhead, K. Knox, J.W. (in preparation): Diffusion of small-scale pump irrigation technologies: evaluating farmer adoption processes in Malawi: Paper ready for submission *to International Journal of Agriculture Sustainability*.

Kamwamba-Mtethiwa, J. Weatherhead, K. Knox, J.W. (in preparation): Pathways for sustainable SSI pumped systems in the SSA: A new conceptual framework for understanding success: paper under preparation *for submission to Journal of Agriculture systems*.

Conference presentations:

Kamwamba-Mtethiwa, J. Weatherhead, K. Knox, J.W. (2015): Diffusion of small-scale pump irrigation technologies: evaluating adoption processes in Malawi. Presented to: *World Water Congress XV,* International Water Resources Association (IWRA), 24 - 29th May 2015, Edinburgh, Scotland

Mtethiwa J.T, (2014), Small-scale irrigation development: Assessing the potential for sustainable small-scale pumped irrigation systems in Malawi. Presented to: *Environmental Manufacturing & Materials Annual Conference*, Doctoral Training Centre (DTC), 5th February 2014, Cranfield University, UK.

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LIST OF ABBREVIATIONS

ADB	African Development Bank
ADD	Agriculture Development Division
AEDO	Agriculture Extension Development officer
AEDC	Agriculture Extension Development Coordinator
ApproTech	Appropriate Technology for Enterprise Creation
ASWAp	Agricultural Sector Wide Approach
CAADP	Comprehensive Africa Agriculture Development Plan
CEBC	Centre for Evidence Based Conservation
CEE	Collaboration Environmental Evidence
CGAIR	Consultative Group on International agricultural Research
CUREC	Cranfield University Research Ethical Committee
DADO	Development Agriculture Division Officer
DAES	Department of Agriculture Extension
DARTS	Department of Agriculture Research and Technical Services
DALHP	Department of Animal Health and Livestock Production
DCP	Department of Crops Production
DFID	Department of for International Development (UK)
DOI	Department of Irrigation
DLRC	Department of Land Resources and Conservation
DWR	Department of Water Resources`
EPA	Extension Planning Area
FAO	Food and Agriculture Organization
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IRLADP	Irrigation Rural Agricultural Livelihood Development Project
IWMI	International Water Management Institute
FSR	Farming Systems Research
GBI	Green Belt Initiative (Malawi)
GDP	Gross Domestic Product
hp	Horsepower
JICA	Japanese International Cooperation Agency
kW	Kilowatts
MGD	Millennium Development Goals
MGDS	Malawi Goals and Development Strategies
MoAFS	Ministry of Agriculture and Food Security
MoAIWD	Ministry of Agriculture Irrigation and Water Development
MM	Money Maker
MMM	Money Maker Max

MP	Member of Parliament
NEPAD	New Partnership for Africa's Development
NIPDS	National Irrigation Policy Development and Strategy
NGO	Non-Governmental Organization
NSO	National Statistical Office
NRC	Natural Resources College
PECO	Population Exposure Comparator and Outcomes
PICO	Population Interventions Comparator and Outcomes
PT	Pump Technical Efficiency
RIDP	Rural Income Development Project
RDP	Rural Development Project
SE	Socio-Economic
SO	Socio
SPSS	Statistical Package for Social Scientists
SSA	Sub Saharan Africa
SSI	Small Scale Irrigation
SSPI	Small Scale Pumped Irrigation
SR	Systematic Review
ST	Systems Technical efficiency
TLC	Total Land Care
UEM	Usability Evaluation Methods

TERMINOLOGIES

Terminology	**Definitions used in this research**
Adoption	*The choice to acquire and use a new invention or innovation.*
Diffusion	*The process by which something new spreads throughout a population.*
Continued-use	*When innovations (e.g. pumps) remain used after adoption.*
Discontinued-use	*When the use of an innovation is stopped after its adoption.*
Incentives	*These are things or external rewards (e.g. subsidies, free, loans) that motivate or encourage individuals or groups to adopt something e.g. small pumps.*
Self-motivated	*The motivation that is derived from values and beliefs (intrinsically) to adopt the something (e.g. pumps) without an external reward.*
Incentive farmers	*The farmers who acquire the pumps through external rewards e.g. subsidies or for free.*
Self-motivated farmers	*The farmers who independently acquire the pumps (e.g. privately); without external financial support.*
Individual pumps	*Pumps owned and used by the individual farmers.*
Group pumps	*Pumps owned and used by the farmer groups.*
Innovation	*An idea, practice or object that is perceived as new.*
Trail/route	*A path or track that a farmer goes through in adopting more than one pump.*
Stakeholders	*These are individuals, groups or organisations that are*

Terminology	Definitions used in this research
	affected by the adoption of SSPI. These include farmers, promoting organizations, donors and pump suppliers.
Other stakeholders	*In this research this refers to all SSPI stakeholders except the farmers.*
Systematic review	*A standard literature review for accessing, appraising and synthesising scientific information whilst minimizing bias and uncertainty. It differs from conventional literature reviews in that it is a rigorous critical appraisal that draws on all relevant evidence with reference to a defined research question*
Sustainability	*The research consider sustainability as whether the farmers will continue using the SSPI and/or build upon it, rather than purely in terms of its technical sustainability*

1 . INTRODUCTION

1.1 Overview

This research explores the achievement of sustainable irrigation development in Sub Saharan Africa (SSA) through a better understanding of effective adoption of small irrigation pump (SSPI) technologies. An overview of large and small-scale irrigation (SSI) development in SSA and Malawi is first presented to contextualise the research. The research aim, objectives and approach are then described with a diagram outlining the thesis structure.

1.2 Research context: small-scale irrigation in SSA

SSA, together with South Asia, is a global hotspot of food insecurity. Population increase, climate change, soil degradation by erosion, decreased availability of water and land competition for urbanization are all factors that have been identified to contribute to this situation (Lal, 2013). In SSA, more than 70% of the poor live in rural areas and mostly depend on agriculture for their livelihoods (You et al., 2011). Considering the current existing challenges, irrigation development is regarded as a viable option to increase agricultural productivity in the region, however recent statistics show that only 6% of the land area is presently irrigated (You et al., 2011). Evidence from South Asia shows that the provision of irrigation infrastructure contributed significantly to the success in improving food security and alleviating poverty conditions (Fujiie et al., 2011). SSA requires similar investment initiatives to South Asia in order to experience a rapid growth in agriculture that can overcome the current poverty and food insecurity conditions.

Irrigation development in SSA was initially promoted as a measure aimed at narrowing the economic gap between the developed and developing countries through the promotion of export crops. Aid agencies facilitated this initiative by providing capital investments and technical assistance in the 1960s. A number of large-scale irrigation schemes were developed but evidence (Fujiie et al., 2011) shows that performance of most systems failed to meet the expectations. The poor performances were due to extremely high capital costs, insufficient benefits, lack of proper operation and maintenance costs, lack of ownership, poor project management and the lack of technical and management skills (Adams, 1990; Fujiie et al., 2011; Inocencio et al., 2005). This led to many aid agencies becoming reluctant to invest further in irrigation development in the region. In response, a new direction was taken which involved transferring management of the schemes to farmers. Thus, most governments in SSA maintained the schemes but handed control over to farmers. Nevertheless, these too led to numerous new challenges including water management, understanding the complexity of the irrigation structures to meet farmers' needs and land tenure issues (Nkhoma and Mulwafu, 2004). Given such experiences with larger more complex schemes, current efforts are instead focussed on increasing agricultural productivity in SSA through SSI development.

SSI is characterized by the use of less formal and much simpler technologies often constructed without design blueprints and heavily dependent on human resources (Fujiie et al., 2011). Carter (1989; pg. 545) defined SSI as ''*an irrigation, usually on small plots, in which small farmers have the major controlling influence, and using a level of technology which the farmers can effectively operate and maintain*''.

Evidence suggests that as irrigation development advances, new technologies emerge to match with the development (Inocencio et al., 2005; Namara et al., 2010a, 2010b). In SSA, one of the major barriers to SSI development is water access technology; the method of moving water from its source to the irrigated fields (Burney and Naylor, 2012). Previously, most rural farmers relied on traditional irrigation methods such as buckets, watering cans and calabashes (Baba, 1993). These irrigation methods have limited productivity since they involve fetching water from water sources and transporting it manually to irrigation fields (FAO, 2000). For this reason, SSA has experienced introduction of a wide variety of other technologies including gravity river diversion and various pump types since the 1990s (Table 1.1).

Gravity river diversions typically involve diverting water flow using gravity for irrigation purposes. These are usually considered as the simplest and cheapest technology (Chidanti-Malunga, 2009). However, their use is limited to specific topographical and hydrological conditions such that not all smallholder farmers can adopt such technology (Kamwamba-Mtethiwa et al., 2015). Small irrigation pumps are considered a suitable alternative, and their use has substantially increased in SSA. Small pumps include all types, from human powered such as treadle pumps, to liquid fuel engine driven systems such as petrol and diesel motorized pumps and renewables-driven pumps such as solar powered (Burney and Naylor, 2012).

Table 1.1: Key attributes of SSI water access technologies used in SSA

Attribute	**Traditional methods**	**Gravity river diversion**	**Treadle Pump**	**Motorized pump**	**Solar/Wind Pump**	**Rope & washer pump**
Power source	Human	Gravity	Human	Fossil fuel	Renewable	Human
Type of lift/pump	Bucket, watering can or calabash	Gravity	Piston pump	Centrifugal pump	Centrifugal pump	Rope & washer
Typical discharge	<1 l/s	>10 l/s	< 2l/s	>2 l/s	>2 l/s	Up to 1 l/s
Water sources	Surface & groundwater	Surface	Surface & groundwater	Surface & groundwater	Surface & groundwater	Surface & groundwa ter
Initial cost	Very low	Low	Moderate ($20-$100)	High ($300-1500)	Very high ($3,000-10,000)	Low
O & M costs	Very Low	Low	Moderate	High	High	Low
Typical Irrigated area	<0.1ha	>10ha	<0.3ha	>10ha	>10ha	<0.2ha

Source: Various including websites for pump manufacturers

1.3 Research focus: the case of SSI technologies in Malawi

In Malawi, agriculture is an important economic sector which accounts for about 37 percent of the gross domestic product (GDP) and employs over 80 percent of the rural population. Most of the agricultural production is dependent on rainfall (Chirwa et al., 2008). However, rain-fed agricultural productivity has failed to meet the demands of the rapid (+3.2 percent pa) population growth (Chirwa et al., 2008). Furthermore, the situation is worse with the declining in soil fertility, natural disasters such as floods and droughts, and low purchasing power of farmers to buy agricultural inputs (Dorward and Chirwa, 2011; FAO, 2000). This has led to increased poverty and food insecurity. In order to redress the situation, the government has been promoting various SSI technologies (Kadyampakeni et al., 2012; Mangisoni, 2008; Wiyo and Mtethiwa, 2014) within the smallholder irrigation sector in order to supplement rain-fed agricultural production. This smallholder irrigation is mainly practiced during the dry seasons (between April and November) in seasonal wetlands (commonly known as dambos).This SSI sector produces mainly cereals (mostly maize and rice) and horticultural crops.

In 1994, the Malawi Department of Irrigation (DOI) introduced ‘Rope and Washer’ pumps to farmers with farms located in the wetlands. These are manual irrigation water-lifting devices intended for lifts of up to 5m, and were offered to farmers at a subsidized price. According to Wiyo (2001), the programme phased out within a few months of its inception because farmers lacked interest in these pump types. In the late 1990s, the DOI introduced small motorized pumps with 5 and 7 engine horsepower (hp) which were received as donations from Taiwanese and Japanese governments (Government of Malawi, 2010a). These were distributed freely to farmer groups. Reports (e.g. Wiyo et al., 2002), indicate that by the end of 1999 almost all these pumps were abandoned due to higher operating cost (fuel) and maintenance problems which were not experienced with the traditional irrigation methods.

Despite the motorized pumps being abandoned, in 2005 the government procured about 2,000 10hp motorized diesel pumps from India (Government of Malawi, 2010a). These were distributed freely to farmer groups and on loan to selected civil servants. Furthermore, although treadle pumps had been in use earlier, in 2000 the government intensified the program by distributing free treadle pumps to increase agricultural 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 (MPs) were distributing the pumps to farmers in their respective constituencies. This initiative led to the distribution of approximately over 60,000 treadle pumps to farmers between 2002 and 2005 (Government of Malawi, 2010a; Kamwamba, 2004; Kamwamba-Mtethiwa et al., 2012). However, there were still concerns regarding the appropriateness of these pumps mostly due to the limitations that these present to farmers (Joseph and Yamikani, 2011; Kadyampakeni et al., 2012; Kamwamba-Mtethiwa et al., 2012; Peters, 2004). Nevertheless, government and other organizations continue to promote SSPI in various forms. Presently, over a third of the irrigated area under SSI is reported to be using pumps (Government of Malawi, 2014).

1.4 Research rationale

It is widely recognized that SSPI can improve food security, create employment, reduce poverty and increase household income (Adeoti, 2006; Mangisoni, 2008; Namara et al., 2010; Burney and Naylor, 2012). However, these pumps are considered as expensive, driven by the promoters such as aid agencies and governments, bureaucratic and gender biased (Ashah et al., 2002; Baba, 1993; Namara et al., 2010b). Despite these differences, there have been several agreements to encourage investment in SSI development in order to reduce poverty and meet the SSA food security targets (Inocencio et al., 2007). For instance, the first pillar of the Comprehensive Africa Agriculture Development Plan (CAADP), advocated by the New Partnership for Africa's Development (NEPAD), stresses on irrigation infrastructure development in which SSPI are components (NEPAD, 2003). In Malawi, various initiatives including the Green Belt Initiative (GBI), Malawi Growth and Development Strategies (MGDS) and Agricultural Sector Wide Approach (ASWAp) have been established to increase smallholder irrigated areas and SSPI are envisaged as one of the main technologies to be promoted (Wiyo and Mtethiwa, 2014). These initiatives seem to suggest that adoption of SSPI has a substantial support in SSA region.

However, it is not clear whether the increased support towards SSPI adoption contribute to achieving sustainable irrigation development. Guided by the diffusion of innovation model (Rogers, 2003), this research focusses on providing new evidence to inform current and future policies on sustainable uptake of SSPI. Sustainability is considered here in terms of whether farmers will continue using and/or build upon the pumps adopted. Previously, most research on SSPI has focused mainly on technical improvements of pumps and scheme designs (Borgia et al., 2013; García-Bolaños et al., 2011; García-Ponce et al., 2013; Kadyampakeni et al., 2012; Kang'au et al., 2011) while the socio technical context and particularly issues related to successful adoption have been largely ignored (Manzungu and van der Zaag, 1996). More importantly, the conditions of examples of successful adoption of SSPI remain largely unexplored. A deeper understanding of the present adoption processes could contribute significantly to informing policy debates for supporting SSPI uptake. The research offers a new conceptual framework for understanding and categorizing success in SSPI adoption as empirical evidence from Malawi shows that adoption due to incentives is not fully consistent with the Rogers model (2003).

1.5 Research aim and objectives

The aim of this research is to assess the adoption processes and sustainability of small-scale pumped irrigation (SSPI) in Sub Saharan Africa, with a focus on Malawi, in order to increase knowledge and inform policies supporting its development. The objectives identified to fulfil the research aim include:

1. To identify the key factors affecting the performance (sustainability) of small-scale pumped irrigation in Sub Saharan Africa.
2. To understand the small-scale pumped irrigation systems currently being adopted in Malawi.
3. To critically evaluate farmers' and stakeholders' opinions on factors affecting the adoption process and subsequent success or failure of small-scale pumped irrigation in Malawi.
4. To critically evaluate the suitability and application of Rogers (2003) diffusion of innovations model to small-scale pumped irrigation in Malawi.
5. To inform policies supporting small-scale pumped irrigation development in Malawi and Sub Saharan Africa.

1.6 Research approaches

The research employs literature review and field survey approaches in which the systematic review (SR) and mixed-methods are used to achieve the objectives. Initially, the SR explored evidence on key factors affecting sustainability of the SSPI in SSA. Insights from these provided grounds for developing strategies (data needs) for subsequent research objectives. The research then conducted two sequential field surveys in which qualitative and quantitative data were collected through interviews with farmers and other stakeholders to understand the adoption processes. Similar data collection techniques were used for both field surveys. For logistical reasons, both surveys were conducted in the central region (3 districts) of Malawi.

1.7 Research structure

The thesis is structured into nine chapters (Figure 1.1). The first four chapters provide the thesis foundation. The SR approaches, results and discussions are presented in chapter 5. For field surveys, both quantitative and qualitative results are described in chapter 6 and their discussion in chapter 7 leads to a proposed new conceptual framework showing pathways of success in SSPI adoption. Chapter 8 aggregates all the evidence, discusses new insights and their wider application to knowledge as well as the methodological limitations. Finally, chapter 9 offers a summary of the major findings for each of the research objective and details how these contribute to the research aim. The appendix section presents field surveys' questionnaires, procedures followed in content analysis techniques, part of the SR and statistical comparison results.

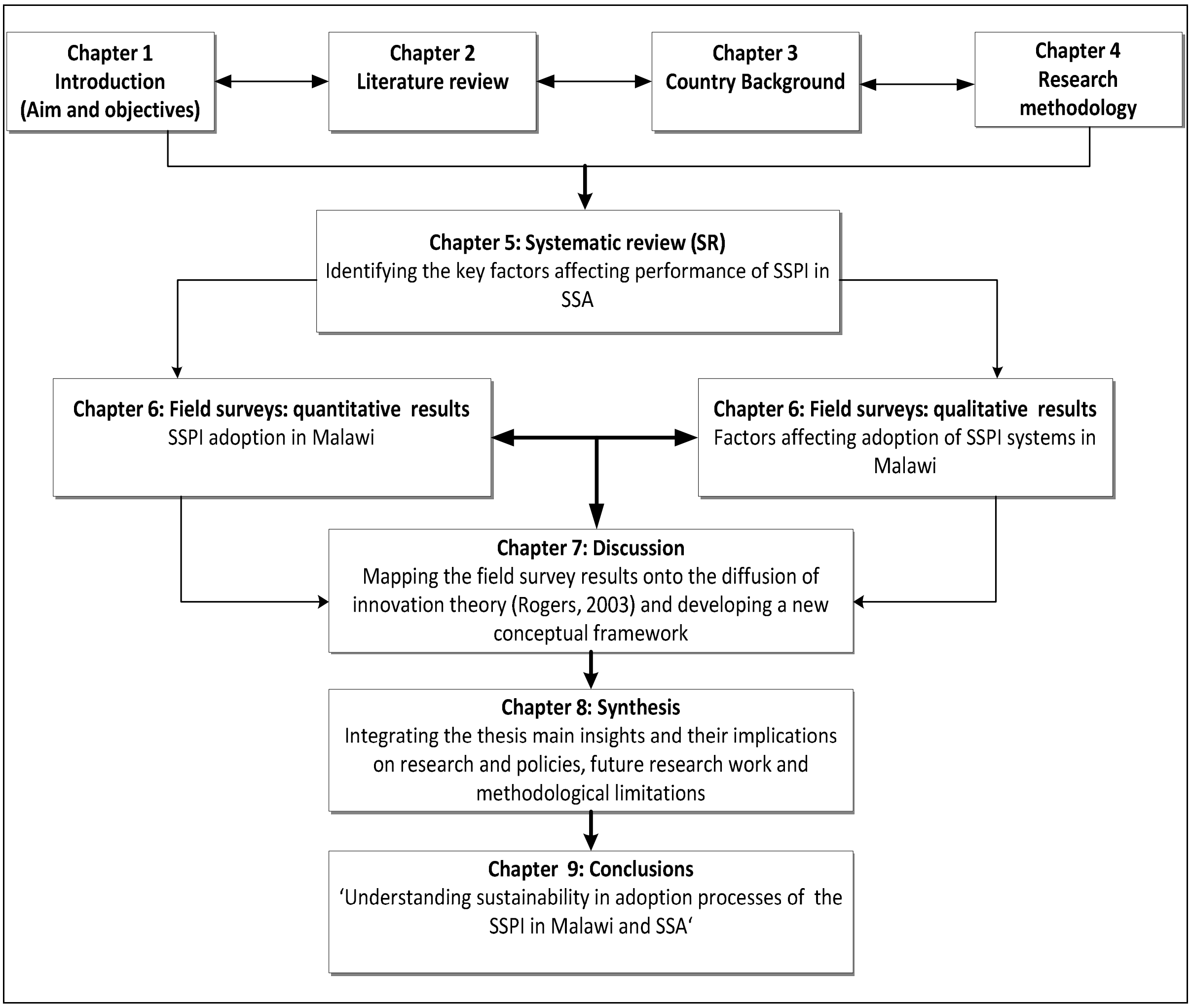

Figure 1.1: Thesis structure

1.8 Research positionality

The researcher has the following past related experiences and study backgrounds which may have intended or unintended influence on this research.

- Family background: the researcher comes from a rural farming background that used traditional watering cans for irrigation.
- Education background: the researcher holds a Bachelor of Science Degree in Agricultural Engineering from the University of Malawi and a Master Degree in International Land and Water Management (specializing in Irrigation Engineering) from the Wageningen University, The Netherlands.
- Research background: Under Master's degree study, the researcher conducted a research project entitled '*The introduction of treadle pump irrigation technology and its impact from a gender perspective*.'
- Working experience: the researcher once worked as an irrigation officer (in the Ministry of Agriculture and Irrigation); the job included the dissemination of irrigation pumps (treadle and motorized) to smallholder farmers.
- Teaching experience: The researcher worked as a Lecturer in Irrigation and Water Management at an Agricultural College; the job involved training agricultural extension workers and irrigation technicians who upon graduating from the College work directly with smallholder farmers in disseminating agricultural production technologies including irrigation pumps.

The experiences and background of the researcher supported a holistic approach to the research. The farming background experience helped the researcher to easily relate to the farmers and understand the adoption processes involved in SSPI systems. The teaching experience supported the researcher in understanding clearly the research gaps requiring further research. The working experiences (e.g. irrigation officer) helped the researcher to develop appropriate methodologies for achieving the research objectives. However, given the researcher's background, there is a risk of ignoring the obvious. Nevertheless, triangulation of data sources helped to ensure that all important data were obtained in the research.

2 LITERATURE REVIEW

Chapter one showed the need for new evidence in adoption of SSPI to inform policy and outlined the objectives for achieving this. In order to stimulate the analytical thinking towards conceptual and methodological issues for attaining these objectives, this chapter reviews models of technology adoption, sustainability and success. These informed the selection of a model that underpins this research.

2.1 Introduction

One way of understanding technology is as a collection of things (e.g. techniques, practices and processes) created by humans that make life easier or solve problems such as machines, computers, devices and factories. These can be operated by persons without detailed understandings of such things.

2.1.1 The concept of technology

Technology is physically constructed by actors working in a given social setting, and is socially created by actors that assign different meanings to it and emphasize various features and utilization (Orlikowski, 1992; Vincent, 1997). It is often argued that once technology is developed and deployed, it becomes institutionalized such that it loses its connection with those who developed it or gave it meaning, and then it becomes part of the objective, and structural properties of those using it. This implies that researchers examining the design and development of a technology are confronted with the constructed nature of technology and their focus is on how designers fashion and construct a technology. It is argued that such studies are less likely to treat technology as fixed or objective, recognizing its dynamic and contingent features. On the other hand, researchers investigating the use of a technology tend to focus on how the given technology influences its users and how it affects the recognized properties of the organization or individuals. Certainly, such researchers ignore the human agency that initially produced the technology, and do not take into account the ongoing construction of technology (socially and physically) that transpires during use of technology (Hall and Khan, 2002).

2.1.2 Appropriate technology

The concept of appropriate technology started in 1970s (Cornish, 1998). The central concept was that technologies designed for developed countries do not match with the conditions in developing countries (Cornish, 1998). Appropriate technology is understood as technologies that ''*are easily and economically used from readily available resources by local communities for the developing world*'' (Pearce et al., 2012, pg. 43). For example, while modern irrigation technologies in developed countries are designed to be more efficient such as improved water use efficiencies, reduced labour and other operating costs; in developing countries these factors are less important compared to factors such as low cost, simplicity of design and operation, reliability, longevity, few requirements for spares and low energy requirements (Cornish, 1998). This suggests that careful consideration of technology attributes is important when promoting technologies in developing countries. Cornish (1998) classified factors such as divisibility, maintenance, risk, operational skill and durability (Table 2.1) of technology as critical in influencing the uptake of modern irrigation technologies in developing countries. According to these factors, appropriate technologies for smallholders should be those that are reliable, not too complex (resource or skill intensive), adapt to suit the existing methods and can work together to link to other processes deployed in irrigation (integrated).

However, the concept of appropriate technology suggests that the priorities of the potential adopters are only translated in design and technical instructions for operation and maintenance of the technology (Cornish, 1998; Waller, 1989). This suggests that little is known on the adoption processes behind these appropriate technologies. Similarly, the SSPI widely promoted in SSA could be considered as appropriate technology for smallholders; consequently its success will not only depend on its design but also an understanding of its adoption processes.

Table 2.1: Factors influencing the uptake of modern irrigation technologies

Technical factor	Level uptake of the irrigation technologies				
	High	**Medium**	**Low**	**Very low**	**None**
Divisibility	Well suited for use on any area and shape of the plot	-	Only applied with difficulty and/or high expenditure to small plots	-	Only suited for use on large and regular-shaped plots
Maintenance	Only require basic skills	Can be maintained by farmers but requires associated with more entrepreneurial farmers	Some special skills required	Specialist technicians with workshop facilities and equipment required	Cannot be maintained
Risk	-	Risk of failure is slight and problems can easily rectified	Failure of the component would only affect the supply of a single unit	Failure of a single component can result in complete shutdown	-
Operational skill	No skills required	Few skills easily acquired	Considerable skills and care required to operate	Needs good understanding of the system	Require complex technical skills
Durability	Systems with no moving parts- unlikely to break-down *(Robust)*	System not likely to suffer breakdown or damage through improper handling *(Durable)*	System require careful operation and extensive workshop and spares back up *(vulnerable)*	System highly prone to breakdown *(Fragile)*	-

Source: Adapted from Cornish (1998)

2.2 Theories of technology adoption

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. According to Hall and Khan, (2002) 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 literature and a comprehensive review of all may not be possible. 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 forms their everyday actions and behaviour (Morris, et.al., 2012). Considering that this research focusses on typical rural farmers, selected theories that associate technology adoption with its end users were reviewed (Table 2.2) and the diffusion of innovations model was finally selected to underpin this research (section 2.2.5).

2.2.1 Model of technology development process

The technology development process model has evolved over time depending on the perspectives of users. Rather than one model, technology development models are like an umbrella approach under which different aspects are investigated (Garforth and Usher, 1997). In general the model suggests *''a simple sequence of stages moving from basic and applied scientific research, through the generation, testing of technology, to dissemination and diffusion of 'proven' technology*" (Garforth and Usher, 1997 pg. 308). According to Garforth and Usher, (1987), an example of these models is the Technology Innovation Process (TIP) which is regarded as more useful and simple than earlier ones because it allows for functional overlapping in some aspects. It perceives the transfer of technology as not simply being passed from developers to the extension agents, but rather both parties are involved in testing, adaptation and integration of the technology into the systems. It is however argued that the model does not explicitly include the end users in technology development stages. Moreover, the approach has substantive success in industry and agriculture with resource-rich clients (Chambers, 1985). Considering that the focus of this research is on rural smallholder farmers who are typically the poor, this model may not be appropriate. However, using the model may help to identify the barriers to effective technology uptake such as human, management and institutions constraints (Garforth and Usher, 1997).

2.2.2 Farmer first model

Farmer first model was developed later in the 1980s (Chambers et al., 1989). The model differs from the TIP and other earlier models by emphasizing the need for the scientists to involve farmers from the beginning in the technology development. The model stresses that the main focus of research and learning is the resource-poor farm rather than research stations and laboratories such that the process should begin with the scientists learning the farmers' resources, needs and problems. The model views research stations and laboratories as referral and consultancy role that serve the farmers as secondary. While the model is criticised because it does not differentiate the interests within communities (Scoones et al., 2008), it has been useful in other research aspects. Using the model, Broerse and Bunders, (2000) identified the reasons for scepticism of biotechnology as a useful tool in poverty alleviation among the development community. That study was able to recommend the implementation of farmers', scientists' and other stakeholders' interactive and participatory approach to innovation process (Broerse and Bunders, 2000). Despite its emphasis on farmers, this model may however not be relevant for this research because SSPI in Malawi are transferred to farmers without their participation in its development processes.

2.2.3 Model of research management process

The model of research management process suggests a framework of reviewing the uptake and impact of renewable natural resources from the donors' perspectives (Garforth and Usher, 1997). Alongside these beliefs, the model posits that the process by which specific research projects are prepared, commissioned and managed are important factors in the production and uptake of the innovations (Garforth and Usher, 1997). The model's beliefs are supported by the identification of key questions within each of its five stages in which the projects' performance can be evaluated. However, there are questions regarding assumptions and explanations that the model uses on levels of uptake of innovations making it unsuitable for this research. However, this model has been useful in assessing performance of development projects.

2.2.4 Farming systems research model

Farming systems research (FSR) model was also developed in order to address the deficiencies of technology transfer models (Johnson and Walker, 2000). The model promotes greater attention to the small farmers, and has a strong interest in the resource dynamics of agro-ecosystems. It draws both on the environmental shaping of production and land use options, but also on knowledge systems that shape adaptation and control of resources for agriculture (Vincent, 1997). This model suggests an interdisciplinary approach whereby it is implemented through the assessments of users, their participation and trials. Although farming systems research approach was developed to address the inefficiencies of technology transfer, the approach is criticised for continuing to implementing a linear technology transfer model. These criticisms are based on grounds that decision-making process in the approach is centrally driven and its emphasis on commodity focus which ignores analysis and development of the whole systems thereby undermining their potential contribution (Johnson and Walker, 2000). This model could have been useful for this research considering that it greatly promotes the assessment of the users. However, since the model ignores the analysis and development of the whole system, it is likely to limit the research's investigations on SSPI adoption processes.

2.2.5 Diffusion of innovations model

The Rogers (2003) diffusion of innovations model (Figure 2.1), perceives innovation as an agent of behaviour change. This model matches well with the aims of this research as it focusses on the technology itself, the adopters and processes involved in the uptake. This implies a holistic approach that allows researchers to extensively explore the internal and external factors associated with SSPI adoption.

The model defines innovation as an idea, practice or object considered as new. According to the model, diffusion is "*the process which an innovation is communicated through certain channels over time among members of a social system* (Rogers, 2003, pg. 15)*".* Four main elements are recognised in the diffusion process: the innovation itself, communication channels, time and the social system. The model perceives that different communication channels have specific impacts on diffusion of innovations. According to the model, mass media and interpersonal communication channels play different roles that are important 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 the individuals with similar attributes (e.g. education, social status, values) compared to those with different attributes.

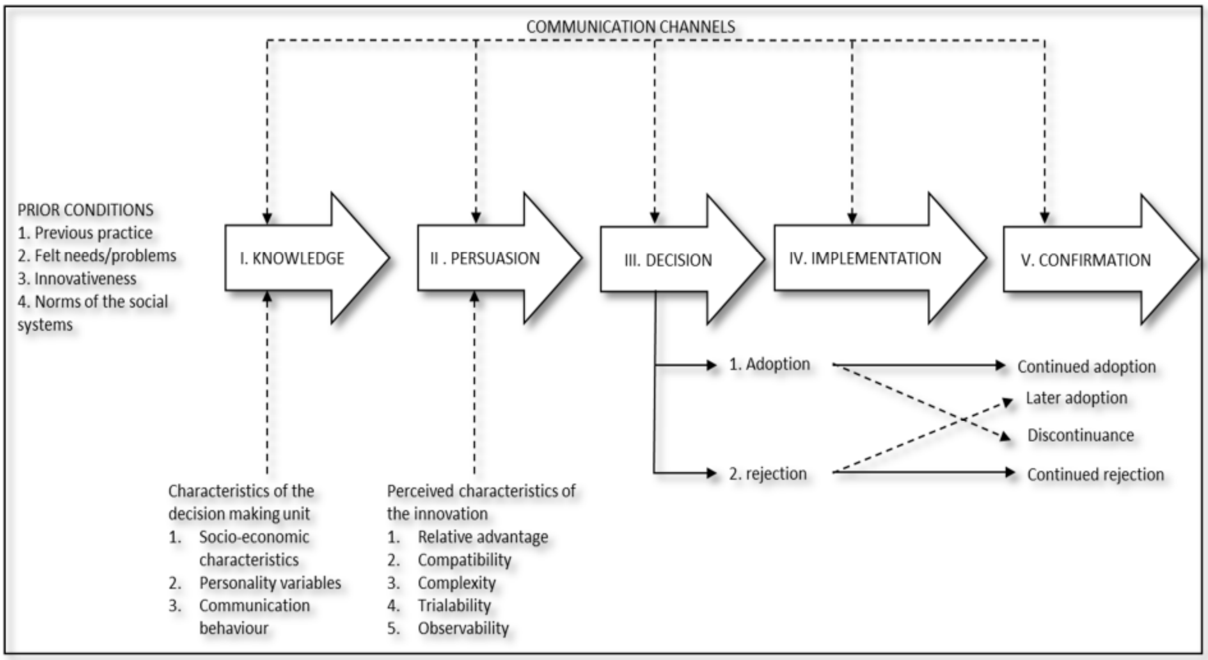

Figure 2.1: The five stages in the innovation-decision making process (Rogers, 2003)

The model considers the innovation as an agent of behaviour change such that both the attributes of the innovation and the characteristics of the adopters determine the rate of adoption (Rogers, 2003). According to Rogers (2003), behaviour is perceived that it changes more rapidly if the innovation characteristics: (1) are considered as better than the options before adopting the innovation (relative advantage); (2) matches with the existing values, experiences and requirements of the potential adopters (compatibility); (3) are simple to understand (complexity); (4) are able to be tested (trialability); and (5) are visible (observability).

The model suggests that diffusion of innovation requires time to occur and the process begins with the recognition of a problem or need. The model perceives that potential adopters adopt innovations at different times; accordingly they are categorised as ‘‘innovators, early adopters, early majority, late majority and laggards’’. According to Rogers, 2003, the adoption process is classified as a normal distribution curve which cumulatively follows an S-shaped curve over time. Innovators are typically characterized as those adopters with bigger farms, more educated, more prosperous and more risk-oriented (Rogers, 2003). Early adopters are typically those that are young, better educated, community leaders and are less prosperous. Early majority adopters are described as typically more conservative but open to new thoughts, active in community and have influence to neighbors. Late majority adopters are mostly the older, less educated, fairly conservative and less socially active. Laggards are perceived as very conservative with small farms and capital, oldest and least educated.

The model suggests that these different characteristics among adopters can be used to develop strategies in which different communication channels can be used to reach the intended audiences. The model suggests that the path towards diffusion of innovation, which should create conditions that lead to the decision to adopt or reject an innovation, occurs in a sequence of five stages, namely knowledge, persuasion, decision, implementation and confirmation. These are briefly described below:

Knowledge stage: This stage occurs when an individual (or other decision making unit) is exposed to existence of an innovation and gets some understanding of how it functions (Rogers, 2003). It is believed that the social system and receivers' variables contribute to the knowledge stage. For example, individuals may get knowledge about a technology through the conduct that they portray. It is believed that individuals hardly expose themselves to messages about a technology unless they have a special interest for the particular innovation. Further, it is also believed that even if the individuals are exposed to knowledge about a technology, such exposure will be irrelevant unless the innovation is perceived as important to their needs and is consistent with their values and beliefs (Rogers, 2003).

Persuasion stage: The stage occurs when an individual forms a positive or negative attitude towards a new idea or technology (Rogers, 2003). At this stage individuals become more psychologically involved with the new technology and actively pursue information concerning the new technology (Rogers, 2003). It is perceived that individuals pursue information that assesses a new technology in order to reduce their doubts concerning the expected consequences related to the new innovation. It is suggested that individuals may relate the new idea to their present or anticipated future situation before making the decision whether or not to try it. Five innovation attributes ‘‘relative advantage, compatibility, complexity, trialability and observability’’ are perceived to influence adopters to form a favourable attitude towards the new technology (Rogers, 2003).

Decision stage: Decision stage occurs when an individual engages in activities that lead to the choice to adopt or reject the innovation. According to Rogers (2003), most individuals do not adopt a new technology without first trying it on probationary basis in order to determine its usefulness in their own situation. It is perceived that innovations that can be tried are generally adopted more rapidly than those that cannot (Rogers, 2003).

Implementation stage: The stage occurs when an individual puts an innovation into use. It involves clear behaviour change as the innovation is actually put into practice. This is the stage where problems on exactly how to use the innovation crop up. Further, there is a certain degree of uncertainty about the expected consequences existing during this stage. According to Rogers (2003), expected questions that individuals would be seeking will be: ‘Where can they obtain the innovation?’ ‘How do they use it?’ and ‘Which problems concerning operations are they likely to encounter and how these can be solved’. It is believed that this stage may continue for a length of time depending on the nature of the innovation. Eventually a point is reached when an innovation becomes established as a regular part of the ongoing processes of an adopter.

Confirmation stage: This stage occurs when an individual seeks reinforcement of the decision process already made concerning a new technology or reverses the decision to adopt or reject the new technology if exposed to contradictory messages concerning the new idea (Rogers, 2003). Individuals seek information that will support or confirm a decision already made and they look for supportive messages that will prevent them from being in uncomfortable state of mind (dissonance). However, in the event that individuals are not satisfied, it is perceived that this may result into discontinuance. Discontinuance is defined as *‘‘a decision to reject an innovation after having previously adopted it’’* (Rogers, 2003 pg. 181). Rogers (2003), suggests that there are two types of discontinuance including replacement and disenchantment. Replacement refers to the choice to reject an innovation in order to adopt a better innovation that supersedes the previous one. Disenchantment refers to the choice to decline an innovation as a result of not being satisfied with its performance. Such dissatisfaction could be due to inappropriate innovation which does not result in the perceived relative advantages over the alternatives.

Criticisms of the diffusion of innovations model

The major criticisms of the model can be summarised into three arguments: (i) the 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 criticised as being prescriptive suggesting a prearranged, predictable and linear progression from awareness through to adoption. However these concerns have been recently addressed (Rogers, 2003); (ii) the inaccuracies in diffusion research. For example, the model relies on respondents to remember the time at which a new idea was adopted suggesting that there are potentials for obtaining data that is inaccurate; (iii) the tendency to emphasise on the adopter side compared to the provider of technology change side (Morris et al., 2000). However, it is argued that the role of the technology provider is prominent in the role of change agents such as extension services and commercial marketing organisations (Morris et al., 2000).

Despite the critiques, the diffusion of innovations model has been widely used in research. For example, Otte (2014) used the model to compare the motivation for adoption of institutional solar cookers in developing countries and was able to establish the pre-requisites for adoption such as economic savings. In the context of Malaysia, Sail and Hamad (1994) used the model to determine the level of technology adoption among smallholder rubber producers. The study attributed the low adoption rate to the attitudes of the users towards the technology, financial constraints, physical limitations (e.g. land size), labour shortages, inappropriate technology and weaknesses in extension and communication services. That study was able to identify the barriers to the adoption process. Likewise, this model would be useful for understanding sustainability in SSPI adoption in this research.

A summary of the analytical review of these five models is outlined in Table 2.2.

Table 2.2: The principles and criticisms of selected technology adoption models

Name of model	**Authors**	**Models principles**	**Model criticisms**
Models of technology development (e.g. Technology development Model-TIP)	Demmott, (1987) in (Garforth and Usher, 1997)	-It perceives the transfer of technology as not just simply being passed from developers to the extension agents but rather both parties are involved in the testing, adaptation and integration of the technology into the systems	-It does not consider the end users in the process. -The approach has substantive success in industry and agriculture with resource-rich clients
Farmers First model	(Chambers, 1985)	-It emphasizes the need for the scientists to involve farmers from the beginning of any processes in technology development. It stresses that the process should begin with the scientists learning the resources, needs and problems of the farmers.	-The model does not recognise the differences in interests within the communities
Models of research management process	Edwards & Farrington, (1993) in (Garforth and Usher, 1997)	-It posits that the process by which specific research projects are prepared, commissioned and managed are key factors in the production and uptake of the innovations.	-There are questions regarding assumptions and explanations that the model uses on the levels uptake of the innovations
Farming systems models	(Johnson and Walker, 2000)	-It suggests an interdisciplinary approach whereby it is implemented through the assessments of users, their participation and trials	-The decision-making process in the approach is centrally driven and it emphasizes focusing on commodity ignoring the analysis and development of whole systems
Diffusion of innovation	(Rogers, 2003)	-It suggests that diffusion is a process by which an innovation is communicated through certain channels over time among the members of a social system. -It posits five stages in innovation decision making stages including knowledge, persuasion, decision, implementation and confirmation. -It perceives five attributes of an innovation thus relative advantage, compatibility, complexity, ability to be tried and observed.	-It is prescriptive, static and deterministic, suggesting an orderly, predictable and linear progression from awareness through to adoption. -It has a tendency to emphasise on the adopter side compared to the technology provider.

2.2.6 Section summary and rationale for selecting the model

Considering the above reviews, it is clear that ‘technology adoption’ is recognized differently by researchers. This is clearly displayed in the expected outcomes and stages of the various models. For example, out of the five models reviewed, the research management process and diffusion of innovations models consider adoption as a process beyond the decision to put an innovation into use (adoption) and include other stages that might lead to continued or discontinued use and/or impact. This conception corresponds appropriately with the aim of this research. However, for research management process model, there are criticisms that the degree of uptake and impact are basically linked to the quality of project management (Garforth and Usher 1997). In this regard, this model is not suitable for this research since the SSPI studied here are not particularly linked to a specific project. Given this, the diffusion of innovations model (Rogers, 2003) is selected as the suitable framework to underpin the research. Furthermore, this model is commended for being well-established for traditional rural studies, especially explaining the adoption and diffusion of agricultural technologies (Morris et al., 2000).

2.3 Technology sustainability and success

The research also reviewed other relevant models related to technology sustainability and success which guided interpretation of 'success' in SSPI adoption. The central insight concepts of sustainability often relates to the continuity of existing over a period of time. In the context of SSPI technology, this may imply continuity in using the SSPI over a period of time or build upon it (growth). In line with this understanding, related models were reviewed.

2.3.1 Sustainability chain model

Carter et al. (1999; pg. 294) defined sustainability in water and sanitation components as ''*whether water continues to be abstracted at the same rate and quality as when the supply system was designed, the excreta and wastewater disposal systems continue to function and be used as planned while continuing to improve environmental quality*''. Based on this, the authors proposed a 'sustainability chain' model whose success depends four essential links including motivation, sustainability, cost recovery and continuing supporting in community water supply and sanitation systems (Figure 2.2).

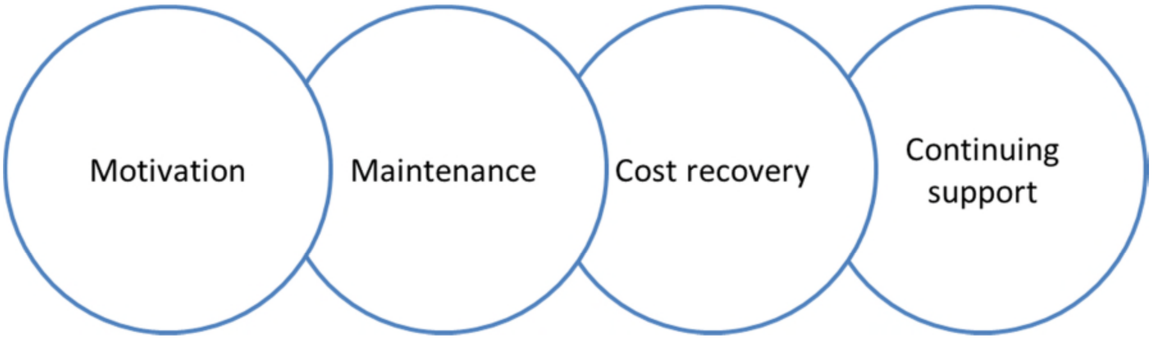

Figure 2.2: A chain of four essential links to ensure sustainability in water and sanitation systems in developing countries (Sustainability chain model Carter, et al., 1999)

The model argues that without ‘motivation’ of the community to utilize the new facilities, sustainability is impossible. It is stressed that although technology promoters might have other priorities, their most important and immediate benefits are to attract users and hence the need to motivate them. In the case of ‘maintenance’, the model suggests that a clearly structured, resourced, and trained maintenance organization is necessary for technology sustainability. The model emphasizes the need for backstopping technology caretakers by ensuring availability of the spare parts, tools and appropriate forms of transport in order to be sustainable. For ‘cost recovery’, the model recognizes that most technologies involve foreign exchange which most rural communities cannot afford and it suggests that the basis of payment, administering and accounting the technology charges should be decided by communities. Finally, for ‘continued support’, the model emphasizes the importance of following up technology or systems by the supporting organizations. It is argued that without continued support, innovations tend to wane within two to three years of its implementation suggesting the need for continued follow ups until a critical mass of good practice within the area are not going back from using the technology. According to the model, failure in any one of these chain links endangers the entire system. This model is a good example that demonstrates the existing linkages between technology adoption and sustainability. However, it assumes that adoption is only externally influenced by the promoters; this may limit its application to those that adopt technologies without the external influence. This perspective however guided the research to develop a better understanding of success in adoption of SSIP influenced by the incentives.

2.3.2 Technology adoption success model

Burney and Naylor (2012) proposed a model of pathways of impact model for small irrigation technologies (Figure 2.3). The model conceptualizes that the successes and failures of the projects can be assessed in three consecutive periods including adoption, realization of efficiencies, and re-investment (Figure 2.3).

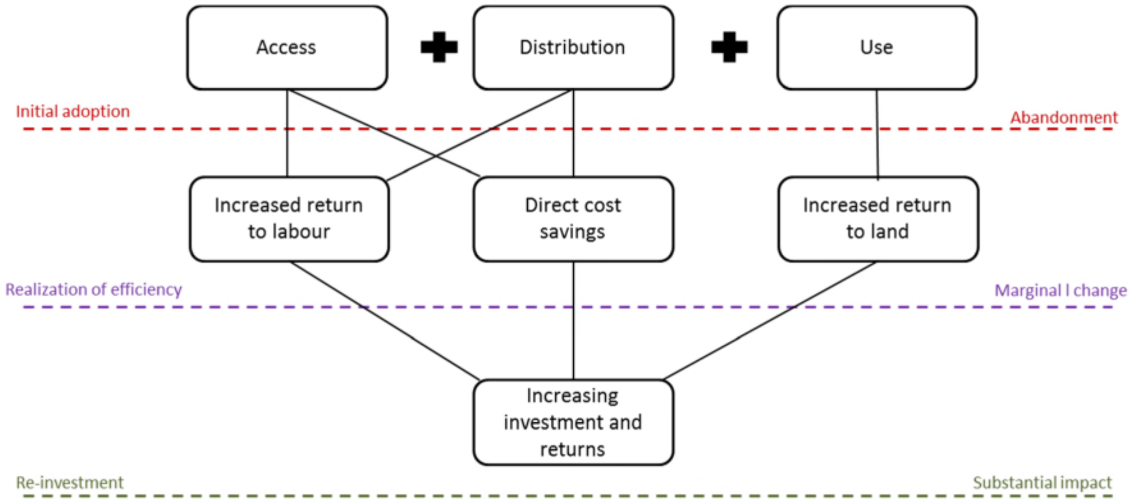

Figure 2.3: Framework for pathways of impact in smallholder irrigation systems (Burney and Naylor, 2012)

The model suggests that an irrigation system would be considered a failure (abandoned) if the adopters are unable for any reason to realize the efficiencies offered by new technologies (Burney and Naylor, 2012). It also perceives that an irrigation system would be an instrument of only marginal change if such efficiencies are achieved but the adopters do not kick-start a greater cycle of investment and prosperity. Finally, success is perceived as ‘‘when smallholder irrigation systems have substantial poverty impact and the adopters realize significant efficiencies that enable them to reinvest the subsequent labour and cost savings, starting up the ladder of increasing investments/returns and asset accumulation’’ (Burney and Naylor, 2012). Although Burney and Naylor (2012) do not highlight the type of motivations that lead to technology adoption, their perspective supports the research’s arguments on success in SSPI adoption (Chapter 7).

2.3.3 Servitization model

The concept of servitization emerged in the late 1980s and was mainly used in the business sector (Vandermerwe and Rada, 1988). In simple terms, it refers to ''*adding value by adding services*''. In essence, it often involves firms (e.g. manufacturers) developing the capabilities needed to provide services and solutions that supplement their traditional product offerings. In academic research, the term 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*'' (Baines et al, 2009; Pg. 547).

The central philosophy of servitization is the integration of offering a product and service that delivers value in use. From the business point of view, servitization is perceived as having potential to sustain annual business growth. Thus the services model triggers product and process innovations, powered by technology, which results in significant year-on-year growth with both new and existing customers. Furthermore, potential adopters lower their own costs through servitization and it provides a significant potential for macro-economic growth. This is based on the fact that since new services are offered, there are new opportunities for new commercial services to exploit. However, there are fears that the new model is inhibited by the lack of awareness and that it has a potential for making losses by some manufacturing firms. This model has provided insights to alternative dimensions of sustainability in SSPI technology adoption and is commended as one of the measures that can be adopted to ensure effective SSPI adoption in Malawi and SSA (Chapter 8)

2.4 Summary

The exploration of theories of technology adoption has shown that numerous models for technology adoption exist but their interpretation towards adoption processes differ. In some models adoption is successful when a critical mass adopts a new innovation whereas in others the adoption process is considered to extend beyond taking the decision to use the technology and includes continued-use or discontinuance. To explore the sustainability of SSPI adoption process, the diffusion of innovations is selected as a suitable model to underpin the research as it provides a comprehensive process for understanding adoption.

3 AGRICULTURE AND IRRIGATION DEVELOPMENT IN MALAWI

This chapter explores the state of irrigation development in Malawi to understand how the research corresponds to the context of development.

3.1 Agriculture in Malawi

In Malawi, agriculture has two main sub-sectors, the smallholder and the estate sub-sector (Chirwa et al., 2008). According to Wiyo et al., (2014) agricultural cropping in the smallholder sector is dominated by maize-based rain-fed cropping systems. The landholding sizes among smallholder farmers at national level are generally small and has on average fallen from 1.53 hectares in 1968 to 0.80 hectares per household in 2000 (Chirwa et al., 2008). This land fragmentation is attributed to the increasing population. The principal crops grown are maize, tea, sugarcane, groundnuts, cotton, wheat, coffee, rice and pulses, whereas the major export crops are tobacco, tea and sugar (Chirwa et al., 2008).

3.1.1 Agricultural sector structure

The agricultural sector is coordinated by the Ministry of Agriculture, Irrigation and Water Development (MoAIWD). The overall mandate of the MoAIWD is to promote and accelerate broad based sustainable agricultural and irrigation policies in order to support economic growth and contribute to poverty reduction (Government of Malawi, 2011). The specific ministry functions include: sustaining household food sufficiency; improving the nutritional status of the population; expanding and diversifying agricultural production and exports; increasing farm income; conserving the natural resources base; promoting agricultural policies, legislation and regulations with stakeholder participation; generating and disseminating agricultural information and technologies; regulating and ensuring quality control of agricultural produce and services; monitoring and managing the food security situation.

The structure of MoAIWD is headed by the Secretary for Agriculture and has eight departments (Figure 3.1). However, the Ministry has been experiencing regular restructuring depending on the government current needs (Chinsinga, 2009). Because of the regular changes, some departments under the ministry have also been changing. One of the departments that have been experiencing regular restructuring is the DOI. This coordinates all irrigation development activities and has been moving back and forth between the former Ministry of Agriculture and Food Security (MoAFS) and the Ministry of Water Development. Presently, these two ministries are merged and hence DOI is under MoAIWD. It is, however, argued that restructuring processes do not affect structures below the top management levels (Chinsinga, 2009). These changes may however have implications on the DOI operations as it operates through the MoAIWD structure.

There are eight ADDs which replicate the activities of the departments at the national level. Each ADD covers several districts however this does not coincide neatly with regional boundaries (Chinsinga, 2009) but with the ecological zones. The ADDs are further split into 28 districts offices referred to as District Agriculture Development Offices (DADOs). This research focussed on two ADDs (Lilongwe and Kasungu) where three districts were selected. The DADOs are divided into 154 Extension Planning Areas (EPAs) which are further subdivided into 2,239 sections. Sections are point of service delivery to farmers through the extension workers who are referred to as Agricultural Extension Development Officers (AEDOs).

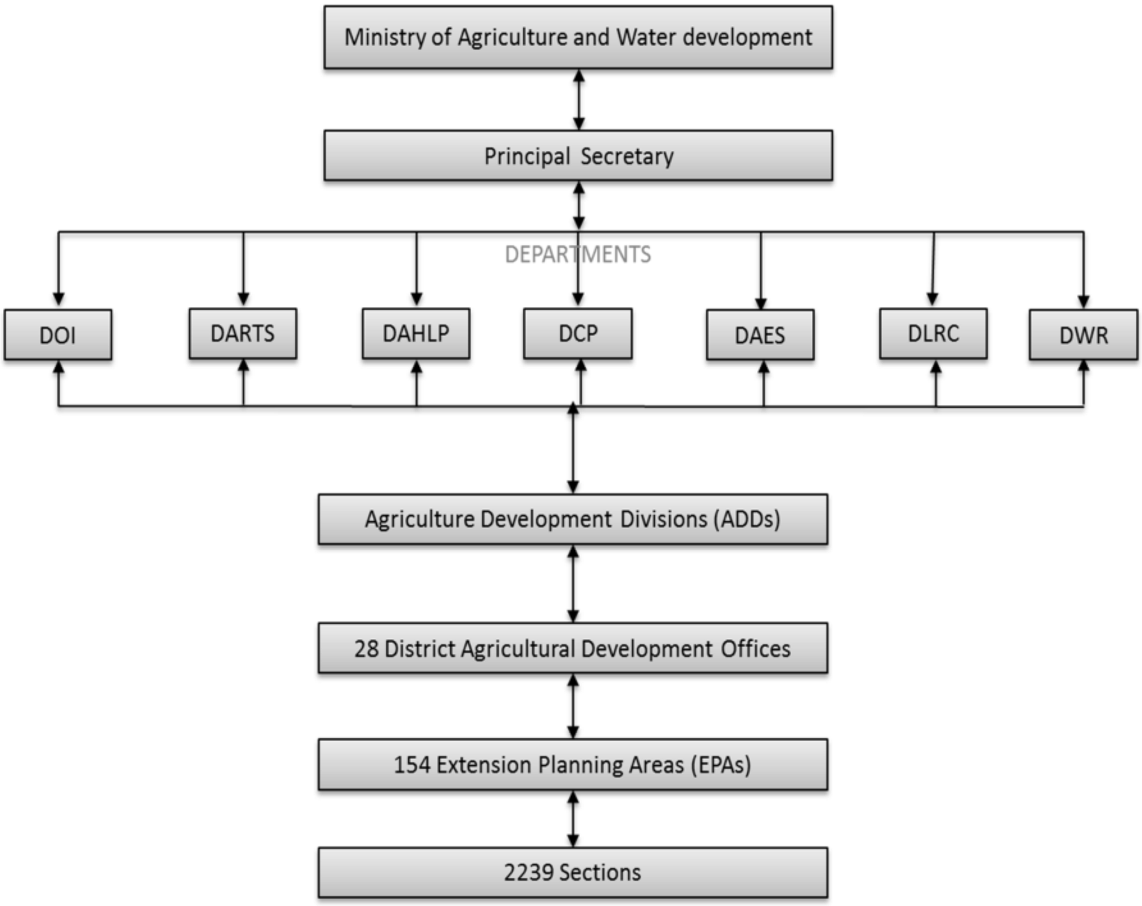

Figure 3.1: Operational structure of the Ministry of Agriculture, Irrigation and Water Development (MoAIWD) in Malawi (Modified from Chinsinga (2009))

3.1.2 The Department of Irrigation (DOI)

The development of irrigated agriculture was mandated to the DOI in late 1980s to facilitate an increase and stabilization in agricultural production, through mobilization of irrigation projects of various magnitudes; beneficiaries from private and public sector supplemented the development with human and financial resource. This mandate was discharged with full participation of the beneficiaries and compliance with environmental aspects to ensure sustained productivity, equitable gender participation, effective poverty alleviation and national economic development (Government of Malawi, 2014). At the regional and district level, the DOI has structures but at EPA level, the DOI operates through the Ministry of Agriculture structures by using the agricultural extension workers (AEDOs) for dissemination of its irrigation activities. Ideally, the AEDOs serve as a link between farmers and irrigation experts. There are however, fears that these AEDOs are overwhelmed since each of the Department (Figure 2.4) uses them as their link to the farmers.

3.2 Development of irrigated agriculture in Malawi

3.2.1 Justification for irrigation development in Malawi

Malawians have historically been dependent on rain-fed agriculture which provides livelihoods for 85% of the population (Mangisoni, 2008). However, evidence shows that within the past two decades, the incidences of frequent droughts have been increasing suggesting that the strategies for depending completely on rain-fed agricultural systems are not reliable (Chidanti, 2011, Mangisoni, 2008). These increased incidences of droughts are associated with climate change and predictions for Malawi indicate that these are likely to continue (Daccache et al, 2014). Moreover, Malawi has three climatic seasons that is warm-wet season (November to April), cool-dry season (May-July) and hot-dry season (August to October) such that during the cool and hot dry seasons (May-October) irrigation is required in order to grow crops.

As one way of adapting to increased rainfall uncertainty (e.g. droughts, dry spells and reduced rainfall events in a season), in Malawi irrigated agriculture is being promoted in order to augment rain-fed agricultural production for smallholder farmers. This irrigated agriculture is used as a means of reducing rural poverty through the production of cereals (maize and rice) and horticultural crops (e.g. vegetables) both for household consumption and income generation for smallholder farmers (Magreta et al, 2010). Farmers mostly practice irrigated agriculture during the dry season in order to supplement rain-fed production. This practice ensures the availability of crops during droughts and supplements agricultural production during periods when rain-fed production is affected by the floods. The practice also helps to extends the cropping opportunities and provide a wider variety of crops throughout the year to: improve nutritional status, especially that of children and women; increase households income through selling of the irrigated products; and supplement households' agricultural rain-fed production which usually is hardly enough for households consumption for the entire year.

Malawi is reported to have plentiful water resources with water bodies that cover about 21% of the country (National Statistical Office, 2008). Given this, irrigated agriculture is considered a viable alternative for increasing agricultural production hence it is one of the government priority areas for reducing poverty (Kadyampakeni et al., 2012). However, it is contested that the current strategies and guidelines do not clearly articulate how water as a medium is used in a holistic manner such that access to water is uneven (Mulwafu and Msosa, 2005).

3.2.2 Historical development of irrigation in Malawi

Irrigation development started in late 1940s with the construction of Limphasa irrigation scheme irrigation in Nkhata Bay district (World Bank, 2011). Development gradually continued so that between 1968 and 1979, the government constructed 16 irrigation gravity-fed schemes in various ADDs covering about 3600 ha (Nkhoma and Mulwafu, 2004). These were developed to increase rice production and serve as farmer training grounds for irrigation skills. However, although it is reported that farmers participated in scheme management , it is argued that their involvement was limited to settling disputes and allocation of plots (Nkhoma and Mulwafu, 2004). This was further aggravated by inadequate funding of the schemes by the government. Consequently, most scheme structures deteriorated (Nkhoma and Mulwafu, 2004). The government then initiated the transfer of scheme management to farmers through involvement of the private sector, but this too encountered numerous challenges (Mulwafu and Nkhoma, 2002; Nkhoma and Mulwafu, 2004). The government then embarked on self-help farmer irrigation schemes; an approach which emphasised ownership of irrigation projects by farmers. According to government, this involved greater participation of farmers in planning, development, operation and management of the schemes. The question is whether the farmers indeed participate in these developments.

The estimated irrigation potential area for Malawi is about 600,000ha, of this only 97,933ha (16%) is currently developed as of 2014 (Government of Malawi, 2014). This suggests that there is a potential for further irrigation development in Malawi in order to reach the targets in reducing poverty and food security.

3.3 Categories of irrigation development

The DOI (2010a) categorize irrigation development in Malawi as private estate managed and smallholder irrigation schemes (Table 3.1).

Table 3.1: Overview of irrigation development categories in Malawi

Characteristic	Estate managed schemes	Smallholder irrigation
Land tenure	Private	Customary
Crops grown	Export crops-tobacco, tea, sugar, coffee	Maize, rice, potatoes, beans, leafy vegetables, tomatoes, onions
Irrigation methods	Surface, overhead-sprinkler, centre pivot, Micro-drip	Gravity river diversion, treadle pumps, motorized pumps, traditional watering cans.
Plot sizes	>1000ha	0.1-0.5ha
Gross area	>1,000ha	<100ha
Management	Private	Farmer managed
Area irrigated (ha)	52,498	45,434
Proportional beneficiaries	<20%	>80%
Objective	Commercial/exports	Household food security & income

Source: Various including government reports.

The private commercially run estates are large-scale (>1000ha) and mainly produce sugarcane, tea and coffee for export. Since the colonial period (1960s), the private sector has championed large-scale irrigation in Malawi with tea farming as the pioneer (World Bank, 2011). Presently, out of the 97,933ha area irrigated, over half (53 percent) is under private estate management (Government of Malawi, 2014). However, the contribution of these private estates to smallholder farmers is very minimal; usually through casual labour. Between 2005 and 2014, the irrigated area under private estates has increased by only 8% (48,360-52,499ha) whereas the area under smallholder irrigation systems has almost doubled (Figure 3.2). This trend suggests that SSI is becoming more and more important sector for supporting agricultural production requiring more evidence to inform its development.

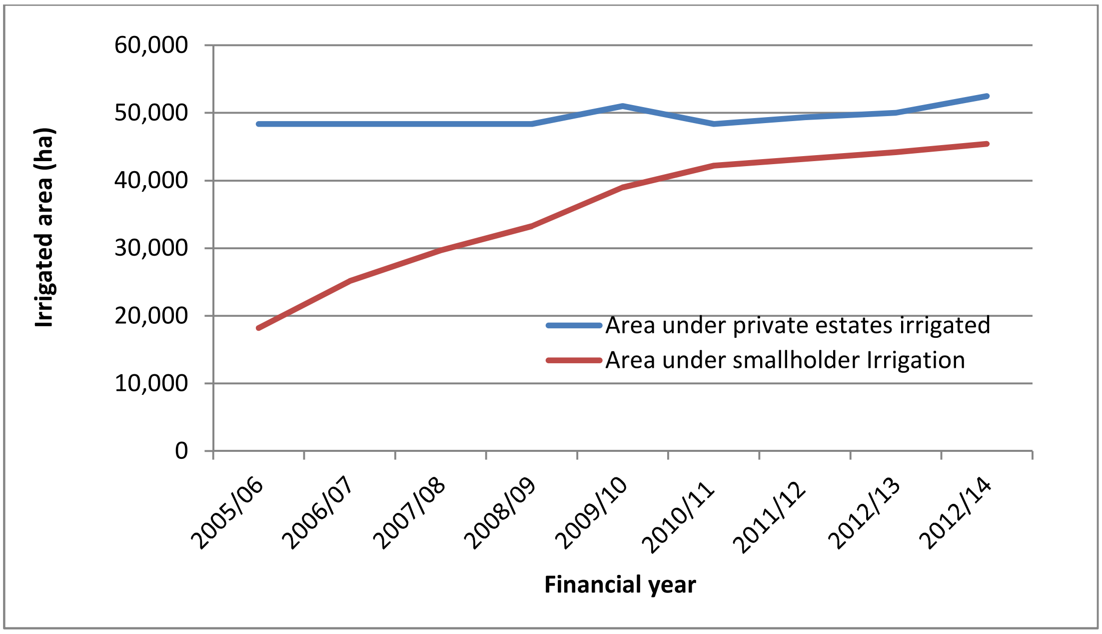

Figure 3.2: Trends (2005-2014) of irrigated areas under private estates and smallholder and in Malawi (Source: DOI Annual report, 2014)

Smallholder irrigation systems are maintained by farmers with minimal support from government (Government of Malawi, 2010a; Gwiyani-Nkhoma, 2011). In contrast to the large estates, the main crops grown in the smallholder schemes are maize, rice and vegetables, which are grown for household consumption and income. According to DOI (2014), the smallholder irrigation schemes are classified into four groups (Table 3.2). These include gravity fed, motorized pump, treadle pump, and watering cans irrigation schemes. As shown in Table 3.2, gravity fed is the dominant (53%) technology followed by treadle pumps (28%) watering cans (11%) and motorized pumps (7%). There is a difference between the area developed for irrigation and the area utilized for irrigation (Table 5). Based on DOI (2014), some areas are not utilized because of the numerous challenges including vandalism of irrigation infrastructure, unreliable water sources, conflicts over land issues for construction of canals and weirs, inadequate funds to maintain the pumps by farmers, lack of farmer skills to operate and maintain pumps, scarcity of spare parts, lack of funds to buy farm inputs, and weak farmer organizations. Despite these challenges, government, NGOs and developing agencies continue to support smallholder irrigation development through various capacities. JICA (2009) indicates that between 2000 and 2011 over 15 aid agencies such as World Bank, ADB, JICA and EU in Malawi supported SSI development in various capacities including construction of new gravity fed irrigation schemes, distributing free or subsidized treadle and motorized pumps to farmers.

Table 3.2: Summary of smallholder irrigated area statistics showing the number of schemes, proportional split in irrigation technology and beneficiaries (gender).

Technology	**Number of Schemes**	**Total area developed (ha)**	**Total area utilized for (ha)**	**Number of beneficiaries**		
				Male	**Female**	**Total**
Gravity fed	3,247	26,015	25,592	107,199	91,316	198,515
Treadle pump	11,856	13,657	13,048	84,925	69,485	154,410
Motorized pump	1,113	3,949	3,591	16,940	16,276	33,216
Watering can	22,419	5,494	3,203	16,276	12,788	29,064
Total	**38,635**	**49,116**	**45, 434**	**225,340**	**189,865**	**415,205**

Source: DOI Annual report (2014)

Gravity river diversion irrigation system is the most wide spread and oldest irrigation method in Malawi which utilizes surface water sources. Its main structure is the diversion weir which diverts stream water into irrigation canals. These weirs are supposed to withstand floods during the rainy season although farmers in some cases build temporary structures which are maintained annually. It is believed that operation and maintenance of gravity fed structures is easy and not costly; however this technology is mostly affected by river sedimentation.

*Treadle pump irrigation system*s were introduced in Malawi in the mid-1990s and are a popular government technology and also supported by many organizations. They are designed to lift water from sources such as hand-dug wells, rivers and reservoirs and capable of lifting water from wells of not more than 10 metres (Kay and Brabben, 2000). Their performance is influenced by the design of the cylinder diameter, stroke length, valve assembly, ergonomics and depth of water source. In general, the pumps are capable of delivering at least 1.3l/s (Njuki et al., 2014).

There are several models of treadle pumps used in Malawi. The most common are the Advaith, manufactured by Balaji from India and the Money Maker (MM) pump manufactured by a charity organization known as Appropriate Technology for Enterprise Creation (ApproTEC) presently known as KickStart (Njuki et al., 2014). The Advaith pump, also known as the Malawi treadle pump, is believed to be the first treadle pump type introduced in Malawi (Joseph and Yamikani, 2011). It is also referred to as a long cylinder pump based on its design and is made from steel (cylinders and pistons), a rope and two wooden treadles (TLC, 2000).

The MM pump is made from galvanised iron and was developed as an improvement of the Advaith pump (KickStart, 2015). Evidence shows that a number of pumps have recently been manufactured by KickStart as further improvements of the original MM type (Njuki et al., 2014). It is also believed that prices of pumps manufactured by Kickstart are kept low in order to be accessible by poor farmers (Njuki et al., 2014). Generally, the major challenge encountered by treadle pump farmers is the increased labour demand (Joseph and Yamikani, 2011).

Motorized pump-based irrigation schemes involve pumping water from surface or groundwater sources. They convert fuel energy such as petrol or diesel, into useful water energy using combustion or electric motors (Kay, 2008). These pumps are sometimes characterised by the drive motor power or by their delivery diameter (Kay, 2008). The major components are the pump and engine, suction pipes, discharge pipe, delivery pipelines, discharge boxes and irrigation canals. Most motorized pump systems in Malawi use canals to convey water to the irrigation fields. These pumps have the potential to be used under topographic conditions that are not possible with other technologies (JICA, 2009). These are mainly challenged by the lack of technical skills, lack of spare parts and higher operational, and running (repairs and maintenance) costs (Government of Malawi, 2010a).

Watering cans irrigation system: These are the oldest and most traditional irrigation method used in Malawi. They are locally manufactured from sheet metal by local tinsmiths and considered as the cheapest and simplest technology widely used by farmers. However, watering cans are claimed to be labour intensive and their use is limited to land located closer to water sources hence only a small area is irrigated (Drechsel et al., 2006).

3.4 Irrigation policies

There have been several policy changes in Malawi particularly in the agricultural sector since the late 1990s (Chilowa, 1998). It is believed that these changes were done because of post structural-reforms and political change (Chirwa et al., 2008). Most of the policies were to guide development of the economy and since irrigation is one of the major options for reducing poverty, a number of policies have been implemented directly to support irrigation development.

The National Irrigation Policy Development and Strategy (NIPDS) clearly states the government's aspirations for irrigation development (Government of Malawi, 2010b). It emphasizes the importance of incorporating irrigation for both food production and commercialization in agriculture. It provides for an establishment of an Irrigation Fund and developing linkages with other partners. It also outlines the government commitments to ensure that environmental issues are given due attention. The policy defines broad objectives including increasing land under sustainable irrigation farming; extending cropping opportunities and facilitate crop diversification; creating an enabling environment for irrigated agriculture; optimizing government investment in irrigation development; enhancing capacity for irrigated agriculture in the public, parastatal and private sectors, disseminating and utilizing irrigation technologies; and promoting a business culture in small-scale irrigated agriculture sector. Furthermore, the policy outlines the institutional arrangements and frameworks as well as key roles and responsibilities of stakeholders in operationalizing the policy. Although the policy appears to have clear strategies and guidelines, successful implementation of these ideas is questionable. For example, the policy stipulates that one of its strategies is to mobilize smallholder farmers to develop and manage their own irrigation schemes through the establishment of local farmer organizations. This implies that the government assumes that all farmers will be using communal lands for irrigation. However, in reality, smallholder farmers practice irrigation individually with access to private land and water sources. This highlights the potential risks associated with the policies and likely inconsistencies in the expected outcomes from the interventions.

3.4.1 Other policies

Apart from specific government policies related to irrigation development, there are other policies and strategies associated with irrigation development in Malawi. For example, the *Malawi Vision 2020* was developed to align the government long-term development plans to the Millennium Development Goals (MGDs). This policy emphasizes long term strategic thinking, a shared vision and visionary leadership, participation by the population, strategic management and national learning in which irrigation development is highlighted as one of the long term strategies. *The Malawi Growth and Development Strategy (MGDS)* was developed in 2006 to translate the Malawi Vision 2020 goals (Government of Malawi, 2006; World Bank, 2011). This strategy MGDS I (2006-2011) was reviewed in 2011 and presently MGDS II (2012-2017) is being implemented by the government. In this strategy, the intention of the government is to reduce extreme poverty and hunger by half through sustainable economic growth and infrastructure development (MGDS, 2012). The strategy outlines six key priorities with irrigation and water development being one of them. The *Green Belt initiative (GBI)* is a recent government initiative that aims to intensify irrigated farming. The initiative recognizes the availability of abundant water resources in Malawi and it challenges the government and private sector to develop one million hectares (World Bank, 2011) of irrigation as a hedge against climate change on food security (Chinsinga, 2012).

While these policies recognize irrigation development as a key priority for eradicating poverty, there are no clear strategies and guidelines for implementing and harmonizing these policies (Mulwafu and Msosa, 2005; Mulwafu, 2010). These policies are implemented in isolation and the implication is that targeted beneficiaries are likely to either be excluded or provided with wrong services that do not contribute to the desired targets e.g. poverty reduction. SSPI currently promoted in Malawi could be one of those strategies whose effective implementation would depend on clear strategies and coordination among the team players.

3.5 Summary

The review of general trends in agriculture and irrigation development in Malawi supports the research context on significance of SSPI technologies in agricultural production. However, policies as well as organizations supporting the development showed discrepancies in the strategies for implementing the SSPI. Given this, the research outlines its strategies (Chapter 4) to explore literature (Chapter 5) and empirical evidence (Chapter 6) to contribute to the debate.

4 RESEARCH METHODOLOGY

This chapter describes the adopted methodological approach, which employs a systematic review (SR) and field surveys to achieve the research aim. The SR approach is extensively presented together with its results and discussion in Chapter 5; however section 4.1 provides an overview of the approach. Section 4.2 outlines the philosophical paradigms informing the designing of field surveys' strategy and an overview of mixed-research method. Detailed field surveys' data collection, analysis and reliability are described in Sections 4.3 to 4.6 respectively. Section 4.7 describes how these strategies are integrated. Section 4.8 summarises the chapter.

4.1 Systematic review approaches

The research initially used the SR to explore published science and grey evidence on key factors affecting performance of the SSPI in SSA. SR is a literature review that focuses on a research question and tries to identify, appraise, select and synthesize all high quality research evidence relevant to that question. According to CEBC (2010), the SR methodology is a recognised standard for accessing, appraising and synthesising scientific information. The main advantage of the SR approach is that it helps to realize the potential of data to inform whilst minimizing bias and uncertainty. It differs from conventional literature reviews in that it is a rigorous critical appraisal that draws on all relevant evidence with reference to a defined research question. The SR approach was selected in order to understand the current research on key factors affecting the sustainability (performance) of SSPI. This motivation was based on the limitations observed in the current evidence (Bos et al., 2005; Burt et al., 1997; Malano et al., 2004) on the critical factors for assessing performance (sustainability) of SSPI. The SR explored how the performance of SSPI in SSA has been measured in the current research and their implications on sustainable adoption processes. This research applies SR to synthesize and use the evidence to inform strategies for the subsequent research objectives. Detailed review of SR approaches and SR methodology employed in the research are outlined in Chapter 5.

4.2 Research paradigms

Based on SR evidence, the research further investigated the sustainability of SSPI adoption processes using field surveys. This relates to interaction between the pumps (technology) and stakeholders. According to Linstone et al. (1981) and Manzungu et al. (1996), this means that the research involves both the technical and social dimensions. Social reality investigations are informed by philosophical paradigms concerning reality (ontology), knowledge of that reality (epistemology) and processes for studying (methodology) them (Blaikie, 1993; Denzin and Lincoln, 2003). These paradigms provide guidance in selecting an appropriate strategy of enquiry and methods of data collection and analysis to achieve the research aims (Robson 2011). Although it contested that most researchers do not fit neatly into the categories of any typology (Hood, 2006), the major paradigms underpinning social reality investigations are positivism, post-positivism, critical theory, constructivist-interpretive, and feminism (Blaikie, 1993, 2000; Denzin and Lincoln, 2003; May, 2001; Robinson, 2011; Schwandt, 2003). A review of features of these paradigms informed the selection of post-positivism and interpretive as theoretical approaches guiding the field survey strategy. The post-positivism paradigm believes that '*reality does not exit but consider that it can only be known imperfectly and probabilistically in part because of researcher's limitations*' (Robson, 2011). Interpretive paradigm is defined as the "*systematic analysis of socially meaningful actions through the direct observation of people in natural settings in order to arrive at understandings and interpretations of how people create and maintain their social world*" (Neuman, 2003, pg 7). A combination of these two paradigms supports the field surveys' objectives and hence the mixed-method approach.

4.2.1 Overview of mixed-method approach

Mixed-methods approaches are defined as the collection or analysis of both quantitative and qualitative data in a study in which the data may be collected concurrently or sequentially (Creswell, 2009). There are claims of incompatibility in the mixed-method approaches and these are based on contrasting philosophical paradigms (Creswell, 2009; Tashakkorie and Teddie, 2003). While quantitative methods are based on positivism which posits that there is only one truth and that an objective reality exists independent of human perception, qualitative researchers beliefs are based on constructivist tradition and work on paradigms that reality and knowledge are both subjective and socially constructed, implying that multiple rather than one objective truths exist. This implies that, mixed research strives to develop a link between cause and outcome, by primarily employing deductive logic and quantitative methods of research while understanding a particular phenomenon in its social context by employing qualitative methods (Tashakkorie, and Teddie, 2003).

Although the approach is deemed incompatible in the design strategies, those supporting mixed-method research reject the claims and recommend a more pluralistic approach (Tashakkorie and Teddie, 2003). Mixed methods are not only used to achieve convergent validity but also investigate and reveal interrelated but different facets of a phenomenon that complement each other. Moreover, it is argued that scholars should use those methods which most adequately respond to their research questions rather than engaging in pragmatic discussions (Creswell, 2009).

Creswell et al. (2009) categorized three general strategies including sequential, concurrent and transformative as procedures for mixed methods approach. Sequential designs seek to elaborate or expand the findings of one method with another method. In concurrent procedures, the researcher converges quantitative and qualitative data in order to provide a comprehensive analysis of a research problem. Different forms of data are collected at the same time and then integrated in the interpretation of overall results. Transformative designs can follow both sequential or concurrent approaches but use a particular theoretical perspective which acts as a framework for data collection and analysis.

4.2.2 The benefits of mixed-methods

Based on established methods by Creswell (2009) and Tashakkorie and Teddie (2009), the benefits for mixed-methods include the following:

- The approach allows researchers to “collect multiple data using different strategies, approaches and methods in such a way that the resulting mixture or combination is likely to result in complementary strengths and non-overlapping weaknesses”.

- The combination of quantitative and qualitative approaches provides corroboration of results from one method with those of another (triangulation) thereby increasing the validity and confidence in the study findings.
- Results from one method can be used to inform the design of a second method, thus serving the refinement and refocusing of research methods.
- To add depth and breadth to inquiry of results and interpretations, inconsistent qualitative and quantitative findings can intentionally be analysed to obtain 'fresh insights'. The multiple research methods can extend the breadth and range of the study.

4.2.3 Review of field survey and sampling approaches

The adopted design of field survey for this research is cross-sectional; the predominant design employed in survey research approach (Nachmias and Nachmias, 1981). In social sciences a cross-sectional study is a type of study that involves the analysis of data collected from a population, or a representative subset, at one specific point in time. Similar research strategies have been used by other scholars (Robson 2011). For example, in Mauritania, Comas et al. (2012) used the approach to understand the reasons why small-scale irrigation did not respond to the expectations with traditional subsistence farmers along the Senegal River. Similarly, in Nigeria, Baba (1993) compared traditional and modern irrigation systems in Bauchi State. The advantages of surveys are that they provide a relatively simple and straight forward approach to the study attitudes, values, beliefs and motives. Furthermore, surveys have the potential for adapting to collect generalizable information from almost any human population and it allows high amounts of data standardization (Robson, 2002).

Whether quantitative, qualitative or mixed research methods, it is vital to design and select samples from a population. The literature characterises sampling methods into two types, probability and non-probability (Ritchie and Spencer, 1994). While probability sampling suggests that each sample within a population has an equal chance of being selected, the non-probability sampling suggests that for each of the samples, it is not possible to specify the probability that any respondent will be included in the sample (Robson, 2011). Sample selection used in this research was purposive and this was due to limitations in time and financial resources. Ritchie et al. (1994) defines purposive sampling as the sample units that are chosen because they have particular features or characteristics which will enable detailed exploration and understanding of central themes and puzzles of interest to the researcher. However, the disadvantage of purposive sampling is that the interviewees and responses may be unrepresentative (Zikumund, 1991). To increase the sample size, purposive sampling can be coupled with the use of snowball technique (Ritchie and Spencer, 1994). These approaches were used to identify the pump farmers, other stakeholders and non-adopters.

4.2.4 Selected strategy for this research

This research employs concurrent mixed approaches in which the qualitative data seeks to complement the quantitative findings by generating both numerical and narrative data that answer similar research questions. Tashakkorie and Teddie (2003), suggest that this design is appropriate when looking for instances of agreement and disagreement between two data sources. The first survey was carried out in two selected districts of Malawi using semi-structured interviews that were administered to farmers and stakeholders. The second survey, aimed at enriching and checking the first survey findings used a similar approach. For logistical reasons, the second survey was carried out in one (third) district. The logic for this was to allow triangulation of data to increase validity and confidence in the findings. Analysis for field surveys (descriptive statistical, textual and content analysis) and SR are integrated and interpreted to address the research aim as illustrated in Figure 4.1.

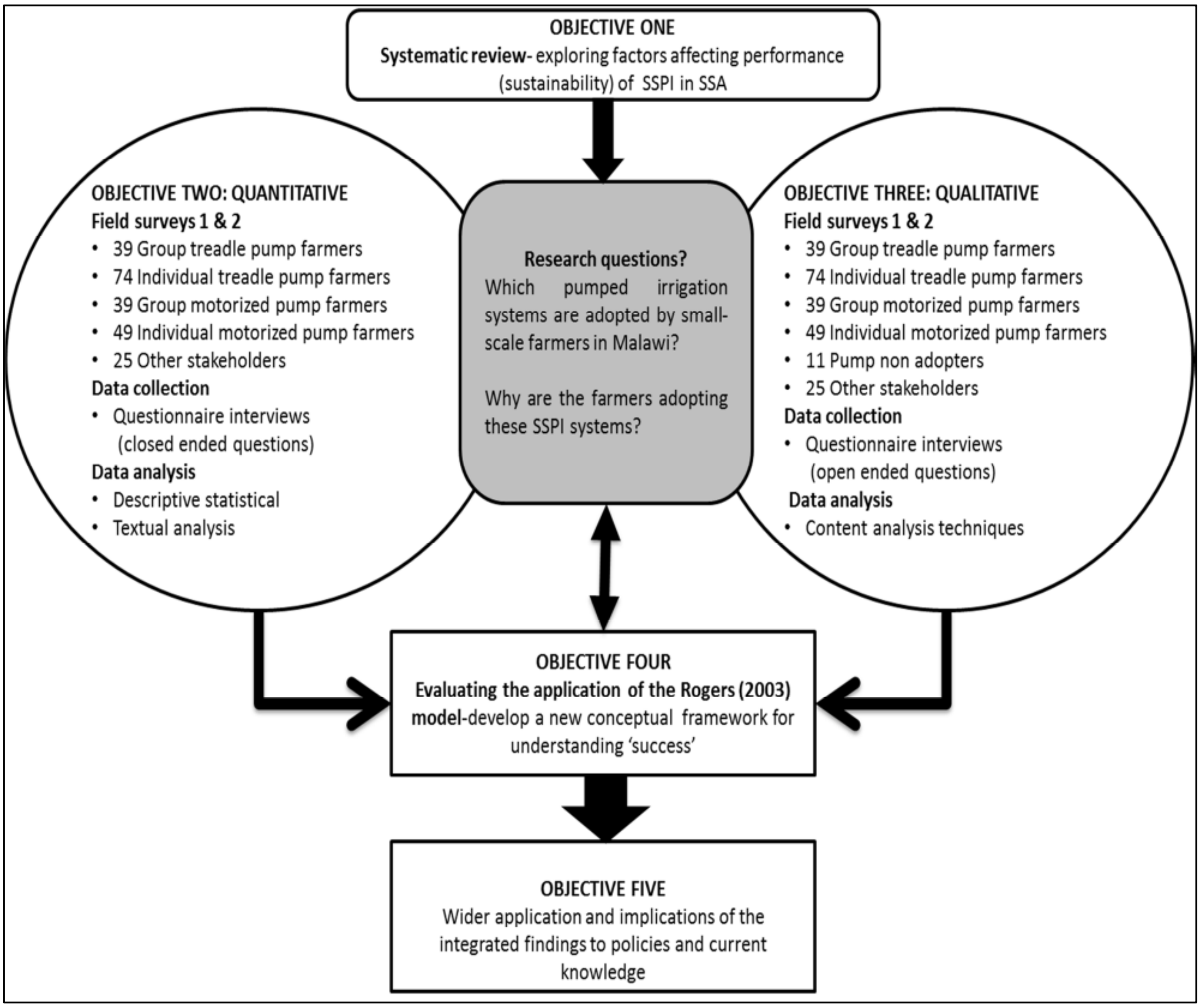

Figure 4.1: Schematic representation of the methodology employed in this research

4.3 Field survey methodology

4.3.1 Description of study areas

This section provides background information on the study districts of Lilongwe, Ntcheu and Mchinji which are located in central Malawi (Figure 4.2). These districts were chosen because: (a) they represent the major agro-ecological zones where SSPI systems are common and potentially applicable. Lilongwe and Mchinji represent the middle altitude warm plains zones (760-1300m) whilst Ntcheu represents both the middle and low altitude (200-760m), and a hot and dry agro ecological zone; (b) of the prevalence of SSPI; (c) of familiarity of the researcher with the culture of the people. The researcher speaks the same language as the people from these districts therefore it was easier to communicate with farmers during interviews. The understanding of the culture of the people from the study area helped the researcher to easily approach and interact with farmers during the surveys; (d) of the easier access to the study districts and; (e) of the time and financial constraints.

In the first survey, Lilongwe and Ntcheu districts were selected. These two districts are from the same ADD (Lilongwe). Lilongwe is the Capital City and has a total land area of 6,159 km^2 representing 6.5% of total country's land area. According to NSO (2008) Lilongwe (rural and urban) has the highest population in the country which registered 1,897,167 representing about 15% of the national population. The rural area has the highest population of 1,228,146. Ntcheu district lies to the south of the central region. It shares the international boundary with Mozambique to the West, and has a total land area of 3,424 km^2 representing 3.63% of the total Malawian land area. The district has a population of 474,464 representing a medium density district (National Statistical Office, 2008). According to DOI (Government of Malawi, 2014), Lilongwe ADD has the largest number of treadle and motorized pumps that are distributed to farmers by both the government and other organizations such as NGOs. Furthermore, the ADD has a diversity of stakeholders including local NGOs, government projects, international NGOs, commercial pump distributors and donors that are involved in promoting irrigation pumps in various ways. These provided better grounds for assessing the adoption processes and sustainability of the pumps.

In the second phase, Mchinji district (Figure 4.2) also from the central region but in a different ADD (Kasungu) was selected. The district was selected with the aim of investigating the same phenomenon, but under different contexts such as: agro-ecological zones and socio-economic profiles. This means that the research interest was not particularly in the differences between the three study districts but rather the groups of adopters (group versus individual farmers, incentive versus self-motivated farmers and treadle versus motorized pumps farmers). The research considered results from the first two survey districts (Lilongwe and Ntcheu) as one case study (survey 1) and the second survey district (Mchinji) as a second case study (survey 2). Kasungu ADD where the second survey district (Mchinji) was selected, is the second ADD with the largest number of SSPI systems after Lilongwe ADD

(Government of Malawi, 2014). Mchinji shares the international boundary with Zambia and is about 109 km from Lilongwe. The total area is 3,356 km^2 representing 3.56% of the total land in Malawi. Mchinji represents a medium density area with a population of 456,558 (National Statistical Office, 2008).

A wide variety of crops are grown in these districts with maize, tobacco and groundnuts considered as the main crops. In irrigated agriculture, farmers normally grow maize, beans, potatoes and vegetables.

Within each district, the selection of the study sites was confined to the EPAs with a high number of irrigation pumps. The first survey was carried out in Mkwinda and Mpingu EPAs for Lilongwe District and Kandeu and Manjawira EPAs for Ntcheu district. In the second survey, the study was confined to Zulu, Mlonyeni and Simphasi EPAs.

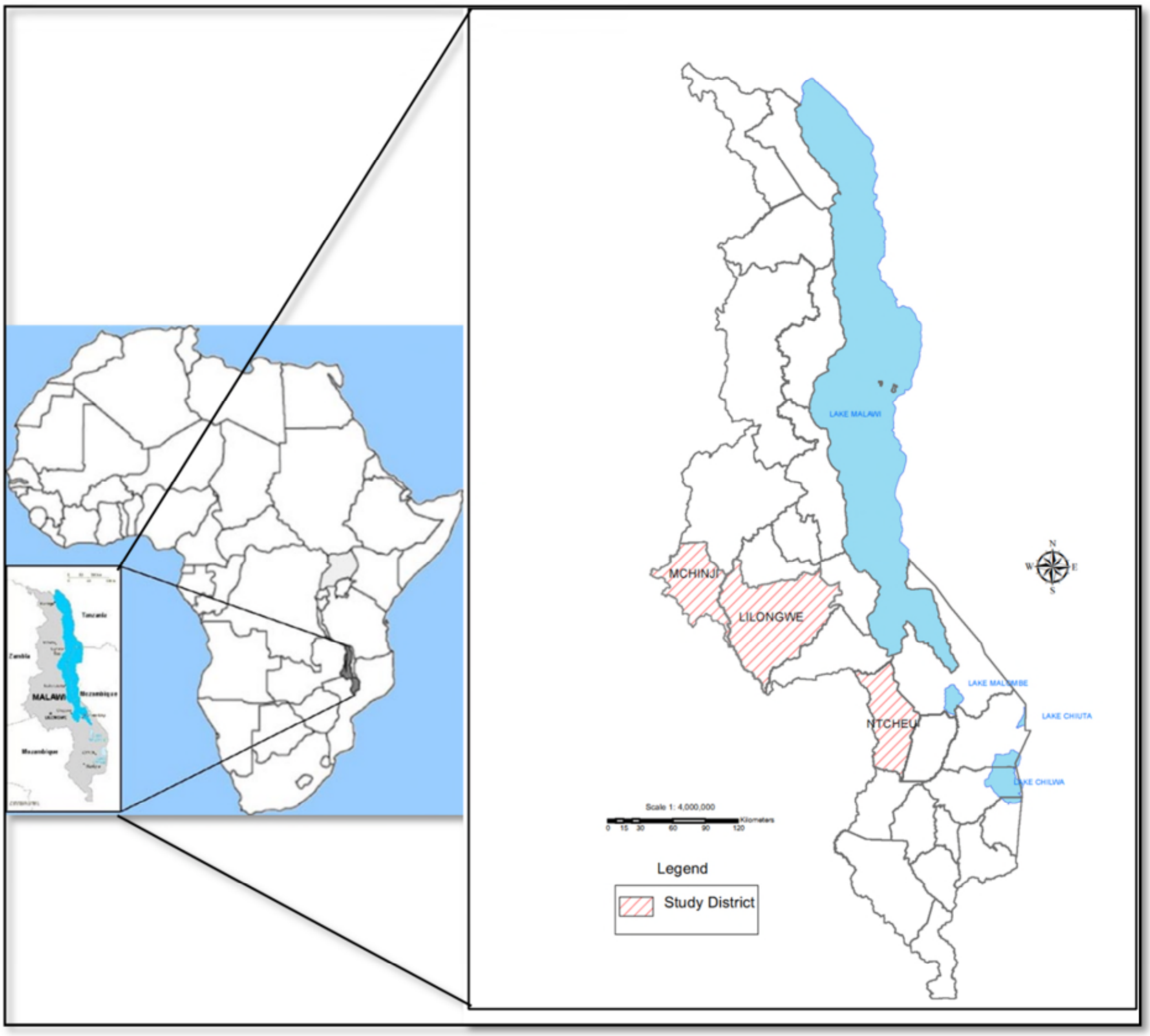

Figure 4.2: Map of Malawi showing the research study districts

4.3.2 Formulation of research questionnaires

Formulation of the farmers' and stakeholders' field research questionnaires (Appendix A-D) was guided by findings from the SR. The SR revealed that technical and socio-economic factors are key drivers in the performance of SSPI. Both surveys used similar processes with some questions in the questionnaires for second survey reflecting the proposed new framework. Except for the additional component on non-adopters in the second survey and the omission of crop production and labour costs from the first survey, the farmers' questionnaires included the following components:

(i) Farmers' socio-economic history (age, sex, education level, household size)

(ii) Pump characteristics (year of adoption, status, type, brand, means of accessing, source of power and water source).

(iii) The adoption process in which the questions included farmers previous irrigation methods, reasons for adopting the pumps and length of using the pumps

(iv) The profiles (farmers, pumps, irrigation management) of pumps currently adopted. This included the type of pumps, operational status, crops grown, size of irrigated areas, farmers' perception on pump labour demand and simplicity, pump repair and maintenance issues, water supply issues, the significance of capital for inputs on pump adoption and pump continuity and discontinuity contributing factors. Since second survey was seeking to verify the findings, most of the questions from this component were seeking 'Yes or No' responses.

(v) Comparison of the pumps with others types and farmers preferences if given a choice; farmers were asked about other pumps they knew and how they were compared with their own; farmers' preferences and future prospects on the pumps were also asked. These were asked to determine the success/failures of the SSPI.

(vi) For pump non-adopters, their view on the pumps were sought and this included whether they knew about any irrigation pump and why they were not using them; if they intend to use the pumps in future and if so which pump and why that particular pump?

For stakeholders, the questions related to the farmer questionnaires. This was done to ensure triangulation of data gathered. Specifically, the questionnaires sought the following information:

(i) The respondents' organization history and types pumps associated.

(ii) The type of support that the organization was providing in relation to pump adoption, their expected benefits and how they compared the pumps supported to the other pumps.

(iii) Their perceptions on current use of pumps; this was seeking the stakeholders' view on factors influencing success of the pumps.

(iv) The future prospects of the pumps which aimed at seeking the stakeholders' view on sustainability of SSPI.

4.3.3 Sampling

First survey

The first survey was administered between August and December 2013. The aim was to understand the SSPI adopted in Malawi and identify factors affecting their success. Selection of respondents from other stakeholders (organizations) was based on information provided by government officials. The process involved gathering information about stakeholders involved in SSPI and potential study sites. To select respondents from other stakeholders, the chief executives of the respective organisations were contacted to suggest the names of potential respondent(s). These were then contacted and an appointment for interview scheduled. However, due to other commitments, most stakeholders opted to respond to the questionnaires at their own convenient time. The option was not effective because the responses were too brief. To obtain a more complete dataset, the author also collected relevant documents from some organizations.

Farmer selection was guided by the government extension workers and this heavily relied on their knowledge about the local communities. The process started with contacting the extension workers' supervisors (AEDCs) from the EPAs. Copies of questionnaires were then sent to extension workers. This was to allow them to clearly understand the research objectives and to provide guidance on selection of potential respondents. Prior to administering the interviews, extension workers mobilized the farmers for a meeting; mostly this was carried out in one of the farmers' irrigated fields. These meetings were to introduce the researcher and present the objectives of the visit. During the meetings, farmers were allowed to ask questions related to the research for clarification.

Finally, farmers who expressed an interest to participate in the interviews and had met the research requirements (i.e. used the pumps at least for a minimum period of six months or full irrigation season) were selected. To increase the sample size, farmers were asked if they knew other farmers using pumps in the surrounding areas. In total, 116 farmers, including 16 pump irrigation groups and 16 stakeholders were interviewed during the first survey (Table 4.1).

Table 4.1: Number of respondents and the sampling techniques in two surveys

		No of respondents			
No	Type of respondent	First survey	Second survey	Total	Sampling technique(s)
1	Group treadle pump farmers	31	8	39	Purposive & snow ball
2	Individual treadle pump farmers	35	39	74	Purposive & snow ball
3	Group members (shared) motorized	27	12	39	Purposive & snow ball
4	Individual motorized pump farmers	23	26	49	Purposive & snow ball
	Total pump farmers	**116**	**85**	**201**	
5	Stakeholders (Government)	6	4	10	Purposive
6	Stakeholders (NGOs)	5	4	9	Purposive
7	Stakeholders (Commercial distributors)	2	0	2	Purposive
8	Stakeholders (Donors)	1	1	2	Purposive
9	Stakeholders (Academic)	2	0	2	Purposive
	Total other stakeholders	**16**	**9**	**25**	
10	Non-adopters	0	11	11	Purposive & snow ball
	Grand total	**132**	**105**	**237**	

Second Survey

The second survey was administered between September and November 2014 in Mchinji district. Selection of participants and study districts followed a similar process to the first field survey whereby information about pump farmers was obtained from the DOI. Information concerning availability of pumps and stakeholders was obtained from the irrigation district office. However, during the site visits it was found that in some places the records provided by the district offices did not match with what was actually on the ground. In some cases there were no farmers with pumps or farmers had relocated. In such cases, the researcher employed snow ball sampling to access other pump farmers. In addition, a number of non-adopters were interviewed in order to triangulate the findings. These were farmers who irrigated using watering cans. Farmers with irrigation pumps were asked if they knew any farmer from their community who irrigated without pumps. Usually these were supposed to be from the same community with those with pumps in order to easily make reference of the pumps.

In the case of stakeholders, following experiences from the first survey, stakeholders were booked in advance for interviews and the questionnaires sent to their organization in advance in order to allow them to prepare for the interview. However, issuing the questionnaires in advance still prompted some respondents to complete the questionnaire thereby avoiding direct interviews. To alleviate this problem, a note was included to remind them that they were not supposed to provide responses on questionnaires. However, for stakeholders who could not be available for direct interviews were still encouraged to respond to the questionnaire. Where the responses were not clear, the researcher followed up through either phone calls or in person. A total of 85 pump farmers, 11 pump non-adopters and 9 other stakeholders were interviewed (Table 4.1).

4.3.4 Pre-testing questionnaires

The questionnaires were first tested as recommended by Brenner (1985) in order to: remove sources of weakness and error; test the suitability of the questionnaire; check if important areas were well covered and remove duplications. Based on this, the researcher modified the questionnaires. For example, in the second survey, it was planned that farmers would initially be informed that the interviews were a follow up to the first field survey conducted in 2013; however during pre-testing it was found that this attracted a lot of questions such that farmers were seeking to learn the responses from the first survey. This encouraged the researcher to pre-empty the responses from first survey; this affected farmers' responses. To avoid this, a summary of findings from first survey was only shared with the respondents after administering the interviews and notes related to farmers' reactions were taken. In addition, pre-testing enabled the researcher to get exposed to field situations and get used to the administering the questions.

4.4 Data collection

This involved gathering both qualitative and quantitative data. Both surveys had two questionnaires, one for pump farmers and another for stakeholders and these were administered as follows.

4.4.1 Administering first survey questionnaires

Each questionnaire interview was administered in person by the researcher. Before administering any interview, consent of the interviewee was sought (Appendix A). The researcher firstly introduced herself and the study's objective. Questionnaire interviews for both the farmers and other stakeholders were scheduled to last about 1-2 hours, however they varied between 30 to 45 minutes depending on the respondents. Subject's responses were completed on the questionnaire and also recorded using a digital voice recorder. The recorded data were meant to supplement the closed questions. However, it was found that farmers' responses were influenced by the presence of extension workers who accompanied the researcher; while this could not be avoided, the researcher ensured that objectives of the visit were clearly explained to the respondents. Following a formal introduction, the respondents' consent to participate in the interviews was sought (i.e. farmers or stakeholders were informed that they were free to withdraw their responses within the period of seven days) as recommended by Cranfield University Research Ethical Committee (CUREC).

Most farmers' interviews were carried out on their irrigation fields since the survey was carried out when irrigation activities were also taking place (Figure 4.3). This provided an opportunity to supplement the data with informal observations which involved taking field notes. Where it was discovered that farmers owned more than one pump, information pertaining to each pump was obtained separately. However, information regarding crop production and labour costs was not reliable as most farmers could not remember the exact costs involved this was eventually omitted during the second survey. Likewise, it was found that closed questions limited farmers from providing sufficient information about the pumps. These questions were left open to capture more information during the second survey. For other stakeholders, interviews were mostly carried out in their respective offices.

Figure 4.3: One of the research participant's families with treadle pump irrigation technology where interviews were conducted right at their own irrigation field, in Ntcheu district.

At the end of each interview, respondents were thanked for their participation. Questionnaire responses were checked and follow up visits arranged in case of any further queries or incomplete information.

4.4.2 Administering second survey questionnaires

Following lessons learnt from first survey, the second survey questionnaire had more open ended questions. Although the process was time consuming, it was found that it provided clear explanations and further understanding of findings from the first survey. Furthermore, this was alleviated by removing the repeated questions. Moreover, because of the open ended questions, it was found that some of the follow-up questions were already addressed in the process thereby reducing the time for administering the interviews. The issue of meeting farmers in groups was avoided because during the first survey those interviewed were influenced by their peers. To ensure this, farmers were not informed in advance about the visit to the sites because this encouraged farmers to gather in groups prior to the interview meetings. Therefore farmers were interviewed right at the places where they were found, this was mostly either at in their household or irrigated fields (Figure 4.4).

Figure 4.4: A farmer showing a motorized and treadle pumps during interviews in Lilongwe district.

In both surveys the respondents were informed that the interview responses will be recorded in order for the researcher to capture the responses correctly. However, it was noted that farmers' presentations of responses were affected with the recorder because they were making sure that their responses should be standard. To avoid this, it was emphasized that the recordings were only to allow easier checking of data, and would later be destroyed. Similarly, some stakeholders were not comfortable with recording of the interviews such that in other cases the recorder was completely withdrawn. In such cases, detailed notes were taken to capture the interviews. In addition, soon after interviews, all the notes taken were reviewed such that wherever it was not clear, clarification were sought from the respondents before leaving.

4.5 Data analysis

4.5.1 Quantitative

The closed-ended questionnaire responses were entered into SPSS 20 for Windows. Some were analysed using Ms Excel. 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 SSPI currently adopted in Malawi and statistical comparison between the classification of the farmers. Tables and bar graphs were used to present the findings. Textual data analysis enriched the results by providing possible explanations where necessary.

4.5.2 Qualitative

Responses obtained from open ended questions and notes taken during questionnaire administration were coded and entered into Microsoft Word 2007. Further, tape recordings were listened to in consultation with the field notes. Rather than generating verbatim transcriptions, field notes were amended accordingly (Halcomb and Davidson, 2006). Content analysis techniques were used to analyse the data by identifying common themes and codes in the transcribed data (Graneheim and Lundman, 2004; Krippendorff, 2003). This procedure is outlined in Appendix E. In cases where new information emerged from the data, new codes were generated and added to the already identified codes as outlined below.

The process of developing the codes

The approach followed to develop the codes for qualitative content analysis was deductive (Appendix E). According to Burnard et al. (2008) this approach is useful in studies where researchers are already aware of the probable participants' responses. In the case of the first survey, the SR findings (Chapter 5) provided the basis for identifying the themes used for coding the qualitative data in advance. However, since new categories were identified as they emerged from the data; an inductive approach was also employed for additional codes (Braun and Clarke, 2006). The process of developing the sub-themes and codes involved the researcher reading each transcript and making notes, highlighting short phrases that sum up what is being said in the text. Thereafter, the researcher collected together all words and phrases from all interviews onto a new Ms Word document where all duplications were crossed out. Consequently, the researcher remained with a shorter list of categories where overlapping or similar categories were further checked. Finally, informed by the SR findings, the categories were refined and reduced by grouping them together. According to literature, the list of categories can be up to a maximum of twelve and in this study, six categories were identified (Figure 4.5). Second survey analysis used similar codes.

The coding process

Using these coding categories, the researcher independently coded one transcript from each of the four groups of pump farmers. After coding each transcript, the researcher discussed the codes with peers and supervisors and finally some codes were added while others were omitted from the coding tree. Using the agreed coding tree (Figure 4.5), the researcher then independently coded all transcripts, including those coded prior to finalization of the coding tree. Given the coding tree, the process of analysing transcripts involves the researcher dividing up all the interviews with the identified codes. This included counting up the number of transcripts that discussed a particular code in order to get the magnitude of an element analysed and offer a summary statement of the issue discussed in the transcripts. From this organized data, the researcher then finally reports the research findings organized based on the coding tree. In cases where there were deviations such as respondents clearly going off track and begun to move away from the topics under discussion, such deviations were simply not coded.

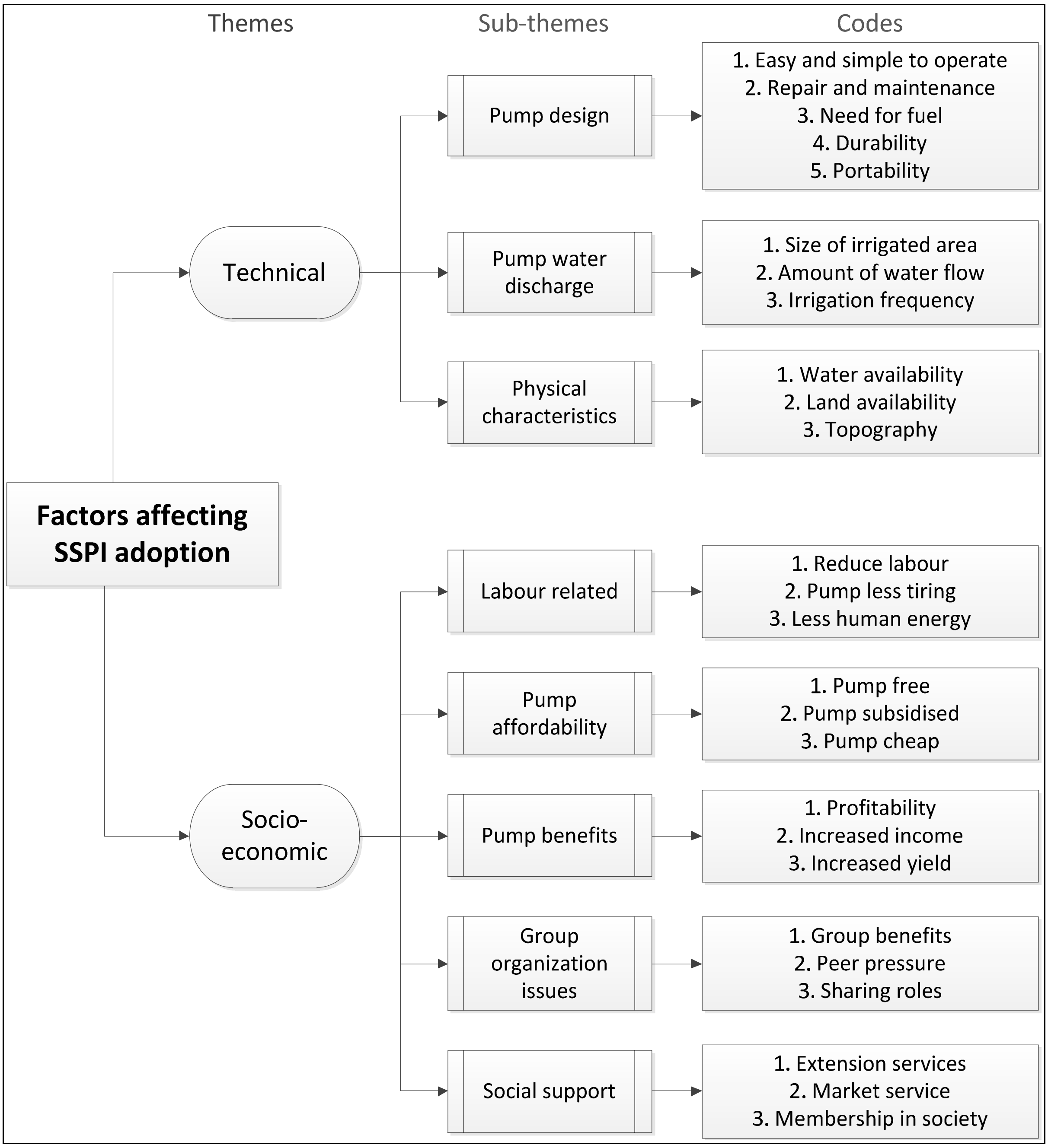

Figure 4.5: Coding tree for content analysis

Reflection process

The process of qualitative research requires a continuous evaluation of subject responses, intersubjective dynamic and the research process itself (Pyett, 2003). In this study, the initial interpretations were further tested by further examination and checking. This involves examining the researcher's role in the construction of the meanings. This process is important because despite the techniques of reporting the valid findings, their acceptance by the third party requires a degree of trust in diligence and integrity of the researcher (Pyett, 2003). This process involved returning again and again to the data to check. Questions such as; whether the interpretations are a true reflection to the data; whether the findings applies to other individuals in the study; if particular topics are raised in all the interviews; and how the researchers' knowledge, position and experiences influences the process; guided the reflection process. Ultimately, this process contributed to reframing of some findings and interpretations.

4.6 Data reliability and validity

Normally quantitative research is constructed to retain the ability to infer a sample to a larger population. Further, validity in quantitative research establishes whether the research results are truthful (Creswell, 2009). Given this understanding, although this study uses purposive sampling to select the respondents, credibility of the quantitative results was as far as possible ensured through triangulation. Multiple data sources including interviews, informal observations and organizational documents were used.

For qualitative research, a number of strategies were considered to ensure the credibility of the results. These strategies included:-

- The reflection process in which the researcher was repeatedly returning to the data to check the processes involved.
- The use of an independent reviewer (peer) to code a proportion of the qualitative data to check for biases in the coding process. The results obtained by an independent reviewer were compared with the researchers'. In the case of differences, the researcher considers that as an opportunity to reflect on the results and reframe some findings and interpretation.
- Checking the codes: the identified codes were initially tested on a number of transcribed data. The results were discussed with the Supervisors before the actual coding process was undertaken.

- Taking back some of findings to participants (farmers and other stakeholders) for checking to determine their accuracy and further develop them for recommendations during the second survey.
- Using triangulation which included the use of multiple sources such as pump farmers, other stakeholders, non-adopters, informal observations and organizational documents.

4.7 Integration and interpretation of findings

The findings from each objective were combined in order to address the research aim (Figure 4.1, page 44). This means that findings in this research are intended to complement, support and confirm each other in order to contribute to the research core thesis. The findings for each objective were compared with the literature to highlight where they support previous research and where they provided new insights (Chapter 8).

4.8 Ethical considerations

The research was classified as low risk based on CUREC evaluation hence appropriate measures associated with the risk were taken. These included the respondents informed consent (Appendix A), avoiding intrusive questions and no use of incentives to encourage participation of the interview respondents.

4.9 Summary

A combination of the systematic review and field surveys strategies helped the research to investigate and understand sustainability in SSPI adoption processes in which the findings are presented in Chapter 5 and 6. Synthesis of these findings is framed around the diffusion of innovations with reference to understanding of the general trends on irrigation development in Malawi (Chapter 8 and 9).

5 THE SYSTEMATIC REVIEW

5.1 Overview

This chapter presents the background of SR the approaches, the SR methodology employed by this research, the findings, the discussion and the conclusions as a complete copy of a paper. The review has been accepted for publication (*Kamwamba-Mtethiwa et al., in Press, DOI: 10.1002/ird.1950*) and a proof of acceptance is presented in Appendices G. There is little duplication between the thesis introduction section (Chapter 1, Section 1.2) and the SR introduction (section 5.2). The main output from this chapter is the identification of the key factors that affect performance of SSPI in SSA and the extent to which these are used as metrics of performance. These findings provided insights for developing methodology strategies for the field surveys.

ASSESSING PERFORMANCE OF SMALL-SCALE PUMPED IRRIGATION SYSTEMS IN SUB-SAHARAN AFRICA: EVIDENCE FROM A SYSTEMATIC REVIEW†

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Abstract

Small-scale irrigation (SSI) has significant potential to increase crop productivity in Sub Saharan Africa (SSA). Pumped irrigation systems are one of the technologies increasingly being used by smallholder farmers. The aim of this study was to systematically review evidence on the performance of SSPI, including motorized, treadle, rope and washer, solar and wind pumps. The study revealed a lack of standardization and use of a wide range of indicators to assess performance. Most evidence related to motorized pumps, these studies confirmed mixed levels of performance; studies relating to other types of pumped system mostly reported a positive impact, although the method of assessment used was critical. Studies reporting positive impacts tended to be those that used socio-economic based factors such as yield and profitability, whereas studies reporting mixed performance tended to be those that relied more on technically based indicators such as pumping and irrigation system efficiency. The analysis highlights the sensitivity of interpreting findings from different studies, and how caution should be exercised when comparing performance within and between different types of irrigation system. The implications for supporting policy development and identifying future research gaps are discussed.

Key words: small pumps; impact; technology; agriculture; performance factors

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† Evaluation de la performance des petits pompe systèmes d'irrigation dans Afique Subsaharienne: preuve d'un examen systématique

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5.2 Introduction

Enhancing agricultural productivity remains a key strategy for poverty alleviation in most low income countries, where the majority of rural livelihoods depend on agriculture (Hussain and Hanjra, 2004). Sub-Saharan Africa (SSA) requires a rapid growth in agriculture to meet Millennium Development Goals and other targets for poverty alleviation and food security (Inocencio *et al.*, 2007). There are thus increasing efforts to expand irrigation development. According to You *et al.* (2011) Africa has potential for both large and small-scale irrigation development, but there are concerns regarding the performance of large-scale irrigation systems as they are perceived as being too expensive and bureaucratic (Adams, 1990).

Small-scale irrigation (SSI) is considered one of the options for increasing agricultural productivity and supporting development in SSA. It is characterized by the use of simple technologies to access water for irrigation. Burney and Naylor (2012) defined water access technology as any method of moving water from its source to where it was previously unavailable. This includes all types of pump, from human powered, rope and treadle pumps to liquid fuel engine driven systems and solar powered pumps as well as gravity/river diversion methods. In SSA, a wide variety of such technologies have been introduced for SSI development since the 1990s. Gravity technology typically involves diverting water flows using open channels without pumping. Motorized systems include engine driven pumps, while treadle and rope and washer pumps are manual and wind and solar use renewable energy (Table 1.1). Previously, most rural farmers in SSA have relied on traditional methods on small plots of land using for example, shadoof, buckets, watering cans, calabashes or blocking streams (Baba, 1993).

Gravity irrigation systems are usually the simplest and cheapest. However, their use is limited to specific topographical and hydrological conditions such that not all smallholder farmers can adopt such technology. SSI pumped systems are therefore a suitable alternative, and their use has substantially increased in SSA. Whilst there has been increased interest in pumped (manual and engine driven) systems, studies reporting on their performance and success have been mixed. Some claim they have had positive impacts on development (Mangisoni, 2008; Adeoti, 2008; Namara *et al.*, 2010b; Kamwamba-Mtethiwa *et al.*, 2012) whilst others argue that they are too expensive and do not make any significant impact on smallholder farmers (Adams, 1990; Ashah *et al.*, 2002; Inocencio *et al.*, 2007; Chidanti-Malunga, 2009).

The term 'performance' has several meanings. In general terms it means the accomplishment of a given task measured against pre-set known standards of accuracy, completeness, cost and speed. Bos *et al.* (2005) described performance assessment as the comparison of the measured value of a parameter against a target or intended value. Irrigation system performance assessment is described as a systematic observation, documentation and interpretation of activities related to irrigated-agriculture with an objective of continuous improvement (Bos *et al.*, 2005). Performance assessment indicators can be categorized into five broad domains including: (i) water delivery and utilization; (ii) agricultural production; (iii) agricultural economics; (iv) socio-economic; (v) environmental. It is recommended that all performance indicators are used to achieve an efficient, productive and effective irrigation system at all levels; however, the choice of which indicators to use in the assessment depends on researchers' interests. It is argued here that evidence on performance of SSI pumped systems can only be obtained if the key drivers are identified and their measurement standardised. Although studies (Daccache et al., 2012; Fujiie et al., 2011; Kimmage and Adams, 1990; Namara et al., 2010a, 2011) have attempted to review performance of irrigation development in SSA, no systematic review (SR) has been undertaken on SSPI development. This research contribute to addressing this gap in knowledge by applying an SR approach to synthesize published science and grey evidence to identify the key factors affecting performance of SSPI systems and use the evidence to inform policies promoting SSI pumped system in SSA.

A number of recent studies have adopted the SR approach to gather evidence. For example, Knox et al., (2012; 2013) assessed the impacts of climate change on yield of eight major crops in Africa and South Asia and on the infrastructural impacts on agricultural development including irrigation, respectively. That latter study reported that about a third of evidence on related to irrigation development impacts on agricultural productivity were positive. The authors used measures such as income and poverty reduction. Fernandez et al. (2011) used a SR methodology to summarize knowledge relating to the usability evaluation methods (UEMs) to evaluate web applications over 14 years. That study identified research gaps which subsequently provided researchers with a framework for new research.

5.3 Methodology

This research followed the SR guidelines developed by the Collaboration for Environmental Evidence (CEE) and Centre for Evidence-Based Conservation (CEBC, 2010). This includes drafting a protocol to define the methodology followed by systematic literature searches and selection based on a set of 'inclusion criteria'. Relevant literatures were screened in two stages; initial filtering was undertaken based on the title; a second filter was then based on the abstract. Full texts were only reviewed for those articles, reports and papers that passed all inclusion criteria. These inclusion criteria included specifying all relevant subjects, types of interventions, expected comparators, methods and outcomes. This involved (1) identifying potential 'effect modifiers' in the studies, (2) specifying the data extraction techniques to obtain qualitative and quantitative data, (3) outlining quality assessment criteria for the studies which included validity of the methodologies and data analysis methods and (4) identifying data interpretation and synthesis techniques depending on the amount and quality of data collected.

Based on CEBC (2010) guidelines, the research question was split into elements considering (1) population (agriculture narrowed down to beneficiaries- smallholders, rural communities, farmers, growers, households), (2) intervention/exposure (SSPI systems also known as irrigation technologies or water management including treadle, rope and washer, motorized (diesel and petrol), solar and wind pumps), (3) comparator (changes relative to the intervention before and after or with and without the interventions) (4) and outcomes (change factors as a result of the intervention including changes in average yield, irrigated area, labour demand, energy need, farm income, food security). These elements are collectively referred to as PICO or PECO terms. Specific keywords were then selected, relevant scientific databases identified, search terms developed and then applied to each bibliographic database.

The search period was limited to studies published between 1990 and 2013 based on indications of increased interest SSI development in Africa (Baba, 1993; Fujiie et al., 2011). The search used trials in Scopus and finally two search strings *(Irrigat* pump* AND Agricultur*)* and *(Irrigat* Pump* OR Water management OR Irrigat* technolog**'' AND *(Smallholder* OR Farmer* OR Grower* OR Rural Communit* OR Household*)* were used to search all relevant scientific databases (Scopus, Science Direct, Web of Knowledge, Environmental Complete and Direct Access Journals), organization websites (e.g. World Bank, Food and Agriculture Organizations (FAO), Consultative Group on International Agricultural Research (CGIAR), African Development Bank (ADB), International Food Policy Research Institute (IFPRI), International Water Management Institute (IWMI) and International Fund for Agriculture Development (IFAD) and search engines (Google scholar and google.com). All references retrieved were exported into bibliographic software (Refworks) prior to assessment of relevance using the inclusion criteria. The bibliographies of identified sources were also searched. Only literature published in English was reviewed. Academic sources were sampled first, to avoid duplication from other databases. For search engines, a maximum 50 'hits' were reviewed using the same search strings.

This SR approach resulted in 1442 articles; based on the inclusion criteria. These were screened by title (331) then abstract (101) and 35 papers finally selected for full review (Figure 5.1). Data extracted included year of publication, country where the study was conducted, size of irrigated area, types of pumped system, crops studied, performance indicators and final outcomes/impacts reported from the studies. The results were analysed using narrative synthesis categorised by performance factor. Attempts were also made to quantitatively analyse data based on crop yield information, however there were too few observations available (Appendix F).

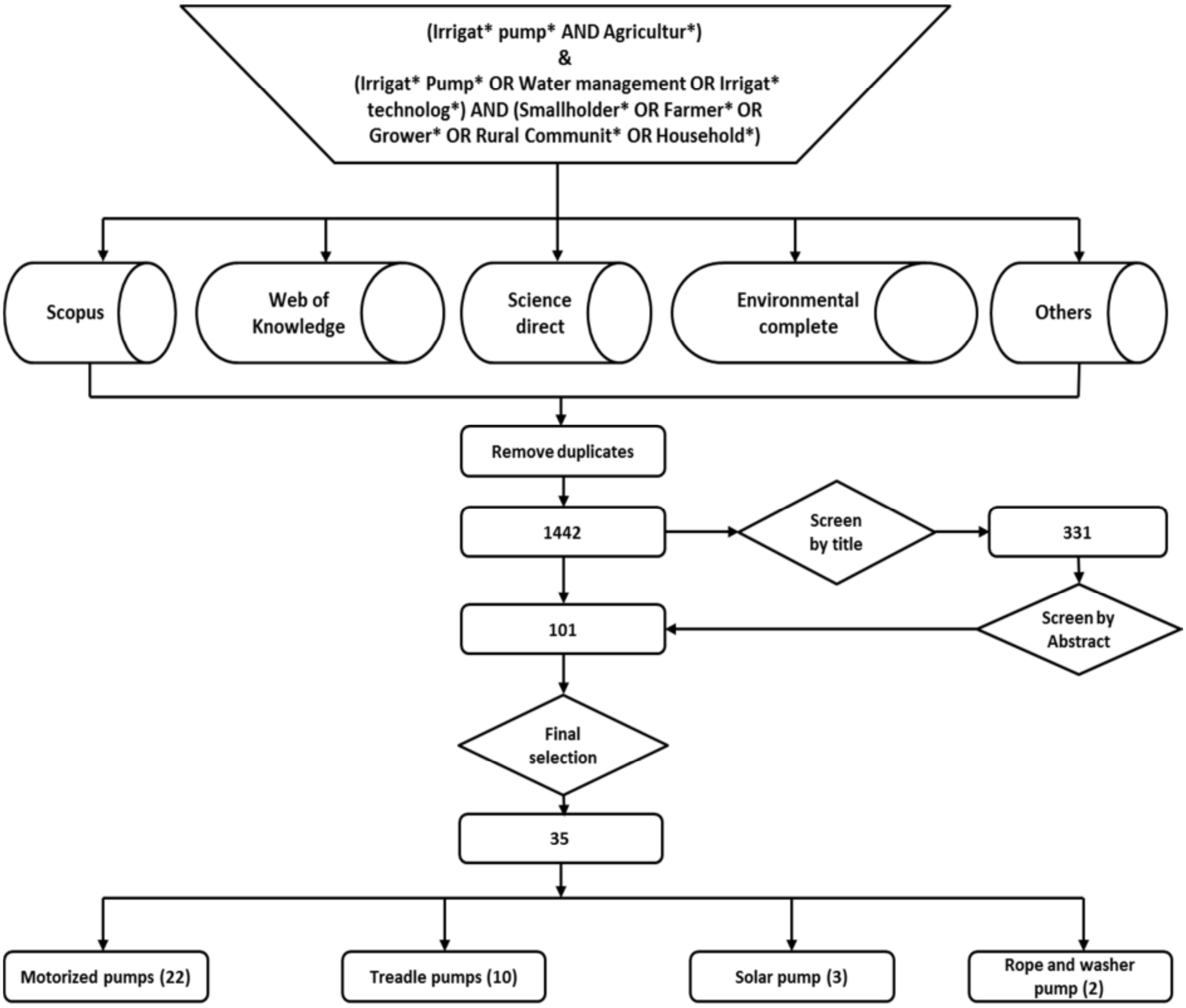

Figure 5.1: Schematic summary of the systematic review process.

Clarification of terminologies and analytical methods

Studies on irrigation performance assessment can be broadly divided into those providing methodological guidelines and those reporting irrigation performances (Yakubov, 2012). This review focused on studies that reported on actual performance. In the synthesis, the 35 selected papers were categorized according to the type of pumped systems studied (motorized, treadle, rope and washer and solar pumps). Data were further analysed by the reported impacts (positive, negative and mixed) and the performance assessment factors used. In order to identify key factors, it was apparent that the final outcomes of the studies be highlighted and linked to the key drivers used to assess performance. Studies were then classified as being positive if the intervention resulted in success, negative if the intervention failed and mixed if the outcomes included both elements of success and failure.

Interpretation considered a factor as significant if performance assessment evidence resulted in mixed or failure outcome.

Given that the choice of performance factors used in studies largely depends on the researchers choice, this study aggregated the proposed five performance assessment domains by Bos et al. (2005) into social (SO), socio-economic (SE), agronomic (AG), technical (system/pump) efficiency (TS &TP) and biophysical (BY). This was based on the reporting patterns in the selected studies. It was noted that studies were directly referring to these identified classes in their assessments although the specific performance indicators varied between the studies (Table 5.1). There was also no clear separation in the studies between economic and financial factors and therefore the economic category in this classification included financial performance. Ideally these classes fit into the five broader domains as proposed by Bos et al. (2005) and Córcoles et al. (2010).

Table 5.1: Performance factors used in for screening the evidence

Performance factor	Parameters /indicators used
Social	Management, technological, product organization, access and knowledge.
Socio-economic (SE)	Human capital (age, household size, education level) poverty levels, association membership, number of extension visits, location, adoption, access to credit, numbers of people emerging out of poverty, gender, threshold increasing levels (with gender, household dependency ratio, distance to the market, owning land, access to irrigation and association membership), food access, food utilization and availability, household consumption
Economic (EC)	Water productivity, land productivity, returns to labour, return to land, return to water, yield, net farm income under rain fed, net farm income under irrigated area, rain-fed land holding size, irrigated production, net revenue, farm size, labour costs, input costs, fixed/capital costs, gross margins, pump repairs costs, fuel costs, marketing, income total per capita daily consumption, net farm income, household expenditure, income from other sources, ability to pay back pump loan, set up costs, labour, production cost, willingness to pay, operation and maintenance, asset accumulation, financial capacity, energy costs, pump prices.
Agronomic (AG)	Crop water use efficiency, yield, plant height, fruit size, water consumption, water use productivity.
Technical system efficiency (ST)	Irrigation efficiency, relative irrigation supply, water depth applied, irrigation supply, irrigation frequency, labour efficiency, adequacy, reliability, flexibility, equity, irrigation intensity, relative water supply, water source reliability, water delivery capacity, main canal losses, seasonal irrigation requirement, uniformity distribution, Christiansen coefficient, wetted diameter, water use efficiency.
Technical pump efficiency (PT)	Body Mass Index (BMI), pump power output, pump discharge rates, pump head range, pump volumetric efficiency, pump mechanical efficiency, rope and washer space, pump pulley rotational speed and pump hydraulic output, pump efficiency, flow rate, hydraulic energy, daily volume, pump fuel consumption, labour input/man-hours.
Biophysical (BY)	Straw/fodder production, stock carrying capacity and shrubland management sustainability.

5.4 Results

The review identified studies relating to thirteen countries of which eight (Mauritania, Ethiopia, Nigeria, Mali, Niger, Kenya, South Africa and Malawi) included motorized pumps, four (Malawi, Zimbabwe, Ghana and Kenya) treadle pumps, two (Benin and Ethiopia) solar pumps and one (Zimbabwe) rope and washer pumps (see full details in Appendix F). The types of pumped systems studied were regionally localised such that the majority that covered motorized and solar pumps were from West and East Africa whilst Southern African studies mostly related to treadle and rope and washer pumped irrigation systems. The majority of literature (63%) focussed on motorized pumped systems, followed by treadle pumps (23%), solar pumps (9%) and rope and washer pumps (6%). The review did not find any relevant studies on the use of wind pumps for irrigation. Detailed results per country are described in Appendix F. The majority of studies on motorized pumps related to rice followed by tomatoes, maize, onions and beans and sorghum. Very few studies reported the crop types under treadle pumps. No crops were reported by the studies on solar and rope and washer pumps. Different methodologies were reported to assess irrigation performance. The majority (60%) used statistical methods based on quantitative data; however, due to 'effect modifiers' it was difficult to compare the quantitative findings. The review also attempted to analyse the impact of different pumped systems on crops; however, interpretation was limited by the very small sample size.

Motorized pumped systems

Table 5.2 summarises the evidence on motorized pumped irrigation, the comparators and performance factors used and reported outcomes. The study then aggregated these results into studies that reported on positive, negative or mixed performance.

Table 5.2: Selected studies for motorized pumped systems, comparators, performance indicators and outcome (impact)

No	Country of study	Comparator	Performance factor assessed**							Outcome	Indicator used to quantify impact	Source
			SO	SE	EC	AG	PT	ST	BY			
1	Nigeria	Traditional		✓						Positive	Resource-use, yield & profit	(Baba, 1993)
2	Mali	Pumped irrigation		✓						Positive	Household consumption, assets & informal insurance	(Dillon, 2011)
3	Mauritania	Pumped irrigation-sorghum Vs rice			✓	✓				Positive	Crop profitability	(García-Ponce et al., 2013)
4	Nigeria	Adoption with and without rainfall risks		✓						Positive	Willingness to investment	(Takeshima and Yamauchi, 2012)
5	Niger	Traditional			✓	✓				Positive	Profits	(Woltering et al., 2011)
6	Ethiopia	Drip and furrow pumped systems				✓				Positive	Crop yield	(Yohannes and Tadesse, 1998)
7	Nigeria	Rain fed agriculture		✓				✓		Positive	Outputs and technical efficiency	(Adeoti, 2006)
8	Ethiopia	socio-economic performance		✓						Positive	Crop revenue	(Mengistu, 2008)
9	Malawi	Different pump and traditional irrigation		✓		✓				Negative	Water and fuel productivity, labour, yield and revenue	(Kadyampakeni et al., 2012)
10	Mauritania	Traditional		✓						Negative	Return to labour and inputs/ workload	(Comas et al., 2012)
11	Mauritania	Pumped systems-scheme performance			✓			✓		Negative	Productivity of land, water and fuel	(García-Bolaños et al., 2011)
12	Kenya	Pumped system-pump efficiency					✓			Negative	Pump efficiency	(Kang'au et al., 2011)
13	Nigeria	Adoption with & without transaction costs		✓						Negative	Transaction costs, gender	(Takeshima, Adeoti and Salau, 2010)
14	Mauritania	Large scale						✓		Mixed	Technical efficiency-Land productivity and energy cost	(Borgia et al., 2013)
15	Niger	Technical capacity with other pumps					✓			Mixed	Pump water discharge and hydraulic output	Norman and Walter (1994)

No	Country of study	Comparator	Performance factor assessed**							Outcome	Indicator used to quantify impact	Source
			SO	SE	EC	AG	PT	ST	BY			
16	South Africa	Economic productivity of pumped systems			✓					Mixed	Water value and productivity	(Yokwe, 2009)
17	Ethiopia	Large scale	✓							Mixed	Technological management	Awulachew (2011)
18	Mauritania	Other production systems			✓	✓			✓	Mixed	Irrigated area, crop diversity and stock carrying capacity	(Connor et al., 2008)
19	Ethiopia	Scheme efficiency of pumped system			✓			✓		Mixed	Water & land productivity, rate of returns on investment	(Hassen, 2004)
20	Mauritania	Before and after rehabilitation						✓		Mixed	Reliability, flexibility and pumping capacity	(Mateos et al., 2010)
21	Mali	Social changes with flood irrigation	✓							Mixed	Organization capacity, water access & knowledge	(Ton and De Jong, 1991)
22	Ethiopia	Socio-economic performance		✓				✓		Mixed	Income and water use efficiency	(van Halsema et al., 2011)
	Total		2	9	6	5	2	6	1			

***SE-Socio-economics, EC-Economic, AG-Agronomic, PT- Pump Technical Efficiency, ST Scheme Technical Efficiency, BY-Biophysical*

Socio-economic factors, followed by agronomic and economic factors; dominated studies that reported positive performance. Five of the eight studies reporting positive impacts used socio-economic factors with measures in yield, profits, resource use, outputs, willingness to invest, household consumption, assets, crop revenues and informal insurance. The majority of these studies used yield and profit indicators. Three studies that assessed impact using agronomic and economic factors also used productivity (returns to land, water and fuel) and yield to measure impact. This reflects the importance of measuring agricultural productivity in understanding performance of small-scale pumped systems. While it may be difficult to compare the findings from such studies, the trends and patterns on use of common indicators in the assessment implied that the factors were significant indicators for positive outcomes of the motorized pumps.

Studies that reported a negative impact had used varied factors linked to productivity (returns to water, labour and energy, initial costs). However, effect modifiers within the studies made it difficult to separate out the direct impacts. Almost all had different comparators and were conducted at different scales.

Nearly half (41%) of the evidence reported mixed impacts; only a few of these studies had used socio-economic factors for assessment. The use of technical (system and pump) efficiency factors was widespread. Positive impacts were mainly attributed to socio-economic assessments and negative impacts mainly related to technical assessments. This highlights the attributes that particular performance assessment factors can have on expected outcomes suggesting the significance of technical factors on performance.

Treadle pumped systems

Nearly a quarter (23%) of evidence selected in the SR related to treadle pumps, possibly implying that these are the technologies that are the preferred choice among developing organizations, donors and researchers. Most studies were from Malawi reflecting the fact that they are being heavily promoted by the Government of Malawi (2010). The majority (70%) of studies reported positive performance impact relating to food security, poverty reduction and crop revenue (Table 5.3). Most studies reporting positive impact used socio-economic factors. Those that reported a negative impact attributed poor performance to the pump labour demand. One study reported mixed performance based on both technical and socio-economic factors. These findings concur with the observations above on motorized pumps.

Table 5.3: Summary evidence on treadle pump performance, by country and performance factor

No	Country of study	Comparator	Performance factor				Outcome	Indicators used	Source
			SE	EC	AG	PT			
1	Ghana	Non adopters	✓				Positive	Adoption factors and poverty	(Adeoti, 2008)
2	Zimbabwe	Different pump types				✓	Positive	Pump and drip designs	(Chigerwe et al., 2004)
3	Zimbabwe	Different pump design				✓	Positive	Pump hydraulic output	(Faulkner and Lambert, 1990)
4	Malawi	Furrow irrigation		✓	✓		Positive	Labour, yield and drip efficiency	(Fandika et al., 2012)
5	Malawi	Non adopters	✓				Positive	Poverty levels and household income	(Mangisoni, 2008)
6	Kenya	Before and after	✓				Positive	Income and loan repayment	(Pandit et al., 2010)
7	Malawi	Non adopters	✓				Positive	Net farm income, adoption, household income, expenditure	(Kamwamba-Mtethiwa et al., 2012)
8	Malawi	Pump efficiency				✓	Negative	Labour and pump discharge	(Joseph and Yamikani, 2011)
9	Malawi	Traditional	✓				Negative	Labour, gross margins	(Chidanti-Malunga, 2009)
10	Malawi	Motorized pump and traditional	✓		✓		Mixed	Labour, yield, crop revenues and water productivity	(Kadyampakeni et al., 2012)
	Total		6	1	2	3			

***SE-Socio-economics, EC-Economic, AG-Agronomic, PT- Pump Technical Efficiency*

Solar pumps

There was very limited evidence found on the use of solar pump technology (Benin and Ethiopia only). All studies on solar pump systems were published relatively recently (Burney and Naylor, 2012; Burney et al., 2010; Jeffries, 2010), indicative of a recently introduced technology in the region. All these studies reported a positive impact; two-thirds used socio-economic factors for assessment; the remainder focussed on assessing the technical efficiency of the pumped system.

Rope and washer pumps

There were only two (Faulkner and Lambert, 1990; Faulkner et al., 1990) studies identified, both from Zimbabwe reporting a positive impact; No recent publications possibly suggest that this is now an abandoned technology.

5.5 Discussion

The increased use of SSPI in SSA has been established on the grounds that larger scale irrigation schemes have often failed (Fujiie et al., 2011). It is believed that pumped systems are among the simple technologies that support smallholder farmers to access water from sources that may not be possible with gravity. Furthermore, it is assumed that the benefits from these pumped systems directly benefit smallholder farmers by increasing agricultural production and farmer incomes (Baba, 1993; Dillon, 2011). However, this study found that evidence relating to SSPI performance is limited, lacks standards and is geographically focused within a particular region in SSA. This study proposes that a number of factors have contributed to these differences found in the literature.

Firstly, this SR has revealed that studies assessing performance of small-scale pumped systems are framed to serve the interests of those driving them. This was demonstrated by the biasness in the evidence on particular pumps that were also supported by the developing organizations. For example, the study found that there were more studies relating to treadle pumps compared to motorized pumps especially in southern SSA; coincidentally, many developing organizations in this region are supporting the up-take of treadle pumps (Mangisoni, 2008). Similarly, it was found that the only evidence relating to rope and washer pumps (Faulkner and Lambert, 1990; Faulkner et al., 1990), were provided by the authors that participated in the pump design. On the other hand, studies involving the IWMI (e.g. Namara et al., 2013, 2014) have reported a rapid rise in the use of private small motorized pump but their evidence in the region is patchy. It is therefore argued that the current evidence on SSPI in the SSA is not entirely based on literature but rather the interest of the various actors involved. This is supported by Sumberg et al. (2012) who argued that most contemporary evidence in the literature exposes major epistemological and ontological divisions in relation to the value of different kinds of knowledge and the nature of the innovation since the focus is on performance of the technology. This might help to explain the reasons why some pumped systems are often positively assessed while others are not.

Second, there are no common approaches or standards adopted for assessing the factors that affect system performance. Socio-economic factors such as profits, assets accumulation, yield dominated the reporting of positive performance while most technically based assessments reported mixed or negative performance (Tables 8 and 9). While the positive socio-economic impact of the systems studied may be consistent with evidence from other SRs (Knox et al., 2013), it is important to recognize that socio-economic changes in smallholder communities could be a result of influences from numerous sources. Considering the household as a unit with a range of income sources, farmers' socio-economic changes cannot be entirely attributed to the contributions made by the pumped systems interventions. For example, evidence from the New Partnership for Africa's Development (NEPAD) (2003) revealed the goals for many developing organizations in SSA are geared towards the rural poor, thus on socio-economic changes. This could explain why socio-economic studies reported positive impact in their performance assessment. However, this study revealed that technical factors are also important in the success of SSPI. This supports previous studies (Adams, 1990; Borgia et al., 2013; Njiraini and Guthiga, 2013) that argued that most small irrigation systems in SSA are not technically effective. Similarly, in Kenya, Kulecho and Weatherhead (2006) suggested that the failure of drip irrigation systems was due to a lack of maintenance and unreliable water supply suggesting that abandonment of most irrigation technologies are likely due to their technical challenges. This has implications for the choice of factors for assessing pumped system performance.

Finally, there was a lack of differentiation between rapid and more detailed comprehensive assessments of small pumped systems. For example in Nigeria, Baba (1993), took three years to conduct a socio-economic assessment of the impact of pumped systems; in contrast, it took only three months to socio-economically assess schemes in Ethiopia (Mengistu, 2008). The outcomes from both these studies showed a positive impact regardless of differences in their duration of assessment. However, it is possible that other factors such as other previous income sources may have contributed to the positive impact on the evidence found in the short duration study. This demonstrates the potential risks associated with the evidence and likely inconsistencies in the outcomes.

The findings from this study have important implications for policies to promote the uptake of small capacity pumps. The limited evidence base means that current policies (e.g. NEPAD, 2003) in SSA are likely to be based on evidence that is not sufficiently robust. This supports recent studies (Matekere and Lema, 2011) that reported on performance assessment in smallholder irrigation to be rather ad hoc, fragmented and mainly conducted at the outset of projects to serve the interest of those that initiated the process. It is thus suggested that further targeted research should be undertaken to inform policy formulation. For the unclear standards, this study has argued that this was likely to be result of different methods and the lack of clear procedures to differentiate comprehensive and rapid performance assessment methods. Given the importance of understanding the technical and socio-economic factors, the research propose that performance assessment standards that incorporate a set of key factors should be developed. This will enable directly comparable evidence on performance of SSPI to be gathered and more objectively compared. It is also suggested that clear guidelines associated with conducting either rapid or comprehensive performance assessments should be developed. Finally, the differences in policies in the SSA countries might help to explain some of the reasons why the evidence found was localized. It is suggested that an inventory of the SSPI should be developed. This will provide a baseline data for developing performance assessment standards that are specific to the pumped system.

Despite the limited evidence base collated from this SR, the study provides valuable insights on the gaps in the knowledge on SSPI in SSA. Furthermore, the review has used robust methods and processes to gather the evidence and thus the findings are a true reflection of the magnitude of evidence that is available in the SSA.

Limitations

The main limitations in adopting a SR approach typically relates to selection bias, inaccuracy in data extraction and the presence of 'effect modifiers'. Selection bias refers to biases in identifying studies for the subsequent analysis; inaccuracy in data extraction refers to the possibility of extracting wrong or inaccurate evidence from the various bibliographic databases or other literature sources; 'effect modifiers' refers to any variable that modify the impact of an intervention or exposure. The evidence identified in this SR differed in terms of its geographical coverage, the varying scales of analysis for example, household to village, and the approaches used for measuring performance impact. In addition, the studies varied widely in their approaches to assessing performance, from comparing pumped systems with rain-fed production, to traditional irrigation, to rehabilitated schemes, to different pumped systems. The time scale over which the studies were conducted was also an important factor; some studies assessed performance over relatively long periods (more than six years) whilst others were carried out over much shorter periods (single irrigation season). Different pump design, pump sizes and irrigation application methods might also have been important effect modifiers. For example, the high frequency or citing in the literature for a certain type of technology, does not necessarily equate to a high significance of the technology in terms of area, production or income. The SR outputs should therefore be interpreted with caution.

5.6 Conclusions

This SR provides a valuable contribution to the international science literature by identifying the key factors that affect the performance of SSPI in SSA and the extent to which technical and socio-economic factors are used as metrics of performance. The study has highlighted the limited evidence on SSPI and that it is geographically biased (treadle pumps-southern SSA, motorized pumps-West and East SSA). Nevertheless, the evidence should be helpful in defining where strategic research is needed to improve methods and approaches for assessing performance and hence the ground for this research. It is suggested that current policies to support SSPI should embrace both technical and socio-economic issues in their development programmes and should adopt more standardized methods for assessment to allow comparison and replication.

6 FIELD SURVEY RESULTS

6.1 Overview

The SR findings suggested that technical and socio-economic factors are critical in SSPI adoption and their performance impact. This chapter takes a step further to understand this by critically analysing the empirical data from field surveys interviews with farmers and stakeholders in Malawi. Findings in this chapter identify the SSPI adopted in Malawi and factors affecting their success or failure.

6.2 Quantitative results: pump characteristics

6.2.1 Pump types and ownership

Four distinct pumped systems, comprising two pump types (treadle and motorized) and two ownership modes (group and individual) are identified. For group treadle pumps, the average number of members sharing a pump is 10 (ranging between 9-23); these are used on individual farmers' irrigation fields. For group motorized pumps, the average membership is 21 (ranging between 12-38); these pumps are used on communal land usually given by either the chiefs or one of the group members on agreed conditions. Throughout the Chapter, the results are presented *first for treadle pumps then for motorized pumps and; first for group owned pumps then for individually owned pumps. Where there are differences between the two surveys, these are highlighted first for survey 1 then survey 2.* Furthermore, farmers are referred to as '*incentive farmers (inc.)'* if they acquired the pumps through subsidies or for free and as '*self-motivated farmers (sm)'* if they acquired the pumps independently without external financial support. A summary table of the results of Chi square tests conducted on selected results is provided in Appendix H.

6.2.2 Pump capacities and sources of power

All treadle pumps use human (manual) energy as their source of power; their capacity depends on the amount of energy applied by the farmers. Two engine capacities, 10hp and 6.0hp are identified among the group motorized pumps (Table 6.1). A majority of group farmers use 10hp pumps while very few farmers use 6.0hp. The engine capacities for individual motorized pumps range between 3hp to 10hp; the most common size is 5.5hp. All group motorized pumps use diesel as their source of power and are all acquired by the incentive farmers while most individual motorized pumps use petrol and are all acquired by self-motivated farmers. There is a significant difference ($p<0.001$) between groups and individual farmers in terms of the pumps' capacity owned. Smaller pump capacity are more likely to be owned by the individual farmers compared to the group farmers who mostly own bigger capacity pumps.

Table 6.1: Engine capacities of the motorized pumps

Qn. Engine capacities for motorized pumps				
Pump engine capacity (hp)	Group	Individual	Total responses	% of total
3.0	0	5	5	6
5.5	0	23	23	26
6.0	4	0	4	5
6.5	0	16	16	18
10.0	35	5	40	45
Total	**39**	**49**	**88**	**100**

6.2.3 Pump manufacturers

Treadle pump brands with different manufacturers (Chapter 3) are identified in both surveys (Table 6.2). Advaith and Money Maker are the most prevalent pumps (Chapter 3). Most group farmers are likely to use Advaith while most individuals use Money Maker pump type ($p<0.001$). This could be because the government only distributes the Advaiths pump types to group farmers.

Table 6.2: Manufacturers of treadle pumps

Qn. Manufacturers of treadle pumps						
Treadle pump manufacturer	Group		Individual		Total responses	% total
	Inc.	Sm	Inc.	Sm		
Advaith	19	1	23	3	46	41
Money Maker	11	2	33	15	61	54
Other	6	0	0	0	6	5
Total	**36**	**3**	**56**	**18**	**113**	**100**

However, based on farmers' perceptions from both surveys, they are generally more in favour of the Money Maker pump (Figure 6.1) over the Advaith. According to farmers, the Advaith pumps are harder and heavier to operate compared to the Money Maker pump (Table 6.3).

Table 6.3: Farmers perceptions between Advaith and Money Maker treadle pumps

Pump features	Advaith pump	Money maker pump
Pump operation	Hard	Simple
Pumping energy	Needs more energy	Needs less energy
Water discharge rate	High	Low
Pump weight	Heavy usually carried by a bicycle	Portable; can be carried by one person
Maintenance	Simple and uses local materials	Difficult & some spare parts unavailable.
Labour	Effectively requires two people	Only one person or a child can operate
Water spillage	High	Low
Priming	Simple and is only done once	Needs to be primed for each pumping

Figure 6.1: An Advaith treadle pump (left) and a Money Maker pump (right) in operation at one of the irrigation sites.

For motorized pumps (Table 6.4), the Variant (manufactured in India), is the most common pump used by group farmers (Figure 6.2).

Table 6.4: Manufacturers of the motorized pumps

Qn. Manufacturers of motorized pumps				
Pump manufacturer	Group	Individual	Total responses	% total
Honda (5.5, 6.5 & 3.0 hp)	0	13	13	15
Hoshano (5.5 & 6.5hp)	0	7	7	8
OHV (5.5 & 6.5hp)	0	7	7	8
Variant (10hp)	23	6	29	33
Yun Shern (6.0hp)	4	0	4	5
Unknown (5.5 & 6.5hp)	12	16	28	32
Total	**39**	**49**	**88**	**100**

Very few groups from the first survey use the Yun-Shern, a Japanese manufactured pump. All group motorized pumps are only distributed by government. There are slight variations between the two surveys on manufacturers for individual pumps. Honda (Table 6.4) is the most common in the first survey area while the unbranded Chinese-manufactured pumps, referred to here as 'unknown' are most common in the second survey. Furthermore, only in the second survey, a number of farmers owned the Variant as an individual pump. This pump was only distributed by the government; farmers acquired it through the civil servants who accessed it on loan and later sold it to farmers.

Figure 6.2: Honda (left) and Variant (right) manufactured motorized pumps found in the surveyed districts.

6.2.4 Pump weight and discharge

Advaith treadle pumps weigh more than Money Maker (Table 6.5). Similarly, Advaiths' water delivery volumes are higher than the Money Makers. For group motorized pumps, the Variant has both larger water delivery volume and weight compared to Yun Shern (Table 6.5). For individual motorized pumps, except for Variant, the majority weigh less than 30 kg and have smaller water delivery volumes.

Table 6.5: Weights and water delivery volumes of selected pumps

Pump Category	Pump capacity	Weight (Kg)	Delivery volume (m^3/hr)	Revolutions per minute (rpm)	Suction head (m)	Total head (m)
motorized pumps	10hp (7.5kW)-Variant	310	72	1500	19	28
	6.0hp-Yun Shern	>100	-	2000-2400	-	-
	6.5hp (4kW)-Hoshano	28	60	3600	7	30
	5.5hp (Honda)	27	66	3600	-	28
	3Hp (Honda)	17	25	3600	7	20
Treadle pumps	Advaith	35-40	3.0	-	4-9	9
	Money Maker	15-20	1.44-4.32	-	4-9	9

6.2.5 Pump operational status

The results show that there is a significant difference ($p< 0.001$) between group and individual ownership, in terms of whether the pumps are still operational or not (Table 6.6). A majority of group treadle and motorized pumps from both surveys were not operational (Table 6.6). In contrast, most individual treadle and motorized pumps were operational. This suggests that individual owned pumps are more likely to be operational than group pumps. Similarly, most of pumps acquired by the self-motivated farmers are likely to be operational compared to those acquired by the incentive farmers ($p<0.001$). The characteristics of both the group treadle pumps and motorized pumps (Table 6.5) may have contributed to them being non-functional. However there is no significant difference between treadle and motorised pumps in terms of whether the pumps are still operational or not.

Table 6.6: Pump operational status

Qn. Operational status of the pumps										
Pump operational status	Treadle pump				Motorized pump				Total responses	% total
	Group		Individual		Group		Individual			
	Inc.	Sm	Inc.	Sm	Inc.	Sm	Inc.	Sm		
Operational	9	2	36	16	15	0	0	40	118	59
Non operational	27	1	20	2	24	0	0	9	83	41
Total	**36**	**3**	**56**	**18**	**39**	**0**	**0**	**49**	**201**	**100**

6.2.6 Pump adoption periods for the present pumps

The majority of group treadle pumps were adopted between 2000 and 2005 (Table 6.7). This corresponded with the period within which government intensified promotion of treadle pumps. Adoption of individual treadle pumps started in early 1990s and has been steadily increasing. Group motorized pumps were in operation since 1996; however their adoption increased in mid-2000s following government promotion. Although there are no significant differences between group and individual farmers in terms of the year of adopting the pumps, it appears most individual motorized pumps were recently adopted. This could suggest that these pumps are the most recent. However, there is some pattern in terms of the proportion of the pumps being discontinued or non-operational (Table 6.6) and the periods in which the different categories of pumps are adopted and discontinued (Table 6.7 and Table 6.8).

Table 6.7: Periods of adopting the present pumps

Qn. When the pumps were adopted?										
Period adopted the pump	Treadle pump				Motorized pump				Total responses	% of total
	Group		Individual		Group		Individual			
	Inc.	Sm	Inc.	Sm	Inc.	Sm	Inc.	Sm		
1990-1999	0	0	2	1	3	0	0	1	7	3
2000-2005	22	1	23	4	3	0	0	7	60	30
2006-2010	8	2	18	7	19	0	0	19	73	36
2011-2014	6	0	13	6	14	0	0	22	61	30
Total	**36**	**3**	**56**	**18**	**39**	**0**	**0**	**49**	**201**	**100**

The majority of the pumps that are being discontinued are those owned by group farmers and are mostly accessed through incentives (Table 6.8). Furthermore, although the relationship between the periods for abandoning the pumps and ownership of the pumps by the farmers is not statistically significant, proportionally the number of group motorized pumps that are being discontinued earlier is higher than that of the group treadle pumps (Table 6.8). Further explanation for this observation is considered Section 7.2.4.

Table 6.8: Number of farmers and periods when the pumps were discontinued being used

Qn. When the farmers stopped operating their pumps?										
Period when the pumps were discontinued being used	Treadle pump				Motorized pump				Total responses	% of total
	Group		Individual		Group		Individual			
	Inc.	Sm	Inc.	Sm	Inc.	Sm	Inc.	Sm		
1990-1999	0	0	0	0	2	0	0	0	2	3
2000-2005	7	0	6	1	4	0	0	1	19	30
2006-2010	5	1	8	0	13	0	0	5	32	36
2011-2014	15	0	6	1	5	0	0	3	30	30
Total	**27**	**1**	**20**	**2**	**24**	**0**	**0**	**9**	**83**	**100**

6.3 Quantitative results: irrigation management characteristics

6.3.1 Irrigation methods used before the pumps

Most treadle and group motorized pump farmers used traditional irrigation methods (watering cans) before adopting the pumps (Table 6.9) indicating that their knowledge on pumps may have been limited. Considering that most of these pumps were obtained for free or subsidized (Table 6.18), it is likely that farmers were partly persuaded to adopt these pumps by the incentives. In contrast, most individual motorized pumps farmers had previously used treadle pumps suggesting that these would have prior experiences with the pumps.

Table 6.9: Irrigation methods used before pump adoption

Qn. Irrigation methods used before pump adoption										
Previous irrigation methods	Treadle pump				Motorized pump				Total responses	% of total
	Group		Individual		Group		Individual			
	Inc.	Sm	Inc.	Sm	Inc.	Sm	Inc.	Sm		
Motorized pumps	0	0	0	0	0	0	0	7	**7**	3
Treadle pumps	3	1	2	11	4	0	0	34	**55**	27
Traditional methods	33	2	54	7	35	0	0	8	**139**	69
Total	**36**	**3**	**56**	**18**	**39**	**0**	**0**	**49**	**201**	**100**

6.3.2 Irrigation water sources

Almost half of farmers used the streams for pump irrigation (Table 6.10). Although there were no significant differences between farmers in terms of pump ownership, and the mode in which farmers acquired the pumps, the results showed significant ($p < 0.001$) differences between treadle and motorized pump farmers in terms of the type of water sources used. A higher proportion of those using private wells were treadle pump farmers suggesting that these probably fitted well in the existing farmers' water sources. None of the group motorized pumps were used on shallow wells and this could be because of their larger water delivery volumes. On average, treadle pumps wells were smaller, 2m x 1.5m x 1.5m (depth, diameter and water depth) in dimension than the dimensions of most individual motorized pumps wells (Figure 6.3).

Table 6.10: Types of irrigation water sources

Qn. Pump water sources										
Type of water source	Treadle pump				Motorized pump				Total responses	% total
	Group		Individual		Group		Individual			
	Inc.	Sm	Inc.	Sm	Inc.	Sm	Inc.	Sm		
Stream	11	2	29	3	28	0	0	27	100	50
Private well	20	0	20	13	0	0	0	14	67	33
Shared well	2	1	5	1	4	0	0	3	16	8
Dam reservoir/pond	3	0	2	1	7	0	0	5	18	9
Total	**36**	**3**	**56**	**18**	**39**	**0**	**0**	**49**	**201**	**100**

Most farmers owned multiple wells in their irrigation fields; this was attributed by the farmers to the pumps' high water flows and low well water yields.

Figure 6.3: Typical sizes of wells for treadle pump (left) and motorized pump (left).

6.3.3 Irrigation water conveyance methods

Most treadle and individual motorized pump farmers significantly ($p<0.05$) used flexible hose pipes to transport water from the pumps to irrigated fields while most group motorized pumps farmers were more likely to use earth channels (Table 6.11). Farmers attributed this to the length of pump water delivery hose pipes and pumps' higher water discharges. Government issued the group motorized pumps with only a 15m long water delivery hose pipe to the farmers suggesting that farmers were limited to irrigate in the fields that were located closer to the water sources. This could also indicate that group motorized pump farmers could not afford to purchase the hose pipes. Furthermore, most famers from both surveys used either furrows or basins to apply water to their crops.

Table 6.11: Means of transporting water to the pumps

Qn. Means of transporting water to the irrigated areas										
Means of water transport	Treadle pump				Motorized pump				Total responses	% total
	Group		Individual		Group		Individual			
	Inc.	Sm	Inc.	Sm	Inc.	Sm	Inc.	Sm		
Flexible hose pipe	25	3	42	14	13	0	0	33	130	65
Earth channel	9	0	10	2	23	0	0	12	56	28
Lined channels	2	0	4	2	3	0	0	4	15	7
Total	**36**	**3**	**56**	**18**	**39**	**0**	**0**	**49**	**201**	**100**

6.3.4 Irrigation crops grown

For both surveys, most farmers grew maize which is the main staple food in the study areas. However, over half of the farmers indicated that they sold maize as green-crop and used the income to buy dried-maize for consumption. Farmers stated that it was more profitable to sell green maize during the dry season. About a third of farmers especially those with individual pumps also grew horticultural crops such as vegetables, tomatoes, potatoes and onions for local sale.

6.4 Quantitative results: farmers' socio-economic characteristics

6.4.1 Farmer gender

The majority of farmers that participated in both surveys (61% & 73%) were male. Although the study made deliberate efforts to interview more females, generally their participation was low suggesting that few females owned pumps. However, reports from the government show that female membership was higher than males for group pumps. Possibly, this was done to impress the authorities.

6.4.2 Farmer age

There is a weak link between farmers' age and ownership of the pumps ($p>0.05$). On average, most farmers were slightly old aged 36-50 years suggesting that aged farmers are slightly more likely to adopt the irrigation pumps (Table 6.12). However, farmers from the first survey were slightly older compared to the second survey. For first survey, almost half (48%) were aged 36-50 years. For second survey, about half (46%) aged 26-35 years. Since one district in the first survey included the capital

(Lilongwe), it is likely that younger farmers found alternative livelihood strategies from the city, hence not involved in pump irrigation. This may explain the reason for the age differences between the two surveys.

Table 6.12: Ages of the pump farmers

Qn. Farmer' age										
Age (years)	Treadle pump				Motorized pump				Total responses	% of total
	Group		Individual		Group		Individual			
	Inc.	Sm	Inc.	Sm	Inc.	Sm	Inc.	Sm		
<25	2	0	3	0	1	0	0	2	8	4
26-35	14	0	18	5	13	0	0	19	69	34
36-50	16	3	15	9	18	0	0	18	79	39
>50	4	0	20	4	7	0	0	10	45	22
Total	**36**	**3**	**56**	**18**	**39**	**0**	**0**	**49**	**201**	**100**

6.4.3 Farmer education level

The majority of farmers from both surveys were educated to primary school level (Table 6.13). This suggests that these were able to read and write and therefore could read extension messages related to pump irrigation. A higher proportion of those educated to secondary school level were the self-motivated farmers ($p < 0.05$) suggesting that these had better knowledge than incentive farmers. Mostly these had retired and settled in the rural areas.

Table 6.13: Education levels of the pump farmers

Qn. Farmers' education levels										
Education level	Treadle pump				Motorized pump				Total responses	% of total
	Group		Individual		Group		Individual			
	Inc.	Sm	Inc.	Sm	Inc.	Sm	Inc.	Sm		
None	4	0	9		2	0	0	4	19	9
Primary	29	1	32	10	27	0	0	26	125	62
Secondary	2	2	15	6	9	0	0	17	51	25
Tertiary	1	0	0	2	1	0	0	2	6	3
Total	**36**	**3**	**56**	**18**	**39**	**0**	**0**	**49**	**201**	**100**

6.4.4 Farmer household size

The majority of farmers had 5 to 6 household members but there were no significant differences between the group and individual farmers, between the incentive and self-motivated farmers and between treadle and motorized pump farmers in terms of household sizes (Table 6.14). Since the quantity of household labour is captured by the household size it can be interpreted here that farmers in the categories had access to labour. There were some also slight differences between household sizes of farmers from the first survey and second survey and this corresponded with the farmers' age differences. As reported earlier (Section 6.4.2), farmers from the first survey were slightly older than those from second survey.

Table 6.14: Household sizes of pump farmers

Qn. Farmers household sizes										
No. of people per household	Treadle pump				Motorized pump				Total responses	% of total
	Group		Individual		Group		Individual			
	Inc.	Sm	Inc.	Sm	Inc.	Sm	Inc.	Sm		
2-4	11	0	24	11	14	0	0	17	77	38
5-6	20	3	18	7	18	0	0	22	88	44
7-8	3	0	7	0	6	0	0	9	25	12
>8	2	0	7	0	1	0	0	1	11	5
Total	**36**	**3**	**56**	**18**	**39**	**0**	**0**	**49**	**201**	**100**

6.4.5 Farmer irrigated area

In general, most farmers adopting the pumps had increased their irrigated areas compared with areas before the pumps. However, most farmers owned a smaller irrigated area (<0.8ha) with most incentive farmers significantly ($p<0.001$) owning smaller irrigated areas (0.04-0.2ha) compared to the self-motivated farmers (Table 6.15). Furthermore, results showed no significant differences between group and individual farmers in terms of the sizes of the irrigated areas. Furthermore, the irrigated areas of farmers from second survey were proportionally larger than those from first survey. Since second survey was carried out in a less populated district (Section 4.3.2), this could explain the difference.

Table 6.15: Farmers' irrigated areas after adopting the pumps

Qn. Size of the irrigated areas										
Size of irrigated area (ha)	Treadle pump				Motorized pump				Total responses	% of total
	Group		Individual		Group		Individual			
	Inc.	Sm	Inc.	Sm	Inc.	Sm	Inc.	Sm		
0.04-0.2	15	0	29	5	10	0	0	2	61	30
>0.2-0.4	8	1	7	9	11	0	0	4	40	20
>0.4-0.8	7	2	8	3	8	0	0	18	46	23
>0.8	6	0	12	1	10	0	0	25	54	27
Total	**36**	**3**	**56**	**18**	**39**	**0**	**0**	**49**	**201**	**100**

6.4.6 Farmer assets owned

Across all the pump categories from both surveys, farmers owned radios, mobile phones and bicycles (Table 6.16). Although the data collected could not allow further statistical analysis to determine whether the differences in terms of assets ownership were significant, proportionally more individual motorized and treadle pump farmers owned more assets compared to the other categories. In addition, out 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. Ownership of bigger assets such as televisions, oxcarts, motorcycles and vehicles suggests that farmers had better access to financial capital.

Table 6.16: Assets owned by farmers

Qn. Assets owned										
Capital assets owned	Treadle pump				Motorized pump				Total response	% Total
	Group		Individual		Group		Individual			
	Inc.	Sm	Inc.	Sm	Inc.	Sm	Inc.	Sm		
Radio	35	3	53	18	37	0	0	49	195	97
Mobile phones	18	3	41	17	28	0	0	45	152	76
Bicycles	22	2	39	16	29	0	0	47	155	77
Iron sheet roofs	14	3	20	13	18	0	0	37	105	52
Television	3	0	5	2	3	0	0	16	29	14
Motorcycles	0	0	0	1	3	0	0	11	15	7
Oxcarts	1	0	1	2	1	0	0	7	12	6
Motor Vehicles	0	0	0	1	1	0	0	5	7	3

6.4.7 Farmer source of pump awareness

Except for the individual motorized pumps, most farmers accessed information about the pumps from extension workers from government and NGOs (Table 6.17). Most individual motorized and a number of individual treadle pump farmers obtained the knowledge from colleagues using similar pumps from the surrounding communities.

Table 6.17: Sources of pump awareness

Qn. Where farmers learnt about pumps?										
Pump awareness source	Treadle pump				Motorized pump				Total responses	% of total
	Group		Individual		Group		Individual			
	Inc.	Sm	Inc.	Sm	Inc.	Sm	Inc.	Sm		
Extension workers (Govt.)	15	1	13	4	39	0	0	2	74	37
Colleagues/friends	3	1	17	8	0	0	0	43	72	36
Organizations (NGOs)	18	1	22	6	0	0	0	0	47	23
Others	0	0	4	0	0	0	0	4	8	4
Total	**36**	**3**	**56**	**18**	**39**	**0**	**0**	**49**	**201**	**100**

6.4.8 Farmer means of accessing the pump

About half of the group treadle pumps from both surveys were provided to farmers for free while over a third was subsidized (Table 6.18). Most individual treadle pumps were accessed through subsidies; about a quarter was accessed privately. All group motorized pumps were accessed for free. Most individual motorized pumps were accessed privately.

Table 6.18: Farmers' means for accessing the pumps

Qn. Means of accessing the pumps by the farmers						
Means of accessing pumps	Treadle pump		Motorized pump		Total responses	% of total
	Group	Individual	Group	Individual		
Private (Self-motivated)	3	14	0	44	61	30
Subsidized (Incentive)	17	47	0	0	64	32
Free (Incentive)	19	9	39	0	67	33
Inherited (Self-motivated)	0	4	0	2	6	3
Borrowed (Self-motivated)	0	0	0	3	3	1
Total	**39**	**74**	**39**	**49**	**201**	**100**

6.4.9 Farmer source of accessing the pump

Most group treadle pumps were either accessed from government or politicians or NGOs (Table 6.19). A majority of individual treadle pumps was accessed from the NGOs. All group motorized pumps were accessed from government. Most individual motorized pumps were privately accessed from commercial distributors.

Table 6.19: Pump sources

Qn. Sources the pumps were accessed										
Pumps sources	Treadle pump				Motorized pump				Total responses	% of total
	Group		Individual		Group		Individual			
	Inc.	Sm	Inc.	Sm	Inc.	Sm	Inc.	Sm		
Government	13	0	2	0	39	0	0	0	54	27
NGOs	17	0	42	6	0	0	0	0	65	32
Private dealers	0	3	3	11	0	0	0	49	66	33
Politicians	6	0	9	1	0	0	0	0	16	8
Total	**36**	**3**	**56**	**18**	**39**	**0**	**0**	**49**	**201**	**100**

6.4.10 Farmer number of pumps owned

Over a third of farmers across all the pump categories owned two pumps (Table 6.20). Very few (7%) farmers owned three pumps. Second and third pumps were significantly ($p<0.001$) owned by the farmers with individual owned pumps especially those with motorized pumps supporting the earlier observation (Section 6.4.6) that possibly these were financially better off than the group farmers. Farmers' reasons for adopting the pumps may have contributed to owning of more than one pump (Section 6.6).

Table 6.20: Number of pumps owned by each farmer

Qn. Number of pumps owned										
Number of Pumps owned	Treadle pump				Motorized pump				Total responses	% of total
	Group		Individual		Group		Individual			
	Inc.	Sm	Inc.	Sm	Inc.	Sm	Inc.	Sm		
One pump	26	1	54	5	15	0	0	10	111	55
Two pumps	10	2	1	12	22	0	0	29	76	38
Three pumps	0	0	1	1	2	0	0	10	14	7
Total	**36**	**3**	**56**	**18**	**39**	**0**	**0**	**49**	**201**	**100**

6.4.11 Farmer pump adoption routes

The adoption routes were analysed for farmers in the second survey, similar trends were also observed in the first survey. The majority of farmers that started with group treadle pumps discontinued using the pumps and mostly joined group motorized pumps (Figure 6.4).

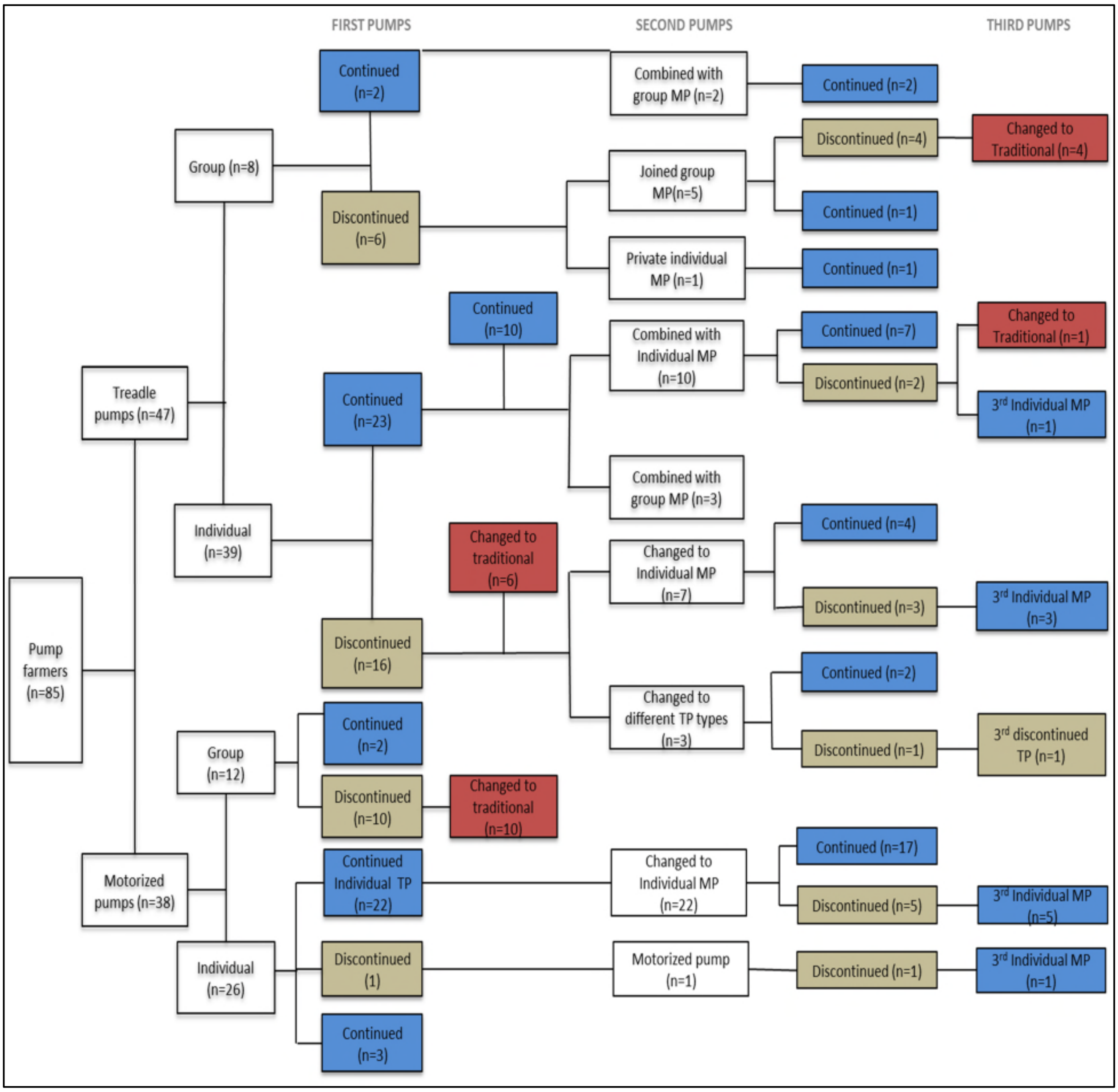

Figure 6.4: The adoption routes pursued by farmers from the second survey when acquiring their first, second and third pumps (*discontinued, continued-use* and *traditional irrigation displayed by shading*)

A majority of farmers with individual treadle pumps continued using pumps. Out of these, about half changed to individual motorized pumps and about another half continued using the pumps. Very few changed to group motorized pumps. For those that initially discontinued using individual treadle pumps, slightly over half later adopted the individual motorized pumps; about a third reverted to traditional irrigation methods; and a number changed to different pump type (usually from Advaith to Money Maker).

Over two thirds of farmers that first started with group motorized pumps reverted back to traditional irrigation methods. Similarly, many farmers that joined groups for their second pumps, discontinued using the pumps. Most individual motorized pump farmers started with the treadle pumps. For those that first started with individual motorized pumps, most of them continued using them. Similarly, those that adopted motorized pumps as second or third pump, continued using the pumps. For farmers that changed to their third motorized pumps, mostly it was due to unresolved repair and maintenance problems.

6.4.12 Farmer access to extension services

Except for the individual motorized pump users, in both surveys, most farmers accessed extension services related to using the pumps (Table 6.21). This could be because most pump promoting organizations (Table 6.17) also provided extension services. However, for group motorized pump farmers, information about pump technical issues were mostly referred to the irrigation experts whose availability to the farmers was uncertain.

Table 6.21: Access to extension services for pump farmers

Qn. Did you receive any extension service related to pumps?										
Received extension services?	Treadle pump				Motorized pump				Total responses	% of total
	Group		Individual		Group		Individual			
	Inc.	Sm	Inc.	Sm	Inc.	Sm	Inc.	Sm		
Yes	21	2	38	8	28	0	0	12	109	54
No	15	1	18	10	11	0	0	37	92	46
Total	**36**	**3**	**56**	**18**	**39**	**0**	**0**	**49**	**201**	**100**

6.4.13 Farmer membership in the cooperative societies

More farmers with the individual owned pumps (particularly those with motorized pumps) are likely ($p<0.001$) to belong to some community groups within their societies such as political, religious and socio-developments (Table 6.22). Moreover, most of these farmers served as leaders in these community groups. This suggests that these were influential people among their communities. For groups, very few farmers belonged to some community groups or some cooperatives within their communities suggesting that most groups are not being founded on existing organisations.

Table 6.22: Membership of farmers in cooperative societies

Qn. Membership in cooperative societies										
Membership in society	Treadle pump				Motorized pump				Total responses	% of total
	Group		Individual		Group		Individual			
	Inc.	Sm	Inc.	Sm	Inc.	Sm	Inc.	Sm		
Yes	3	3	31	17	7	0	0	40	101	50
No	33	0	25	1	32	0	0	9	100	50
Total	**36**	**3**	**56**	**18**	**39**	**0**	**0**	**49**	**201**	**100**

6.4.14 Farmer pump-related support services received

Incentive farmers especially those with treadle pumps were more likely ($p<0.001$) to receive pump-related support services (Table 6.23). This corresponded with the organizations promoting the pumps. Various organizations supported farmers with pump repair and maintenance services, pump spare parts, extension and technical advices and free farm inputs (fertilizers, seeds & herbicides). Most treadle and group motorized pump farmers received these support services although most group motorized pump farmers only received these during their early stages of adopting the pumps. Most individual motorized pump farmers did not receive any support.

Table 6.23: Number of farmers receiving pump-related support

Qn. Did you receive any support related to your pump/s?										
Received pump extension services?	Treadle pump				Motorized pump				Total responses	% total
	Group		Individual		Group		Individual			
	Inc.	Sm	Inc.	Sm	Inc.	Sm	Inc.	Sm		
Yes	30	1	36	7	27	0	0	3	104	52
No	6	2	20	11	12	0	0	46	97	48
Total	**36**	**3**	**56**	**18**	**39**	**0**	**0**	**49**	**201**	**100**

6.4.15 Farmers pump preferences

A majority of farmers in most pump categories preferred having an individual motorized pump if given a choice (Figure 6.5). Farmers provided various reasons including being independent and free to use the pumps, increased irrigated area, less labour demanding, easiness and simple to use. Slightly a higher proportion of farmers (mostly from first survey) preferred having an individual treadle pumps. This could be because of the type of water sources that farmers owned; shallow wells were common in the first survey while streams were common in the second survey areas. Other than independently using the pump, farmers also indicated that they preferred the pump because it does not require fuel. Very few farmers preferred group motorized pumps while none preferred group treadle pumps. The majority of those that preferred group motorized pumps were those that already belonged to the group motorized pumps. Further investigations showed that these farmers made the choice in fear of losing their group pumps. Group benefits such as sharing roles and responsibilities were given as the main reasons for their choice.

In contrast, over 80% of the other stakeholders preferred to promote the individual treadle pumps given the choice. Reasons such as less operational costs and simple to use were given. This suggests that the needs of farmers and other stakeholders agreed on pump ownership but varied on pump types. This partly contradicts with the government policy which encourages accessing farmers in groups.

On whether, farmers expected to be using the same pumps in the next decade, most individual motorized pump farmers indicated 'yes' while most treadle and group motorized pump farmers indicated 'no'. Most farmers indicated that they would change to using individual motorized pumps. Similar reasons as provided in their preferences were given by the farmers. For other stakeholders, most of them expressed that they would be promoting the same type of pumps and with same approaches in the next decade because of the prevailing policies and influence from their donors.

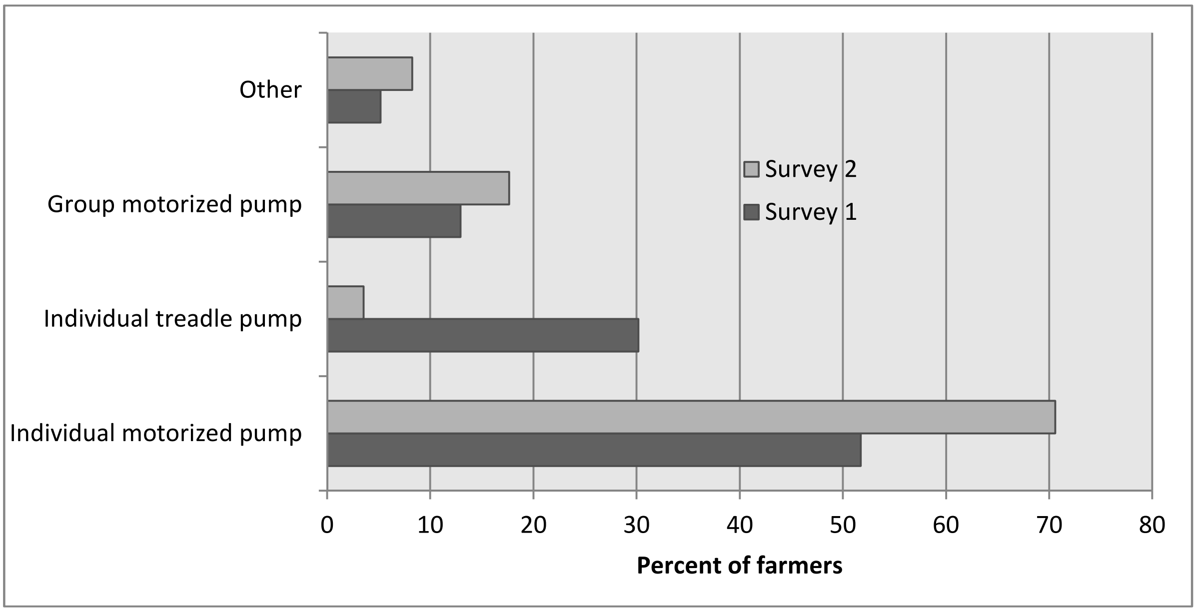

Figure 6.5: Farmers pump preferences if given the choice.

6.5 Quantitative results: Stakeholders' characteristics

A number of stakeholders related to SSPI were identified (Table 6.24). Most supported treadle pumps compared to motorized pumps. Except for commercial distributors, no organization supported individual motorized pumps. These stakeholders either directly or indirectly supported pump adoption and/or their continued-use.

6.5.1 Stakeholders influencing pump adoption

Organizations that directly supported pump adoption included public institutions, donor-initiated government projects and private institutions. Analysis revealed that these organizations were mandated to support pump adoption through the distribution of free/subsidized pumps, provision of irrigation extension, capacity building of farmers and construction irrigation infrastructures. The strategies that these organizations used were different. For example, government promoted free group treadle pumps whereas most Projects promoted subsidized individual and group pumps. Similarly, the government only provided pumps' with little or no technical assistance while most Projects also provided farmers with other services such as free farm inputs and technical support. For commercial pump distributors, although there were very few and only available in town centres, these too directly supported adoption by ensuring pumps and accessories' availability.

Most NGOs supported treadle pump adoption, although their mandates were not related to SSPI. Promotion of pumps was considered as one of strategies for attaining their respective goals. For example most local and international NGOs (Table 6.24) were mandated to improve food security or reduce poverty. To achieve such goals, they distributed free or subsidized treadle pumps in anticipation to increase the farmers' yields. However, the strategies used differed. For example, one NGO indicated that it disseminates subsidized treadle pumps by setting targets (e.g. number of pumps) for its extension workers to distribute to farmers within a specific period. Another NGO indicated that it distributes the pumps if farmers had potential irrigated areas. Whether, these approaches corresponded with the farmers' needs is unknown.

6.5.2 Stakeholders supporting pumps' continued-use

A number of organizations provided support that encouraged pump to be continued-use (Table 6.24) especially for treadle pumps. Unlike government that used general agriculture extension workers (AEDOs), most other organizations used own extension workers who were skilled in SSPI. About a third supported farmers with irrigation structures such as constructing and maintaining water sources (e.g. wells, ponds, and dams) for pump use. Since some farmers were challenged with pump water supply, this possibly encouraged them to continue using the pumps. A number of organizations (Table 6.24) supported farmers by facilitating group formations (e.g. Water User Associations-WUAs). Some organizations trained farmers on pump management, repair and maintenance and gross margin analysis. For example, treadle pump farmers were trained on local repair and maintenance by the NGOs and some Projects organizations. Further, most NGOs and some Projects (Table 6.24) combined pump distribution with free farm inputs (seeds, fertilizers and herbicides) and technical services to farmers. This approach motivated farmers to continue using the pumps. Apart from vendors, no organization supported farmers in marketing of their irrigated products.

Table 6.24: List of other stakeholders involved in SSPI in Malawi

No	Stakeholder	Pump type & category	Type	Service provided	Level of delivery	Activities involved
1	Department of Irrigation (DOI)	Motorized & treadle (group & individual)	Govt.	Free pump distribution, technical skills e.g. scheme designs	National	Free pumps distribution, installation, operation maintenance & water management
2	Ministry of Agriculture	Group motorized & treadle	Govt.	Extension and training services	National	Crop and irrigation management techniques
3	World Bank	Treadle and motorized (group)	Donor	Providing funds through Projects e.g. IRLARDP	National	Providing funds and guidance to government in support for SSPI development.
4	Universal distributors	Motorized & treadle	Com. supplier	Pump & accessories sells	District	Selling pump accessories i.e. water delivery hose and other spare parts
5	Land Resources Trust	Motorized & treadles	Com. supplier	Pump & accessories sells	Regional	Selling pump accessories i.e. water delivery hose and other spare parts
6	Total Land Care (TLC)	Treadles (group & individuals)	Int. NGO	Subsidized pump distribution & extension	National	Subsidized pump distribution, installation, maintenance extension, free farm inputs
7	RIDP	Treadle (group & individuals)	EU Project	Subsidized pump distribution & extension	National	Subsidized pump distribution, installation, maintenance extension, free farm inputs
8	Concern Universal	Treadle (group & individuals)	Int. NGO	Free pump distribution and extension	National	Free pump distribution, installation, operation, maintenance, free farm inputs
9	Africare	Treadle (groups)	Int. NGO	Free pump distribution & extension	District	Free pumps, installation, operation and maintenance, water & crop management
10	Self Help Africa	Treadles (groups)	Int. NGO	Free pump distribution & extension	Districts	Free pumps distribution, technical skills and farm inputs
11	CARD	Treadles (groups)	Local NGO	Subsidized pumps distribution and extension	Regional	Subsidized pumps distributing, installation, operation, maintenance, free farm inputs
12	IRLADP	Motorized & treadle (group & individuals)	World Bank Project	Supporting operation, maintenance of irrigation structures & committees	National	Supporting wells construction for SSPI. Formulation of farmers' scheme committees' e.g. WUAs.
13	Action Aid Malawi	Treadle (group and individual)	Int. NGO	Support farmers with pump related services	National	Support farmers with pump related services e.g. farm inputs
14	Lilongwe University	N/A	Acad.	Training irrigation experts	National	Research and training on irrigation
15	NRC	N/A	Acad.	Training technicians	National	Training irrigation technicians and agriculture extension workers
16	Fellow pump users	All pumps	Fellow farmers	Irrigated farm produce buyers & technical skills	Local	Buying farmers irrigated products and pump sharing technical advises

**Acad. – Academic, Com.- Commercial, Govt- Government, Int.-International*

6.6 Qualitative results: factors motivating pump adoption

There were some agreements and disagreements on factors that motivated farmers and other stakeholders to adopt/promote the various pumps (Table 6.25). These factors (technical and socio-economic) are organized from highest to lowest frequencies based on the coding tree (Figure 4.5) and are jointly discussed with the other stakeholders' opinions.

Table 6.25: Factors (ranked) for motivating farmers to adopt the different pump types

Adoption factor (theme)	Reason for pump adoption (code)	Number of farmers reporting the factor								**% total (of 201)**
		Survey 1				Survey 2				
		Treadle		Motorized		Treadle		Motorized		
		Gp n=31	Indv n=35	Gp n=27	Indv n=23	Gp n=8	Indv n=39	Gp n=12	Indv n=26	
Technical Pump design	Less labour	11	19	1	16	4	25	5	21	**51**
	Simple & easy	8	13	15	9	4	12	4	9	**37**
	Less tiring	2	6	10	5	3	15	3	20	**32**
	less energy demand	0	2	2	4	1	3	5	7	**12**
Pump discharge	Increased irrigated area	24	34	35	21	4	26	7	26	**88**
	High water flow	16	11	13	12	3	25	6	23	**54**
	Less irrigation time	8	3	10	12	3	12	9	6	**31**
	Long irrigation intervals	0	14	12	0	3	11	4	13	**28**
Physical factors	Water Availability	2	6	8	4	6	1	4	5	**18**
	Land Availability	1	0	1	4	4	0	3	2	**7**
SE Affordability	Pump Subsidized	7	5	4	0	1	15	0	0	**16**
	Pump for free	0	4	14	0	3	2	7	0	**15**
	Pump cost	1	1	1	1	0	3	0	1	**4**
Group organization	Sharing benefits	12	19	13	0	3	0	7	0	**27**
	Convenience (Indv.)	0	2	1	4	0	7	0	6	**10**
Benefits	Profitability	22	17	18	9	4	13	9	11	**51**
	Increased yield	3	11	14	4	3	16	6	17	**37**
	Increased Income	8	6	9	2	2	11	2	10	**25**

**SE- Socio-economic, Indv.-Individual*

6.6.1 Technical factors motivating pump adoption

Pump design: Overall, almost half of farmers across all the pump categories agreed that they were motivated to adopt the pumps because of reduced labour. However, this was expressed more by the individual motorized pump farmers. This could be so because treadle pumps use manual labour while group motorized pumps are typically heavy and not portable by hand (Table 6.5). Farmers also highlighted that irrigation was easier with the pumps because only few people are involved in irrigation. Treadle pumps farmers while acknowledging this, complained about the energy demanded by the pumps. However, farmers still considered treadle pumps as being simpler and easier compared to watering cans since they were able to irrigate more land and in fields located away from water sources. In contrast, most other stakeholders did not consider the reduced labour by pumps as an important factor for promoting them. This was demonstrated by types of pumps promoted (Table 6.17) and their perceptions as one organization's respondent (ID5) indicated;

> '…… Yes we do promote the Advaith treadle pumps… and of course we know that the pump is harder to operate than the Money Maker……Our main concern is to get the water to the farmers' irrigated fields…. after all farmers have all the time and labour…. what else do you think they would be doing apart from farming?.....'

Pump water discharge: Generally most farmers and other stakeholders were attracted to adopt pumps because of their ability to increase the irrigated areas. Farmers attributed the increased irrigated areas to the pumps' higher water flows. It was highlighted that their previous irrigation methods were harder and demanded more labour to increase the irrigated areas. For example, treadle pump farmers reported that the traditional watering cans used before, provided small water flows and were harder to increase irrigated areas. Similarly, motorized pump farmers who previously used treadle pumps reported that the pumps demanded a lot of labour and provided less water flow to increase irrigated areas. Farmers also indicated that pumps provided long irrigation intervals such that less time was spent on irrigation activities. This provided them with an opportunity to do other productive activities. Likewise, most other stakeholders including government used the farmers' increased irrigated areas as a measure for assessing their success suggesting that this was also an important factor for promoting the pumps.

Physical factors: Overall, very few farmers (Table 6.25) related the availability of land and water to factors that motivated them to adopt the pumps. Since most farmers were previously engaged in irrigation activities (Table 6.9), it is obvious that they already had access to irrigated land and water hence not a major motivating factor. However, slightly more group farmers considered land and water availability as a motivating factor compared to the individuals. This possibly suggests that the provision of group pumps by the organizations provided an opportunity to farmers with no access to irrigated land to get involved in irrigation activities as narrated by one farmer (ID 14) who discontinued using a group motorized pump but continued using an individual owned treadle pump:

> '……when I was initially using a watering can, I was struggling to irrigate crops that were located far away from the water source and from the deeper sources. For example, during summer, our water level goes deeper so it was so hard for me to fetch water using the watering can …..so that is why I decided to have a treadle pump………. and later I joined the group with an engine pump because I thought it would be much better since my irrigation field is located very far away from water source……. Unfortunately we stopped using the group motorized pump because we could not manage the cost of …….'

This may support the finding that group farmers were socio-economically lower than the individuals.

For other stakeholders especially those promoting group motorized pumps, land and water availability were their most important factors for promoting pumps. For example, the government indicated that their initial stage for disseminating group motorized pumps was to assess the feasibility of potential pump sites. This included checking the potential of the water supply, land availability and topography. Thereafter, potential farmers were approached for the uptake of pumps. However, this strategy supports the earlier argument (Chapter 3) that SSPI promoting organizations assumed that water and land were accessed as communal resources by farmers.

6.6.2 Socio-economic factors motivating pump adoption

The socio-economic factors that motivated farmers to adopt pumps are summarised in Table 6.25.

Labour: Most factors that were associated with labour as a motivation to adopt the pumps were linked to pump design and water discharge as already described in Section 6.6.1.

Affordability: A number of farmers indicated that they were motivated to adopt pumps because they were affordable. This was mostly expressed by those who adopted pumps through subsidized and for free. This possibly suggests that the actual market prices for pumps were not affordable to most farmers. It can be inferred here that other stakeholders supported this understanding and could explain why most of them distributed pumps through subsidized or for free.

Pump benefits: A number of farmers from both surveys were attracted to adopt the pumps because of the profits made by other colleagues who used similar pumps. Farmers associated assets such as iron sheet houses, bicycles, livestock and food secure households as profits obtained from pump irrigation. Other farmers related the pump benefits to the increased yields and incomes. Similar perceptions were also expressed by other stakeholders who mostly measured their success using the farmers' increased incomes and/or improved household food security (Table 6.25). More importantly, the majority of other stakeholders promoted pumps to reduce poverty.

Group organization: Only a number of group farmers were motivated to adopt the pumps because of group shared roles, responsibilities and benefits. Farmers indicated that pump sharing enabled them to share other related benefits such as pump fuel costs. Group treadle pump farmers also reported that labour sharing was more important when using pumps. In contrast, most groups abandoned the pumps because they could not cope with the group disorganizations issues. For example group treadle pump farmers complained that it was difficult to access the pump when they needed it and this resulted in some of them giving up and revert to using the watering cans. Group motorized pumps complained that it was hard to mobilise resources from group members for pump fuel and other related costs. These issues could also be linked to how these groups were founded (Section 6.4.13). Nevertheless, a number of other stakeholders including the government promoted pumps in groups and these were controlled by the prevailing policies (Chapter 3).

Social support: Although farmers did not directly report that availability of social support services (e.g. markets and extension services) motivated pump adoption, their attraction to the pumps by its affordability and profitability could be considered as an influence from the social system. In addition, most individual farmers learnt about pumps from their colleagues suggesting that these too were attracted to adopt pumps because of the existing social networks.

6.7 Qualitative results: factors limiting pump adoption

The technical and socio-economic factors limiting pump adoption are summarized in Table 6.26.

Table 6.26: Factors limiting pump adoption and continued-use

Adoption factor (theme)	Factors limiting adoption (code)	Number of farmers reporting the factor								**% total (of 201)**
		Survey 1				Survey 2				
		Treadle		Motorized		Treadle		Motorized		
		Gp n=31	Indv n=35	Gp n=27	Indv n=23	Gp n=8	Indv n=39	Gp n=12	Indv n=26	
Technical Pump technical design	Pump repair and maintenance	15	19	14	10	6	29	8	14	**57**
	Lack of spare parts	0	1	1	1	1	2	3	1	**5**
	Pump weight	0	0	14	3	0	0	2	1	**10**
Physical factors	Water unavailability	8	12	7	2	4	7	5	13	**29**
	Land unavailability	5	5	0	4	1	2	5	0	**11**
SE- Labour related	Increased labour	14	17	0	0	6	26	5	13	**40**
	Hard to operate	8	7	2	1	4	7	0	0	**14**
	Lack of labour	1	1	3	1	1	1	0	0	**4**
Cost related	Lack of capital	10	24	3	11	4	13	11	16	**46**
	Pump fuel costs	0	0	18	23	0	0	11	14	**33**
	Less profitable	1	2	7	0	0	0	3	1	**7**
Groups related	Group disorganization	5	0	4	0	6	0	7	0	**11**
	Sharing inconvenient	17	1	1	0	4	0	0	0	**11**
Social support	Lack of reliable markets	2	7	3	6	1	6	0	5	**15**
	Lack of technical skills	1	0	3	9	0	0	2	12	**13**
	Higher operating cost	0	0	7	0	0	0	3	1	**6**
	Pump security	0	0	5	1	0	0	2	1	**4**
	Lack of extension services	0	0	0	1	0	0	1	3	**2**
	Pump transportation	0	0	3	0	0	0	1	0	**2**

**SE- Socio-economic*

6.7.1 Technical factors limiting pump adoption

Pump design: Over half of the farmers agreed that pump repair and maintenance was the major challenge encountered. Whilst there were variations on the specific problems, frequent worn out water delivery hose pipes affected the majority of farmers from all pump categories. Most treadle pump farmers also indicated that were affected with frequent worn out pump valves. Some farmers replaced these valves with parts of bicycle tyres while others bought the part from local markets and others received assistance from the promoting organizations. For example, a number of NGOs provided spare parts for treadle pumps and other services as narrated by one discontinued treadle pump farmer (ID14):

> '……..we were receiving support related to the pump from Total Land Care (TLC) and we received maize and bean seeds, fertilizer as well as herbicides. Actually the type of support that we were receiving from TLC was equivalent to an amount that was enough for us to pay back our pump loan (paying for the subsidized pump by instalment was translated as loan to the farmers)..……….. I had problems with repair and maintenance of the treadle pump especially with the rubbers (pump valves) and leakages of the delivery hose pipe. TLC gave us the spare rubbers so this issue was resolved but for the pipe it could not be replaced and it was expensive to buy……. So after the hose pipe was completely worn out, I stopped using the pump and now I am using a watering can….'

In contrast, most group motorized pump farmers were affected with sourcing of the spare parts. Although government partially provided some with spare parts, farmers struggled to find the pumps' spare parts from the local markets. For individual motorized pumps, most farmers were challenged with the cost of servicing, repairing the pumps and also lack of spare parts. Most individual farmers however improvised strategies by replacing some pump spare parts with those from motor-cycles or vehicles. A number of farmers engaged experts (motor vehicle mechanics) for pump servicing and maintenance. Most discontinued group and individual motorized pumps were however due to the unresolved repair and maintenance problems. A number of farmers with individual motorized pumps also modified the pumps' water outlets to reduce flow rates in order to fit the hose pipes designed for treadle pumps since these were cheaper than for those of the actual pumps (Figure 6.6). This can be regarded as re-invention and understood as an indicator for pump acceptance (Rogers, 2003).

Most stakeholders agreed with farmers on these challenges and this could be the reason why some supported farmers with spare parts and technical training services on repair and maintenance especially for the treadle pumps (Table 6.24).

Figure 6.6: An individual motorized pump with a modified water delivery outlet (hose pipe) to match with the flexible pipes designed for the treadle pumps.

Physical factors: A number of treadle pump farmers were challenged with unavailability of water. Considering that most treadle pump farmers previously used traditional irrigation methods, this suggests that their water sources were not sufficiently developed to adapt the pumps' higher water flows. Other stakeholders agreed with farmers on these challenge such that some supported farmers by further developing their water supply sources (Section 6.5.2). On the other hand, most individual motorized pump farmers privately developed their water sources supporting the fact that these were financially better off than others. Very few farmers were affected with availability of land for pump irrigation. The increased irrigated areas by the pumps created the need for more land and hence farmers required larger irrigated areas which they could not afford to access. Farmers also indicated that availability of water supplies contributed to land challenges because not every farmer owned land located closer to water sources. Some farmers alleviated this problem by renting or borrowing the irrigated land from other farmers (e.g. pump non-adopters).

6.7.2 Socio-economic factors limiting pump adoption

Table 6.26 outlines the socio-economic factors limiting farmers to adopt the pumps.

Labour related: As expected, almost half of farmers (with treadle pumps) were greatly challenged with the increased labour required. This could also be because of the increased irrigated areas after the adopting the pumps. Most farmers that discontinued using treadle pumps or changed to motorized pumps attributed this to the increased labour demand. Only group motorized pump farmers were challenged with the heaviness of the pumps (Table 6.5). Very few group motorized pumps were permanently installed in the irrigated fields with support from the government. Those whose pumps were not permanently installed in the fields were faced with two choices either; to leave the pumps in their irrigated fields until the end of season and provide daily security for the pump; or ferry the pump on daily a basis through hiring transport services e.g. oxcarts. This suggests that these pumps demanded new behaviour from farmers. This contradicts with the earlier motivations (Section 6.6.1) expressed by farmers suggesting their experiences with these pumps were contrary to their prior motivations. Most other stakeholders considered farmers that complained about labour demand as not being grateful to the pumps given for free or subsidized.

Affordability: Almost half of farmers agreed that *lack of capital for buying farm inputs* affected pump irrigation. The increased irrigated areas resulting from using the pumps may have contributed to this problem. However, some individual motorized pump farmers improvised strategies such as staggering planting, reducing area irrigated and selling upland crops to alleviate the challenge. Contrary, most farmers with free and/or subsidized pumps were further supported by the promoting organizations especially the NGOs (Table 6.23). For individual treadle pumps, the provision of continued support helped them to continue using the pumps such that the majority later graduated to using individual motorized pumps (Figure 6.4). This suggests the external support may have influenced pumps continued-use. For group pumps, some organizations promoted the development of farmers' revolving of funds by encouraging them to save some of the profits acquired from pumps. However, most groups had stopped these revolving funds and farmers attributed this to the little or no profits obtained from pump irrigation and the lack of members commitment.

The *cost of fuel* was another major challenges faced by motorized pumps farmers and this was highlighted more by the group farmers. This contradicted with the farmers' earlier motivation (Section 6.6.1) in which they were attracted to adopt the pumps because of shared group benefits. Furthermore, some treadle pump farmers indicated that they could not adopt motorized pumps because they could not afford the pumps' fuel costs. Similarly, a number of individual farmers indicated this as a challenge although very few discontinued using the pumps because of fuel costs. This could be because these farmers were financially capable of supporting the pump related costs e.g. fuel. In contrast, most stakeholders (especially NGOs) perceived that motorized pumps were not a suitable technology for smallholder farmers because they are poor and cannot sustain the pump operational costs. For this reason, many organizations except the government did not support the motorized pumps.

Lack of group organization: A number of group farmers considered pump sharing as not convenient. Farmers mentioned factors such as lack of; pump ownership, responsibility to repair and maintain the pumps; trust of the leadership; and general group organizations as the challenges encountered with shared pumps. A number of pumps discontinued were ascribed to group disorganization related issues. Although most organizations promoted pumps to groups, it was interesting that most of them complained that group disorganization was also a major challenge faced with pump adoption. However, for other stakeholders, it was easier for organizations to access and monitor farmers in groups than as individuals and hence the policy.

Social support: A number of farmers especially those with motorized pumps were challenged with the lack the pump technical skills. Farmer indicated that they were not familiar with the pumps and hence the challenge. The situation was worse with the lack and unavailability of spare parts. A number of individual farmers abandoned the pumps and purchased second or third pumps (Section 6.4.10) because they could not fix the pump's technical problems. This suggests that motorized pumps lacked technical support. This can be supported by the number of organizations that supported these pumps (Table 6.24). Very few farmers (mostly individuals) were challenged with market unavailability for their irrigated products. The main buyers were middlemen (vendors) followed by people from surrounding communities (Table 6.24). However, farmers highlighted that middlemen controlled prices for their irrigated products such that profits made were very small. This was worse with most farmers growing the same crop types which resulted in increased supply against the demand. This indicates that farmers also needed support in crop diversification and marketing strategies. A summary of similarities and differences between farmers' and stakeholders' opinions is outlined in Table 6.27.

Table 6.27: Commonalities and differences between the farmers' and stakeholders' opinions on factors motivating and limiting adoption of SSPI

Factor	Farmers	Other stakeholders
	Motivators	
Technical	**1. The pumps increase the irrigated area** 2. The high water flow by the pumps 3. The reduced labour 4. The pumps are simple and easy to operate 5. The pump are less tiring 6. Pumps require less irrigation time 7. Pumps provides long irrigation intervals 8. Water availability 9. Pumps demands less energy (motorized pumps) 10. Land availability	• **To increase the area under irrigation**
Socio-economic	**1. To increase the profits** **2. To increase yield** 3. To access group benefits **4. To increase income** 5. The pumps are subsidized and or free 6. The pumps are cheap 7. The pumps are convenient to be individually used	• To improve food security • To reduce poverty • **To increase income and profits**
	Limitations	
Technical	**1. Pump repair and maintenance** 2. Increased labour demand (treadle pumps) **3. Water unavailability for pumps** 4. Pumps are hard to operate (treadle pumps) 5. Land unavailability 6. Pumps are heavy (group motorized pumps)	• **Pump repair and maintenance** • Lack of pump spare parts • **Water unavailability**
Socio-economic	1. Lack of capital for farm inputs **2. The cost of pump fuel (motorized pumps)** 3. Lack of pump technical skills **4. Group disorganizations** 5. Lack of reliable markets 6. Less profits 7. Higher operating costs 8. Lack of labour 9. Lack of extension services	• **Group disorganizations** • **Fuel costs (motorized pumps)**

6.8 Qualitative results: reasons why farmers continue or discontinue using the pumps

Most individual farmers indicated that were likely to continue using their various pumps because of; increase irrigated areas, easiness and simplicity to operate and freedom to use the pump at their own convenient time. Farmers expressed different views on reasons likely to stop them from continuing with the pumps. Most treadle pump farmers indicated that aging and sickness were likely to stop them from using these pumps; these were linked to pump labour demand. For group motorized pumps, fuel costs, repair and maintenance were indicated as the likely reasons that will stop farmers from continuing using the pumps. Most individual motorized pump farmers mentioned that repair and maintenance problems were likely to stop them from continue-using the pumps. These findings suggest that energy, pump technical skills and availability of spare parts are critical in pump adoption while increased labour and pump technical skills are the major limiting factors.

6.9 Qualitative results: non-adopters perceptions and preferences

Selected pump non-adopters were interviewed in the second survey in order to confirm the perceptions of the pump farmers (Chapter 4). Most farmers wished to adopt a pump (mostly treadle pumps) later (Table 6.28). About half of the farmers indicated that they were making some savings in order to buy their own treadle pump suggesting that these farmers were likely to adopt pumps in future. This suggests that although treadle pumps are given for free or subsidized to farmers, not all the farmers are able to access these pumps. Over a third of non-adopters once borrowed or rented a treadle pump from colleagues and tried them in their irrigated fields. This may support the fact that innovations that can be tried have the potential of being increasingly adopted (Rogers, 2003).

For preferences, a majority preferred having individual treadle pumps (especially the Money Maker). Reasons such as being simple and easy to operate, freedom to independently use the pump, no need for fuel and use of simple water sources were provided for their choices. Very few non-adopters preferred having individual motorized pumps; factors such as lower labour demands, increased irrigated area and less irrigated time were the reasons for their preferences. None of the farmers preferred group treadle or motorized pumps. Farmers indicated that group disorganizations and lack of ownership to repair the group pump affect the effectiveness of these pumps. These preferences may support the finding that individual pumps are preferred more than group pumps by the farmers.

Table 6.28: Perception of the pump non-adopters

Farmers ID	Wished to have a pump	Tried the pump	How the pump was accessed		Pump type preferred	
			Borrowed	Rented	Indv.TP	Indv. MP
ID 1	x	x		x	X	
ID2	x	x	x		X	
ID3	x				X	
ID 4						
ID 5	x					x
ID 6	x	x		x		x
ID 7	x				X	
ID 8	x	x	x		X	
ID 9	x				X	
ID 10	x				X	
ID 11	x	x	x		X	
Total	**10**	**5**	**3**	**2**	**9**	**2**

** TP-treadle pump, MP-Motorized pump*

6.10 Summary

The findings in this chapter identified four distinct pumped systems, comprising two pump types (treadle and motorized) and two ownership modes (group and individual) are adopted in Malawi. Farmers generally prefer to adopt pumps that are technically less difficult to operate (e.g. portable, simple and easier to operate, less energy demanding) and can be individually managed. Most organizations promote treadle pumps rather than motorized pumps implying that adoption of these pumps is largely influenced by the external support. Farmers are motivated to adopt the pumps to resolve the technical challenges with previous irrigation methods while most stakeholders promote pumps to increase food security and reduce poverty. Farmers and stakeholders agree that pump repair, maintenance, operational costs and group disorganizations are major challenges encountered with SSPI. However, stakeholders disagree with farmers that increasing labour demand (for treadle pumps) and lack of capital for inputs are also the major challenges. The implication is that organizations strategies used to promote the pumps may not be addressing the actual requirements of the farmers thereby affecting SSPI continued-use and sustainability as discussed in chapter 7.

7 DISCUSSION

7.1 Overview

This chapter discusses the field survey results (Chapter 6) by mapping them onto the five stages of Rogers (2003) model. It then presents a new conceptual framework for understanding and classifying ‘success’ which highlights the routes taken by farmers who successfully adopt or discontinue using the pumps. The framework is checked by evaluating success in adoption of SSPI in Malawi based on second field survey data; findings support the framework.

7.2 Mapping SSPI adoption onto the diffusion of innovations model

In this chapter, farmers are referred to as ‘*self-motivated farmers’* if they acquired the pumps independently without external financial support and as ‘*incentive farmers’* if they acquired the pumps through subsidies or for free.

7.2.1 Prior-conditions stage

The results showed that the self-motivated farmers had more positive conditions prior to adoption of the pumps than incentive farmers (Table 6.13, Table 6.15, Table 6.16, Table 6.22 and Table 6.9). Their attributes included good education, large irrigated areas, capital assets, having leadership skills and experiences in pump irrigation. This indicates that the conditions of the self-motivated farmers are consistent with the prior conditions advocated in Rogers (2003) model. In their study Kamwamba-Mtethiwa et al. (2012), found that relatively well-to-do farmers had a significantly higher probability of adopting treadle pumps than their poorer counterparts using logit model. These results support the findings and suggest that socio-economic attributes of self-motivated farmers played an important role in influencing their decisions to adopt pumps. The findings are also consistent with previous studies (Adeoti, 2008; Mangisoni, 2008; Namara et al., 2013), which argued that socio-economic characteristics such as capital assets (irrigated land), human capital (age, education) and social institutions have a great potential for influencing adoption of irrigation technology.

On the other hand, the results (Table 6.13, Table 6.15, Table 6.16, Table 6.22 and Table 6.9) showed that the incentive farmers lacked a lot of attributes to support their decisions to adopt the pumps. With the exception of the age, household sizes and sources from which farmers learnt about the pumps, most farmers were only educated to a basic level, lacked leadership skills, owned small irrigated areas, lacked capital assets and were not innovative. These attributes suggest that these farmers were not fully prepared (ready) to adopt the pumps but rather the external incentives influenced their decisions. For example, farmers explained that they were motivated to adopt the group motorized pumps because they were simple and easy to use (Section 6.6.1), but farmers were limited with technical skills to repair and maintain the pumps. This implies that the quality of performance, progression towards adoption and positive feelings about the pumps may have been lower for these farmers (Herath, 2010). In South Africa, Fanadzo (2012) found that weak institutions and poor technical skills of farmers were the major factors that led to under-performance of most SSI systems. For this reason, that study supported approaches that enhanced human capital such as training in order to revitalize the SSI systems. It can be argued here that the attributes of the incentive farmers support this evidence suggesting that these too may need support to build their capacity and facilitate the adoption process.

7.2.2 Knowledge stage

For self-motivated farmers, knowledge about the pump was mostly gained from friends who used similar pumps (Table 6.17). Farmers either borrowed or rented pumps from friends before making the decision to adopt. This means that these farmers had the opportunity to test and fully understand the pumps before making their decision. This indicates that self-motivated farmers had better exposure to information about the pumps compared to the incentive farmers. This supports previous evidence (Morris et al., 2000; Rogers, 2003) that highlighted that adoption is more effective if the innovation can be tried by its potential adopters. Furthermore, renting of the pumps may suggest that these farmers were exposed to alternative income sources by adopting the pumps. Although this research did not explore more on the contributions and effects of renting the pumps to the potential adopters, this is an interesting area that should be further investigated.

On the other hand, most incentive farmers learnt about the pumps through organizations that promoted them (Table 6.17). However, since these organizations had different criteria for pumps' dissemination (Section 6.4.8); it is likely that these farmers received the pumps before they fully understand how they function and their related benefits. It is also possible that these farmers did not have the opportunity to test the pumps before their decisions to adopt. For example, group motorized pumps were completely new to farmers and the only source of the information about the pumps was through the government (Table 6.17). Furthermore, these pumps were only available in selected communities. Conversely, although treadle pumps were also accessed through their promoters, the pump was commonly available among the communities. This indicates that apart from promoters, farmers could explore further information about these pumps from fellow users in their surrounding communities. This likely increased the farmers' exposure to the pumps thereby reducing their uncertainty towards the pumps. This demonstrates the importance of interpersonal communication in the adoption process (Morris et al., 2000; Rogers, 2003). These findings could also be used to explain some of the reasons for the consistent treadle pump adoption routes and patterns (Figure 6.4).

7.2.3 Persuasion stage

Farmers seek evaluation information and messages to reduce their doubts on the expected benefits of the pumps. Rogers (2003) defined such information as innovation attributes and categorized them into five groups (Chapter 2). This study explored how these attributes affected the decisions of farmers to adopt pumps (Table 7.1). 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 incentive farmers. As shown in Table 7.1, most pumps adopted by the self-motivated farmers were often portable by hand, could be used on individual farmers small irrigated plots and could easily be tried by other farmers within the communities suggesting that these pumps were consistent with most of the innovations attributes advocated by Rogers (2003) model. This may explain the reasons for the increased adoption and continued-use of pumps adopted by the self-motivated farmers.

Table 7.1: Attributes of treadle and motorized pumps that influenced their adoption

Pump attributes	Level of Influence	Research findings
Relative advantage	+ve	-All pumps had high water flow, increased irrigated areas, were considered simple and easier to use and enabled farmers to access far-away and deeper water supply sources compared to previous irrigation methods. -Motorized pumps had a potential for irrigating remarkable larger irrigated areas and demanded less labour compared to treadle pumps.
	-ve	-Treadle pumps used manual labour to operate. -Group motorized pumps were not portable. -Motorized pumps required fuel to operate.
Compatibility	+ve	-Treadle pumps used same water sources used by the previous irrigation methods, irrigated smaller and irregular irrigated plots and could be transported by head to the fields. -Individual motorized pumps could be modified to irrigate smaller and irregular farmers' fields and transported by head or bicycles to fields.
	-ve	-Group pumps interrupted individualism and was considered inconvenient -Motorized pumps required modified water sources to accommodate their larger water flows. -Group motorized irrigated smaller and irrigated fields with difficulties and required special transportation to and from irrigated fields.
Complexity	+ve	-Treadle pumps spare parts were locally available. -Individual motorized pumps' spare parts could be locally sourced.
	-ve	-Some treadle pumps' spare parts were expensive e.g. hose pipes. -Motorized pumps required technical skills to operate, repair and maintain -Group pumps lacked ownership especially when they break down.
Ability to be tried	+ve	-Individual treadle and motorized pumps could be borrowed or rented to be tested by the potential adopters before adoption.
	-ve	-Group treadle pumps could not be tried as they were mostly committed. -Group motorized pumps could not be tried because of size and weights
Observability	+ve	-Treadle and individual motorized pumps could easily be observed
	-ve	-Group motorized pumps were only available in selected communities and could not be easily observed

For incentive farmers, the situation was different, the pumps adopted by these farmers (e.g. group motorized) were often heavier, required water supplies with large volumes and were not portable by hand while most farmers typically owned smaller irrigated areas and accessed smaller and undeveloped water sources (Table 6.10). In addition, some pumps require financial resources for fuel while most incentive farmers had limited access to financial capital. This may suggest that farmers adopted the pumps that were not compatible with their status and it partly contradicts evidence (Rogers, 2003) that argues that the decision to adopt is influenced by the innovation attributes. This partly supports the farmers' opinions on the factors limiting the pump adoption (Section 5.7) and corroborates with previous evidence that underlines that SSI development does not conform with the traditional irrigation methods (DFID, 1999; Kimmage and Adams, 1990; Kimmage, 1991).

7.2.4 Decision and implementation stages

Role of continued support and re-invention

In these stages farmers sought confirmation of the earlier information regarding the pumps' attributes (e.g. the ability to reduce labour, increase water flow and increase irrigated area) in order explore whether their expectations prior to adoption were genuine. The results (Section 6.7) showed that adoption of the pumps created new demands such as increasing labour demand (in the case of treadle pumps), higher operational, repair and maintenance costs and the need for modified or alternative water sources (for the motorized pumps). Farmers required additional financial resources, access to labour and technical knowledge in order to successfully adopt and continue using these pumps. Furthermore, according to the motorized pumps' design specifications (Chapter 3), it is likely that most farmers used oversized pumps in relation to the sizes of their irrigated areas. In Kenya, Kang'au (2011) found that farmers used oversized pumps because of the lack of technical knowledge suggesting that farmers in this research also lacked the pump technical skills. However, farmers addressed these challenges differently and depending on their associated characteristics.

Most self-motivated farmers improvised various strategies in order to cope with these challenges. For example; farmers replaced pump spare parts with locally available materials (e.g. replacing treadle pumps valves with parts of bicycle tyres) because they were innovative; some hired mechanics for pump repair and maintenance because they had access to financial resources and; others received support from colleagues using similar pumps because they were influential and innovative people within their societies. Based on Rogers (2003) model, the creation of these strategies can be understood as innovation re-invention which signifies technology acceptance. It can therefore be argued 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 incentive farmers, since most of these had poor conditions prior to adopting the pumps, they struggled to understand how the pumps function after adopting. For example, treadle pump farmers struggled to cope with the pump high labour demand, repair and maintenance issues. Group motorized pump farmers struggled to sustain the pump operational costs. However, since most organizations continued supporting other farmers (Table 6.23), this may have contributed to their ‘learning curve’ (Burney and Naylor, 2012) and reinforced the continued-use of the pumps. According to Carter et al. (1999), provision of continued support ensures sustainability and reduces the possibility of adopters going back to their previous technologies. However, not all farmers received external support (Table 6.23); for example, despite the need for technical skills and financial resources by group motorized pumps, these farmers only received support during their early stages of adoption. Without external support, farmers would struggle to clearly understand the technical aspects of the pumps. This may have implications on further adoption process suggesting that implementation and continued-use of these pumps would be uncertain. This supports Chancellor (2000) who argued that the poor farmers in SSA cannot effectively afford the various demands required to use the small irrigated pumps. This may also help to explain the reasons for discontinued use of most group motorized pumps.

Role of pump groups versus individuals

Almost all group pumps were adopted through incentives. The results indicate that the differences between the group and individual pumps played an important role in the implementation stage. Literature contradicts on the advantages of groups versus individual performances (Aramovich, 2014; Hill, 1982; Michaelsen et al., 1989). Those supporting groups attribute group project’s success to factors such as pooling of resources to achieve certain goals, higher levels of creativity, solving complex problems (Aramovich, 2014; Burney and Naylor, 2012). Conversely, evidence supporting individual performance argues that the freedom of using the technology, good management and lack of shifting responsibilities are the factors that makes individual projects successful (Cornish, 1998; Kay and Brabben, 2000). Similar trends were also observed between the groups and individual farmers in this research. Although it was expected that farmers’ pump groups will benefit from collective group actions such as fuel cost (motorized pumps) and sharing the labour (treadle pumps), the results revealed that farmers were greatly challenged with issues regarding group organizations (Section 6.7).

For treadle pumps, most farmers indicated that pump sharing was not convenient (Section 6.7). Farmers mentioned that the demand for the shared pump was high such that it was difficult for all members to access it and hence only few members could access the pumps. In addition, there was a lack of commitment by group members to repair and maintain pumps (Section 6.7). Normally, group leaders were supposed to mobilize the resources for repairing and maintaining pumps, however it was difficult to mobilize the resources considering that the pumps were not adequately accessed by all members. For group motorized pumps, investigations showed that most groups were formed prior to receiving free pumps (Section 6.4.13). Further, farmers were expected to use the pump on the communal irrigated fields and share the cost of running the pumps e.g. fuel costs. It is likely that these interventions disturbed the farmers previous irrigation practices (Table 6.9). For example, the use of communal irrigated land may have created land insecurity for farmers. This may explain the reasons for failure of most group pumps in the study areas.

According to Hill (1982), an effective group is supposed to have clear goals, allows that participation and leadership are distributed among all group members and there is mutual commitment and trust. Others (e.g. Brown, 2011) argue that where leadership is lacking, processes fail to take off. Most pump group leaders lacked leadership qualities (Section 6.4.13). Very few (13%) group farmers indicated that they belonged to some cooperatives in their societies. Membership in the farmers' cooperative society is a social asset which indicates some leadership qualities of a farmer (Adeoti, 2008). This may explain the reason why a higher proportion of group owned pumps were not operating (Table 6.6). It could be that group pumps farmers lacked leadership skills to mobilize the resources, which may have resulted in most the pumps being abandoned. The differences in the rationales for the groups between farmers and the promoting organizations may have also contributed to the pump groups' inefficiencies. For individual farmers, this supports the earlier argument that farmers' freedom to individually use the pumps provided them with the opportunity to be creative in dealing with the pump challenges. This also supports the previous evidence (Cornish, 1998; Kay and Brabben, 2000) which argued that smallholder irrigation technologies in SSA are better managed by individuals than the groups.

Another interesting finding was the length of period that group pumps were used before being abandoned. Although, this research has limited evidence (Section 6.2.6), it appears that group motorized pumps were abandoned earlier (between 0.5 to 1 year) after adoption compared to the group treadle pumps (over 2-3 years). A number of explanation could be provided for this observation. First, this could be because treadle pumps received continued external support and possibly farmers were motivated to continue using the pumps because of this. This could be used to emphasize the need for continued external support on pumps accessed through incentives. Second, although the treadle pumps were shared, farmers still used them on their existing individual plots and water sources (Section 6.2.1) suggesting that these pumps did not completely interrupt the farmers' previous irrigation practices. Third, these pumps were maintained using locally available materials and were portable by hand suggesting that the costs incurred for these pumps were relatively lower compared to the group motorized pumps. Based on this, future studies should consider providing more empirical evidence on reasons why group motorized pumps are abandoned earlier than group treadle pumps and possibly explore the effects that this would have on further adoption processes. It may be that the length of period for using these pumps before abandoning them contributed to changing the farmers from being incentive to self-motivated adopters.

7.2.5 Confirmation stage

After the decision to implement the pumps, farmers secure further information that may persuade them to stop using the pumps. The results showed that most farmers preferred individual motorized pumps over the other pumps (Figure 6.5). This could suggest that the other pumps categories were likely to be abandoned after adoption. On the other hand, most pump non-adopters preferred individual treadle pumps (Section 6.9) suggesting that these would be a better option for farmers who are just starting to practice pump irrigation. These farmers' choices have implications on the continued-use of the various pumps; their sustainability would depend on understanding the factors that attracted farmers to the specific pumps. As illustrated in Figure 7.1, the interpretation is that individual treadle pumps were more attractive to farmers because they: provided farmers with freedom to be used independently; could be easily tried by others and required local spare parts. For individual motorized pumps, in addition to having similar attributes as the individual treadle pumps, factors such as the ability to; have high water flows; be modified to fit the farmers existing conditions; increase irrigated areas much more; and demand less labour made them more attractive than other pumps. These findings correspond with the previous studies (Cornish, 1998; Dessalegn, 2013) that highlighted factors that are critical to the success of SSI irrigation technologies.

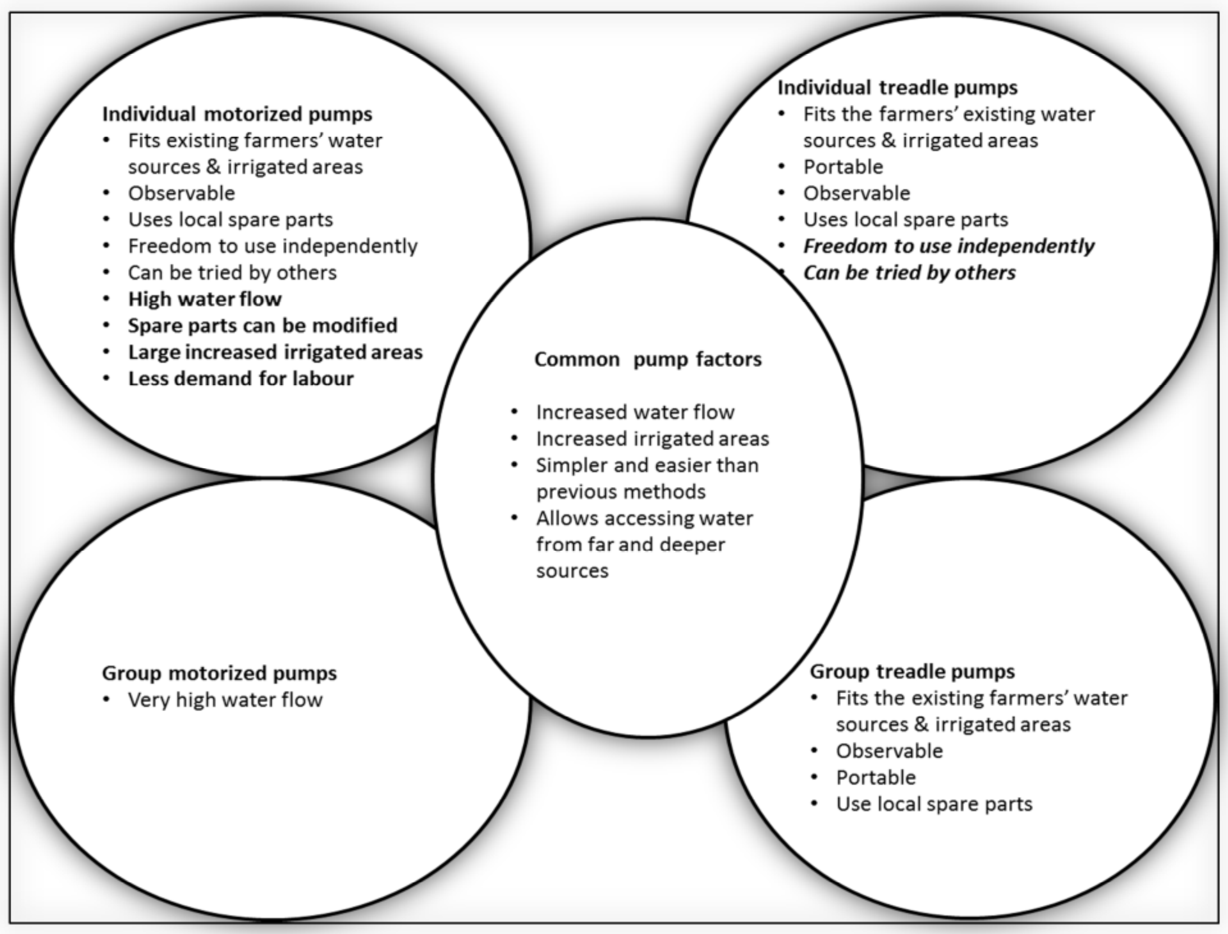

Figure 7.1: Positive characteristics (identified from field survey-Chapter 5) that differentiate individual motorized and treadle pumps from other pumps.

A summary of how the field surveys' findings are mapped onto the five stages of the Rogers model (2003) is outlined in Table 7.2.

Table 7.2: Mapping the decision-making stages in adoption of pumps in Malawi.

Innovation stage	Conditions influencing the farmer's decision to (non) adopt the pump	Pump type & ownership			
		Motorized		Treadle	
		Indv	Gp	Indv	Gp
Pre-conditions	Farmers had previous experience in pump irrigation	x			
	Farmers had potential human capital-Age, education, household size	x	x	x	x
	Farmers had access to physical capital- e.g. larger irrigated areas	x		x	
	Farmers had financial capital-owning capital assets	x		x	
	Farmers belonged to cooperative societies-social capital	x		x	
	Farmers felt the need (self-motivated) to adopt the pumps	x		x	
Knowledge	Accessed pump information through interpersonal & socio-networks	x		x	
	Accessed pump information through the promoting organizations		x	x	x
Persuasion	Farmers tested the pumps before adoption	x		x	
	Farmers were persuaded with the pump affordability (incentives)		x	x	x
Decision & Implementation	Pumps were rejected/abandoned after previously adopted		x		x
	Pumps were accessed from commercial sellers in town and cities	x		x	
	Pumps were accessed from the promoting organizations through subsidy or for free		x	x	x
	Knowledge on how to operate the pumps were obtained from colleagues	x		x	
	Knowledge on how to operate the pumps were obtained from the organizations providing the pumps		x	x	x
	Technical challenges faced with the pumps were usually resolved by the adopters	x		x	
	Technical challenges faced with the pumps were usually resolved by the promoting organizations		x	x	x
	Farmers continuously received support services such as training, extension, inputs (seeds, fertilizers, herbicides) related to the pumps			x	x
	Farmers once received support services (e.g. pump maintenance, start up fuel) especially at the onset of adoption.		x	x	x
Confirmation	Pumps continued being used	x		x	
	Pumps were discontinued and replaced with better pumps (e.g. individual motorized pumps)			x	
	Pumps were discontinued (disenchantment) and farmers returned to traditional irrigation methods		x		x
	Farmers preferred individual motorized pumps if given a chance to choose	x	x	x	x
	Farmers preferred individual treadle pumps if given a chance to choose		x		

*X means that the condition was applicable to a majority of farmers in that particular pump type

7.2.6 Implications of the findings on Rogers model

The findings from the mapping process established that not all the paths that lead to the farmers' decisions to adopt the small pumps are consistent with the five stages of the diffusion of innovation model (Rogers, 2003). However, the self-motivated farmers were consistent with the stages of the model. For incentive farmers, results showed that these tend to ignore the other stages advocated in the model and hence are not fully consistent with the model. These farmers decide to adopt the pumps (decision stage) before they actually get through the 'prior-conditions', 'knowledge' and 'persuasion' stages of the model. The implications is that these farmers would have little experience with pumps, struggle to use them and are likely to abandon them as in the case of group owned pumps (Table 6.6 and 6.8). However, despite not fully satisfying the other stages of the Rogers (2003) model, adoption of other pumps such individual treadle pumps showed that most farmers continued using them; these farmers also received continued external support from the pump promoting organizations. This suggests that the provision of external support may have reinforced the pumps' continued-use. This research suggests that adoption of these pumps followed a different adoption pathway referred to here as the 'incentive' and hence a proposition to restructure the Rogers model to include this pathway (Figure 7.2). This recognition can help future research and policies to develop appropriate strategies for successfully promoting the uptake of SSPI initiated by incentives.

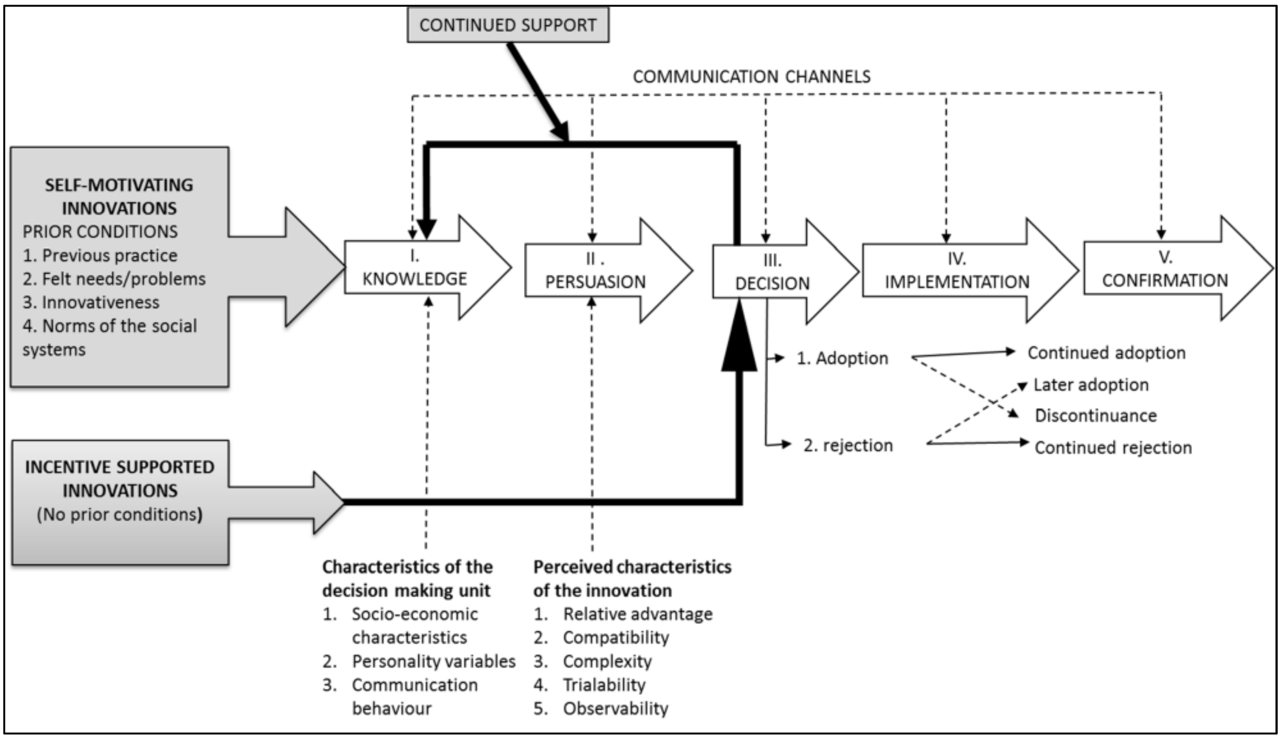

Figure 7.2: Rogers (2003) model of five stages in innovation-decision making process modified according to this study (Modification displayed by shading and **bold** lines)

7.3 Developing a new conceptual framework for understanding success in adoption of SSPI

This section presents a new conceptual framework that the research has developed.

7.3.1 Rationale for a new conceptual framework

The field survey findings (Chapter 6) prompted the need to review the approach for understanding success on the adoption process of small pumps. The results revealed that 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 SSPI. A better understanding of success could assist in effective dissemination of new SSPI. In this section evidence from literature and field surveys on how success in adoption process is understood is described.

Evidence from literature review

There is no common approach for identifying success for SSI systems (Burney and Naylor, 2012; Hussain and Hanjra, 2004; Kamwamba-Mtethiwa et al., 2015). For example, most theories for technology adoption (Chapter 2) 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 new 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 SSI 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 considered by Burney and Naylor (2012) as moving beyond innovation continued-use.

This above review demonstrates that success in the adoption process can be independently measured by; using the number or proportion of adopters accepting the new innovation, operational status (continued-use) and the socio-economic changes of the farmers that occur after adoption as illustrated in Figure 7.3. Bos et al. (2005) developed a set of five indicators to enable comparison of irrigation performance across all irrigation systems including agricultural output, water supply and financial returns. However, for SSPI in SSA the information required to estimate these indicators is rarely available. These clearly demonstrates that there is no approach that is all-encompassing in assessing success in adoption of SSPI suggesting that the choice of success elements depends on those carrying out the assessment. This supports previous evidence that argued that selection of measures for assessing success or impact of SSPI depends on the interest of those executing the studies (Kamwamba-Mtethiwa et al., 2015; Matekere and Lema, 2011).

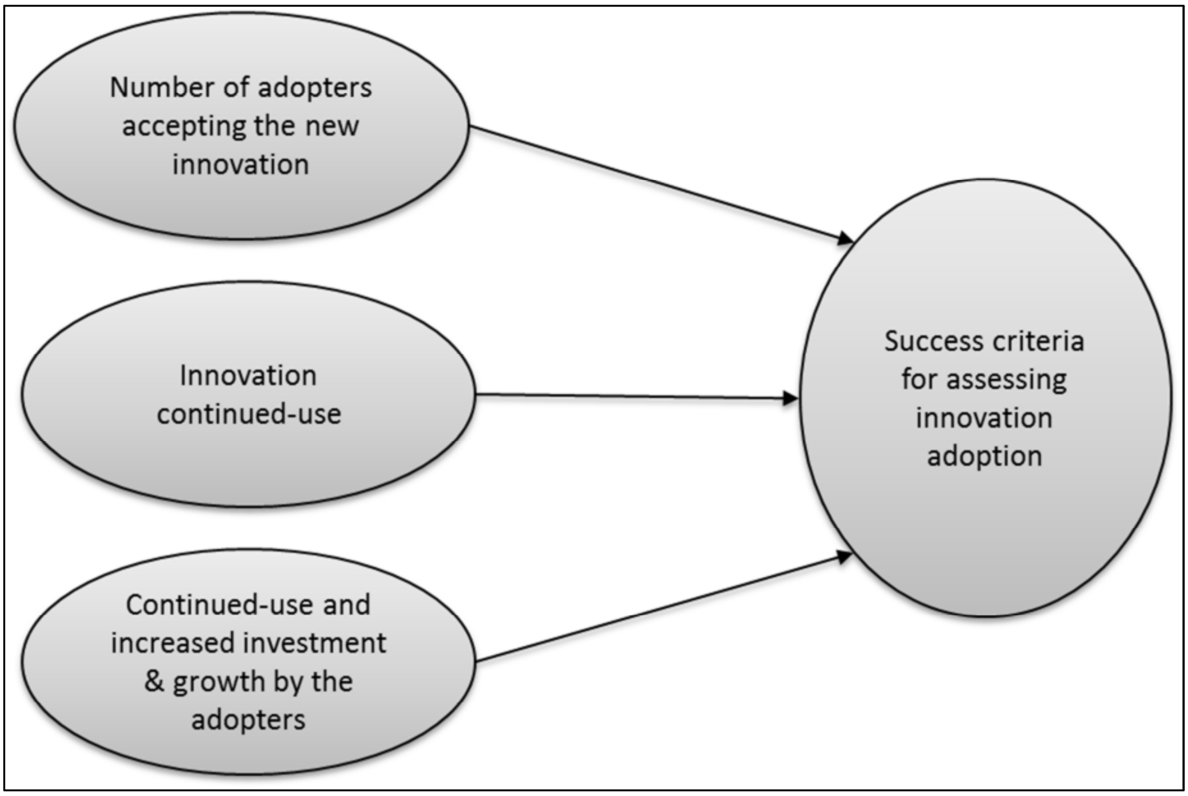

Figure 7.3: Alternative definitions for success in adoption process.

Recently, a number of studies in SSA have attempted to address this gap (Van Averbeke, 2011; Djagba et al., 2014; Fanadzo, 2012; Mutiro and Lautze, 2015; Ofosu et al., 2014; Sumberg et al., 2012; Yakubov, 2012), however, most of these studies are specific to irrigation schemes and the criteria used to measure success are not particularly focussed on SSPI. For example, Mutiro and Rautze (2015) systematically examines existing literature in southern Africa to determine the proportion of irrigation schemes that can be considered successful. That study determined that nearly 60% of the irrigation schemes in the region can be considered successful. However, the set of criteria used to measure success did not consider the types and conditions of the irrigation technologies but rather the outputs.

The above interpretation is also supported by evidence that showed variations in the use of success element on studies that assessed the impact of SSPI in other parts of the SSA. For example, evidence showed that most studies (Adeoti, 2008; Baba, 1993; Dillon, 2011; Mangisoni, 2008; Ofosu et al., 2010; Woltering et al., 2011) use socio-economic factors to determine the success of SSPI. A critical review (Chapter 5) showed that studies that used socio-economic elements mostly concluded with positive success outcomes. Conversely, studies (Connor et al., 2008; van Halsema et al., 2011; Kadyampakeni et al., 2012) that combined success elements (such as technical, agronomic and socio-economic) in their assessment approaches concluded with mixed success outcomes.

Evidence from field survey

Findings from the research's field surveys agreed with most of the evidence in the literature on the success elements for SSPI. 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 a number of pump types. Continued-use here is considered as when farmers used the pumps for a minimum period of six months or full irrigation season (Section 4.3.3). Based on the analytical understanding, those pumps could be categorized as successful by using any of the success definitions (Figure 7.3). 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 of the pumps were adopted through the 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 SSPI 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 the continued and discontinued-use of the pumps are significant and should be incorporated in the adoption processes of the incentive adopted pumps. The results also found that most treadle pump farmers advanced to better pumps (individual motorized pumps) suggesting that success can be recognised beyond the increasing investment as advocated by Burney and Naylor, (2012). These results support the need for better understanding of 'success' in adoption of SSPI. The analytical process leading to the development of a new framework is also summarised in Figure 7.4.

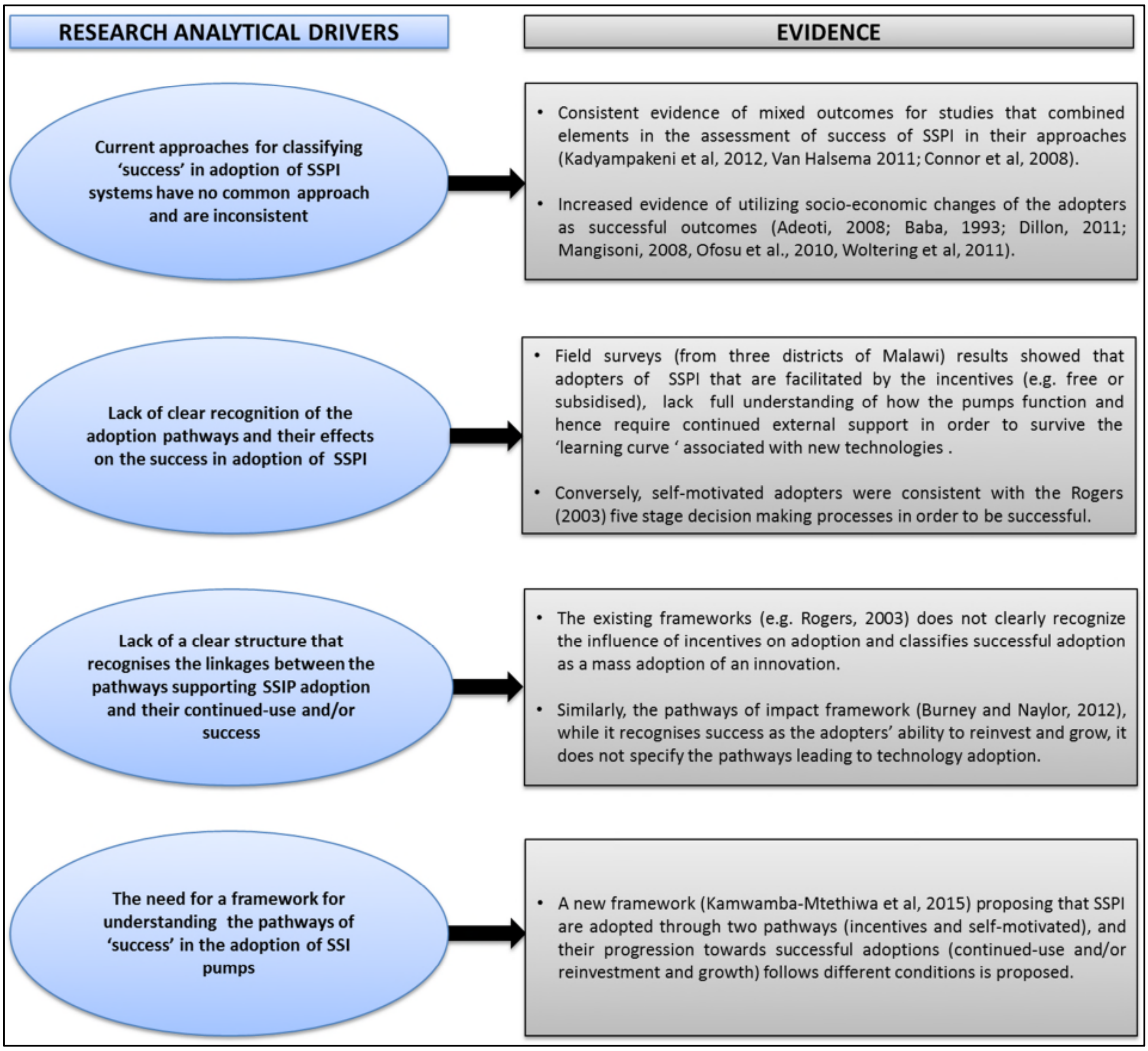

Figure 7.4: Analytical drivers for developing the new conceptual framework for identifying success in SSPI.

Defining success

The discrepancies between evidence from the literature and field survey led to the revised definition and categorization of success in adoption of SSPI. It is suggested that success can be realized when adopters have accepted the pumps, continue using them and are able to increase investments and grow. Success will be: 'marginal' if the pumps are simply being continued-use; 'substantial' if they are continued-use and adopters are able to increase their investments; and 'major' if pumps are continued-use, adopters are able to increase investment and grow e.g. advancing to better pumped systems. This definition partly supports the pathways of impact model by Burney and Naylor (2012) although the authors did not clearly include technology continued-use and growth in terms of advancing to better technologies as part of success outcomes. Given the different adoption pathways and the revised definition of success, a new framework is developed below.

7.3.2 Description of the new framework

A framework (Figure 7.5) for understanding success in the adoption of SSPI was derived by linking the adoption pathways to the theories of diffusion of innovation (Rogers, 2003), sustainability chain (Carter et al., 1999) and pathways of impact (Burney and Naylor, 2012). In the context of adoption process for SSPI in Malawi, the framework is presented in three stages (Figure 7.5).

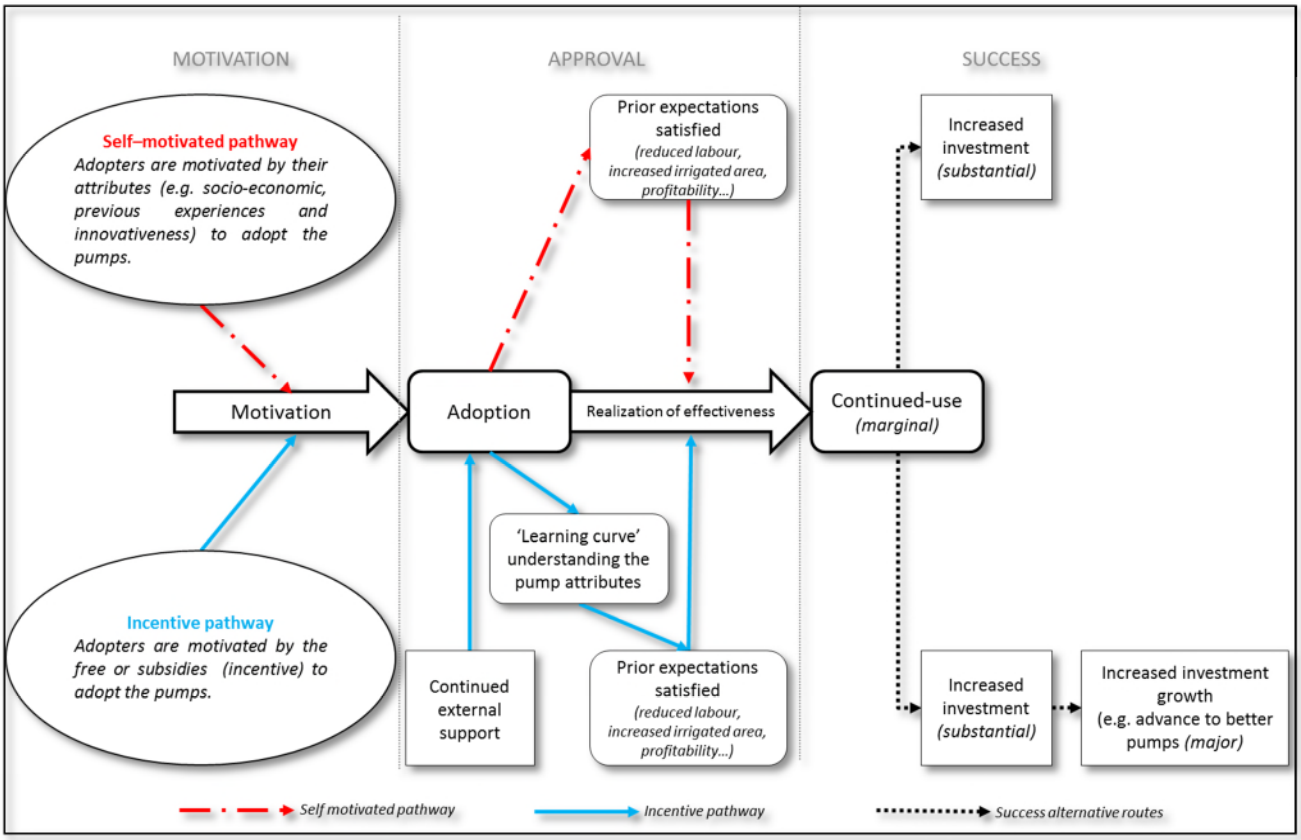

Figure 7.5: **A new conceptual framework showing pathways of success in SSPI**

Motivation stage

Awareness or motivation is the initial stage in the adoption process. Motivation refers to the reasons for acting or behaving in a particular way. It can be categorized as either intrinsic or extrinsic motivation. Intrinsic motivation is understood as doing something for the enjoyment or doing it rather than for an external reward (Nikou and

Economides, 2014). It is argued that intrinsic motivation is derived from values and beliefs and is associated with greater long-term change. Intrinsic motivation is also characterized by satisfaction and interest. Others (e.g. Herath, 2010), describe it as the most self-determined form of motivation which is mostly associated with positive outcomes like persistence, performance quality, goal attainment and positive feelings. Although Rogers (2003) model did not clearly include motivation, the description of the stages such as the preconditions, knowledge and persuation stages matches with the characteristics for intrinsic motivation. This means that farmers that followed Rogers (2003) model in the adoption of SSPI were intrinsically motivated and hence referred as self-motivated in this study.

Conversely, extrinsic motivation is derived from the social environment and mostly associated with material and/or social rewards. Farmers that adopted the pumps through incentives are perceived as extrinsically motivated and hence driven by the availability of free or subsidized pumps. However, evidence suggests that there is a relationship between intrinsic and extrinsic motivation (Deci and Ryan, 1985). It is argued that extrinsic motivation can gradually be reduced and replaced with the intrinsic motivation. Given this understanding, this stage entails exploring the conditions of the potential farmers before adopting the pumps in relation to the type of motivation that influenced adoption.

Approval stage

This refers to conditions which support the implementation leading to the pumps' continued-use. For self-motivated farmers, at this stage the pumps are used and it is anticipated that they will be seeking relevant information to reinforce their adoption decisions. Rogers, (2003) argued that farmers are likely to reverse the decision if they are exposed to conflicting messages about the pumps. For incentives farmers, the framework suggests that farmers will initially be exploring ways for further understanding the attributes of the pumps adopted. However, considering their attributes, it is likely that it will be hard for them to independently support their understanding (learning curve) of the new pumps. This creates the need to close the gap between the farmers' attributes and their interest to learn about the pumps. The framework suggests that this gap would be filled by the provision of continued external support (e.g. technical training, extension, pump repair and maintenance services, farm inputs, and access to spare parts). Once the farmers have fully understood the pumps, the framework anticipates that they may gradually change from being extrinsically to intrinsically motivated, thereafter following the self-motivated pathways. Two scenarios are therefore envisaged: either farmers will approve the pumps if their expectations are satisfied; or farmers will reverse their decision if exposed to the conflicting messages.

Success stage

In this stage, the framework prescribes that pumps that satisfy the farmers' expectations or realized their effectiveness will be approved and progress towards successful outcomes. Regardless of the adoption pathway, pump continued-use will be defined as the primary indicator for this stage. The framework suggests that success outcomes will be continued use and/or increased investment and/or growth. These successful outcomes are further categorized as shown in Figure 7.5. Furthermore, the framework suggests that failure can occur at any point before the success stage.

7.3.3 Evaluating the success in adoption of SSPI in Malawi

Extraction of the field surveys data and analysis

The study extracted relevant data for testing the new framework from the second field survey (Chapter 6). The following data were used for analysis:-

Motivation stage: Data included the means by which pumps were adopted, the socio-economic characteristics of farmers (e.g. age, education, household sizes, size of irrigated areas before adoption, assets owned before the pumps, previous irrigation methods used, sources of obtaining information about the pumps and social relations) and their previous experiences before the pumps (Table 6.9, Table 6.12, Table 6.13, Table 6.15, Table 6.17 and Table 6.18).

Approval stage: Data included the farmers' access to external support services (extension, inputs, repair and maintenance services, pump spare parts) and pump attributes such as portability, water sources, irrigated fields, water flow, operational costs, ability to increase the irrigated areas (Table 6.5, Table 6.10, Table 6.15, Table 6.21 and Figure 6.4).

Success stage: Data included the proportion of farmers in each pump category that continued using pumps, other related benefits including capitals assets and changing to better pumps (Table 6.6, Table 6.16 and Figure 6.4).

Rating success levels

The study tested the framework on the four identified distinct pumped systems group (treadle and motorized) and individual (treadle and motorized). For the purpose of this analysis, individual treadle pumps were further split into those independently (privately) adopted and those adopted by the incentives. Within all the stages, success outcomes were tested on a scale of weak, intermediate and strong. A stage in the framework was classified as: ‘weak’ if less than half of the pumps/farmers’ conditions contributed to the adoption process; ‘intermediate’ if between over half but less than two-third (>50% - <75%) of the pumps/farmers’ conditions of contributed to the adoption process; ‘strong’ if over two third (>75%) of pump/farmers’ conditions contributed to the adoption process. Motivation and approval stages were evaluated separately by assessing the magnitude of conditions for each pumped systems. The final success outcomes for each pumped system were determined based on the scale of not successful, marginal, substantial and major as illustrated in Figure 7.5.

7.3.4 Results and discussion

Motivation stage: Conditions motivating the decision to adopt

Table 7.3 summarises the prior-conditions supporting the farmers' decisions to adopt the pumps. The results showed that the self-motivated (private) farmers had much more positive conditions prior to adoption of the pumps compared to the incentive farmers (Table 7.3).

Table 7.3: Conditions supporting the farmers' motivation (decisions) to adopt pumps

No	Prior-conditions	Pump type and means of adopting				
		Treadle group (incentives)	Treadle individual (incentives)	Treadle individual (private)	Motorized group (incentives)	Motorized individual (Private)
1	Adopters mostly middle aged	√	√	√	√	√
2	Adopters well educated (secondary school or above)			√		√
3	Adopters had large household sizes	√	√	√	√	√
4	Adopters owned large irrigated areas before the pump			√		√
5	Adopters owned more capital assets before the pumps			√		√
6	Adopters were influential leaders in the cooperative societies			√		√
7	Adopters previously used other pumps before the present pumps					√
8	Adopters learnt about the pumps through the promoters	√	√		√	
9	Adopters learnt about the pumps through colleagues with pumps			√		√
Totals		**3**	**3**	**7**	**3**	**8**
Score		**Weak**	**Weak**	**Strong**	**Weak**	**Strong**

√ denotes that most farmers in the particular pumped system met the condition

This confirms the earlier findings that argued that the self-motivated farmers are consistent with the Rogers (2003) model corroborating that their socio-economic attributes played an important role in influencing the decisions to adopt the pumps. Conversely, the incentive farmers lacked a lot of attributes (such as leadership skills, irrigated areas, capital assets, innovativeness and education) to support their decisions to adopt the pumps. This supports the previous argument (Section 7.2.2) that these farmers are often not fully prepared to adopt the pumps but rather the external incentives influenced their decisions.

Approval stage: conditions supporting pumps acceptance

The results revealed that the incentive and self-motivated farmers who passed the approval stage met certain conditions and experiences (Table 7.4).

Conditions supporting the self-motivated pathway

The self-motivated farmers either adopted individual treadle or individual motorized pumps (Table 7.4). As Table 7.4 illustrates, individual treadle pumps farmers had much better attributes than individual motorized pumps farmers. For example, treadle pumps used the existing farmers' water sources whereas the motorized pumps often required modified water sources in order to accommodate their higher water flows. Similarly, treadle pumps required less operational cost compared to the motorized pumps. In addition, despite being privately acquired, treadle pumps received external support while the motorized pumps did not. The attributes of the treadle pumps support other studies (e.g Cornish, 1998b) that highlighted factors that determine the uptake of the irrigation technologies such as few skills requirements and ability to match with the small and irregular smallholder irrigated areas. Nevertheless, other factors made the individual motorized pumps more attractive to the farmers; these included the larger water flow, lower labour demand and larger irrigated areas. This suggests that the conditions supporting the implementation of the individual treadle pumps were stronger than those for the motorized individual pumps. However, both these pumps continued being used supporting the earlier finding that their socio-economic attributes reinforced their adoption process. This also supports other studies (e.g. Oni et al., 2011), that argued that farmers' attributes are essential in the adoption of the new irrigation technologies.

Conditions supporting the incentive adoption pathway

The incentive farmers adopted group treadle pumps, individual treadle pumps and group motorized pumps. Considering the farmers' conditions prior to adopting the pumps (Table 7.4), continued external support would be essential in order to clearly understand the pumps and accept them. However, not all these farmers received external support (Table 6.23 and Table 7.4). This suggests that those without the support might have struggled to fully understand the pumps. More importantly for treadle pumps, apart from receiving much external support, most of their attributes matched with those adopted by the self-motivated farmers suggesting that their conditions supporting pump continued-use were much stronger than other pumps. For group treadle pumps, although they too had more positive conditions supporting their implementation, sharing of the pumps was one of the major challenges encountered by the farmers. Group motorized pumps had much less conditions to support their implementation including partly receiving external support and higher water flows. However these pumps required to be used on communal irrigated areas and were not portable by hand (Table 7.1) whereas farmers previously used individual irrigated plots with watering cans which they easily carried by hand to and from fields after use. This supports the earlier argument that these pumps interrupted the farmers' normal irrigation practices. According to Rogers (2003), innovations that are complex i.e. do not fit in the existing norms of adopters do not diffuse easily.

The above conditions for incentive farmers emphasises the importance of providing continued support to farmers that adopt pumps by the incentives. This would facilitate the farmers' understanding of pumps and finally contributed to steady graduation of farmers from incentive to self-motivated adoption pathway. Conversely, for group farmers who lacked continued support this would likely increase their uncertainty towards the pumps which may lead to pump discontinued-use. This would be further aggravated by the attributes of the pumps which disrupted the farmers existing normal working as individuals.

Table 7.4: Conditions supporting approval (implementation & confirmation) of pumps

		Pump type and means of adopting				
No	Conditions	Treadle group (incentives)	Treadle individual (incentives)	Treadle individual (private)	Motorized group (incentives)	Motorized individual (private)
1	Adopters received extension services from pump promoters	√	√	√	√	
2	Adopters received farm inputs from the promoters	√	√			
3	Adopters were assisted with pump spare parts, repair & maintenance services	√	√		√	
4	Adopters received technical training related to the pumps	√	√	√		
5	Adopters used the pumps on their existing irrigated fields	√	√	√		√
6	Adopters used the pumps on their existing water sources	√	√	√		
7	Pump portable by hand	√	√	√		√
8	Pumps had higher water flows				√	√
9	Pumps used individually		√	√		√
10	Pumps easily transported to the irrigated fields	√	√	√		√
11	Pump demanded less labour to operate					√
12	Pump required low operation costs	√	√	√		
13	Pumps increased irrigated areas					√
Total		**9**	**10**	**8**	**3**	**7**
Score		**Intermediate**	**Strong**	**Intermediate**	**Weak**	**Intermediate**

√ denotes that most farmers in the particular pumped system met the conditions

Success stage: How farmers displayed success in pumps adoption

Success outcomes of the five SSPI systems are summarized in Table 7.5.

Incentive group treadle pumps

The study rated group treadle pumps as being not successful. Although these pumps received continued support, results showed most were eventually abandoned and this was linked to withdrawal of external support. This suggests that farmers heavily depended on the external support and therefore lacked growth. Since these pumps interrupted farmers existing irrigation practices of using individual technologies (watering cans), it is likely that farmers lacked commitment and therefore could not entirely accept the pumps. However, since there was provision of external support, farmers continued using them until after the support stopped. Based on the new framework, this can be interpreted as these farmers did not change from being extrinsically to intrinsically motivated. This could explain why most farmers later changed to join group motorized pumps which were also promoted by incentives. Possibly, these pumps did not create more positive interest to motivate the farmers.

Despite being unsuccessful, a critical analysis (Figure 6.4) showed slight trails of success within this category. For example, almost a quarter of farmers who changed to join group motorized pumps, eventually graduated to adopt private individual motorized pumps. This created a new insight which partly diverts from the proposed new framework. For example, the framework indicates that continued-use is the primary indicator for success. However, the advancing of some farmers after the pumps were abandoned suggests that perhaps the definition and categorisation of success can further be modified. However, this required adequate evidence. Nevertheless, these slight traces of success can further be associated with the continued provision of external support. This realization can be used to emphasize the importance of continued support to the incentive pumps.

Incentive individual treadle pumps

The success category for this pump was rated as ‘major’. Results showed that most pumps continued to be used although farmers had poor conditions prior to the adoption. Further, over half of the farmers eventually changed to adopt the individual motorized pumps. This supports the framework and demonstrates the importance of providing continued-support to the incentive farmers so that they become satisfied with the pumps adopted.

Self-motivated individual treadle pumps

Self-motivated treadle pumps were also rated as ‘major’. It was found that most pumps continued being used and eventually the majority advanced to adopting the individual motorized pumps. Considering the cost of the motorized pumps in relation to treadle this indicates a high increase in investment and hence growth.

Incentive group motorized pumps

Group motorized pumps were rated as ‘not successful’. Most of pumps were abandoned and farmers returned to their traditional methods. It is suggested that farmers’ conditions prior to adopting and the attributes of the pumps contributed to this outcome. Furthermore, this was aggravated by the poor provision of external support and the poor management of the pumps. While confirming the framework perspective, these findings also demonstrated the need to consider technical characteristics and ownership of technology in order to support their dissemination (Cornish, 1998; Fanadzo, 2012; Rogers, 2003).

Self-motivated individual motorized pumps

The self-motivated motorized pumps were rated as ‘substantial’. The results showed that almost all pumps continued being used and farmers increased investments. This was demonstrated by the enormous increase in their irrigated areas. It is suggested that this was supported by the strong attributes of the farmers prior to adopting the pumps supporting the conditions advocated by the Rogers (2003) model.

Table 7.5: Summary of typical pre-conditions, approval conditions and success outcomes for treadle and motorized pumps

No	Pump type & adoption means	Motivation stage	Approval Stage	Success stage			Success outcome
		Pre-conditions	Pump/Farmers' attributes	Operational status	Subsequent actions		
1	Group treadle (Incentive)	**Weak** (Typically only educated to basic level, owned small irrigated areas, lacked capital assets, lacked leadership skills and lacked experience on pumps)	**Intermediate** (Typically, most farmers received external support, used the pumps on existing water sources and irrigated fields. For pump attributes; were portable by hand and required less operation costs. However, pumps demanded more labour, required sharing by group members and slightly increased irrigated areas).	Mostly Abandoned	-Mostly joined group motorized pumps and later most were abandoned	-some later adopted individual motorized pumps	**Not successful**
2	Individual treadle (Incentive)	**Weak** (Typically only educated to basic level, owned small irrigated areas, lacked capital assets, lacked leadership skills and lacked experience on pumps)	**Strong** (Typically most farmers received external support, used the pumps on existing water sources and irrigated fields. For pump attributes; were portable by hand, used on individual irrigated fields, required less operation costs and increased irrigated areas. However pump demanded more labour.	Mostly continued-use	Mostly increased irrigated areas and standard of living.	Over half changed to private motorized pumps.	**Major success**
3	Individual treadle (self-motivated)	**Strong** (Typically well educated, having large irrigated area, capital assets, leadership skills and innovative. However, lacked experience on pumps)	**Intermediate** (Typically some farmers received external support, used the pumps on existing water sources and irrigated fields, For pump attributes; were portable by hand, required less operation costs, used on individual plots, and increased irrigated areas. However, pump demanded more labour	Mostly continued-use	Mostly Increased irrigated areas and standard of living.	Mostly changed to private motorized pump	**Major success**
4	Group motorized (Incentive)	**Weak** (Typically only educated to basic level, owned small irrigated areas, lacked capital assets, lacked leadership skills and lacked experience on pumps)	**Weak** (Typically a number of farmers received some slight support; pumps could not be used on existing water sources and irrigated fields. For pump attributes; were not portable by hand, demanded more labour, required water sources with large volumes, required higher operational cost and slightly increased irrigated areas. However, pumps had higher water flows)	Mostly abandoned	Mostly reverted to traditional watering cans.	-	**Not successful**
5	Individual motorized (self-motivated)	**Strong** (Typically well educated, having large irrigated area, capital assets, leadership skills, innovative and experienced on pumps)	**Intermediate** (Typically most farmers did not receive any external support, pump required higher operational costs and often required slight modifications on water sources. However, pumps irrigated fields, were portable by hand, demanded less labour, were used on individual plots and largely increased irrigated areas)	Almost all pumps Continued-use	Large increased in irrigated area.	-Some purchased second or third pumps	**Substantial Success**

(dark blue)	**Strong**	(teal)	**Intermediate**	(light blue)	**Weak**

7.4 Summary

The mapping of the field surveys' findings onto the diffusion of innovations model (Rogers, 2003) demonstrated that the adoption routes followed by the incentive farmers are not fully consistent with the model. The research proposed a modification of the model to include incentives as an alternative pathway leading to adoption process and revised definition and classification of success in SSPI adoption. This led to the development of a new conceptual framework for understanding and classifying success. The framework conceptualizes two pathways (self-motivated and incentive) that motivate farmers to adopt SSPI. Self-motivated farmers are perceived to be motivated by the attributes of the pumps supported by their socio-economic attributes such that their adoption process is consistent with the Rogers (2003) model. Farmers motivated by incentives are perceived to require continued support in order to fully understand the nature of the pumps and realize their effectiveness. Regardless of adoption pathway, the framework perceives that success outcomes will be continued use and/or increased investment and/or growth as partly defined by Burney and Naylor (2012). Evaluation results supported the framework suggesting that it is a reliable tool for identifying success although it needs further testing in other regions. These findings have yielded a number of interesting results which have implications on policies supporting the SSPI as described in Chapter 7.

8 SYNTHESIS

8.1 Overview

The main purpose of this research is to assess the adoption process and sustainability of SSPI development in Malawi and SSA. Having reviewed the current literature on factors affecting performance of SSPI in SSA and analysed the empirical evidence on pumps adoption processes in Malawi, the question is ‘so what does this mean?’ This chapter summarizes the findings of the entire research project and suggests how adoption of SSPI could effectively be accelerated in SSA. This chapter also outlines the contributions which the research has added to policies and current research. It also suggests areas for further research and outlines the methodological limitations.

8.2 Evidence on performance of SSPI in SSA

The key factors affecting performance of the SSPI in SSA were determined using a systematic review and these insights were then used to inform the design strategies of the research subsequent objectives. In summary, the review led to the understanding that evidence relating to SSPI performance is limited, lacks standards and is geographically confined within particular region in SSA. These findings have important implications for policies promoting the uptake of SSPI. It is argued that the limited evidence base means that current policies (e.g. NEPAD 2003) in SSA are likely to be based on evidence that is not sufficiently robust. It is suggested that further targeted research should be undertaken to inform policy formulation.

However, some of the above identified research needs were recently addressed by the International Water Management Institute (IWMI) through the various studies (Colenbrander and van Koppen, 2012; Dessalegn and Merrey, 2015; Dessalegn, 2013; De Fraiture et al., 2014; Giordano and de Fraiture, 2014; Namara et al., 2013, 2014) with funding from the Bill and Mellinda Gates Foundation. The central insight for most of these recent studies is the realization that pumps (especially small private motorized ones) are increasingly becoming an important irrigation technology in SSA. This development has however received mixed reactions by scholars. Those that have embraced the development argue by relating this to the green revolution in Asia and they suggest different measures that need to be undertaken to ensure effective implementation of SSPI (Colenbrander and van Koppen, 2012; Giordano and de Fraiture, 2014; Namara et al., 2014). For example, Colenbrander et al. (2012) systematically analysed the supply chains of the motorized pumps in Zambia and found that there are several imperfections in the supply chain which required to be addressed e.g. by improving the flow of information between the farmers and suppliers to sustainably promote the pumps.

On the other hand, scholars that reject the development highlight the effects that these pumps are bringing to society. For example, in Ethiopia, there are fears that the SSPI disregard the social aspects thereby undermining the long term benefits of the rural livelihoods (Dessalegn, 2013). The study highlighted that the private motorized pumps interrupt the social cooperation such as water use regulations and water allocation rules that have existed under traditional irrigation practices. The implication for this is that there is increased competition for water among the farmers and experiences of water shortages (Dessalegn, 2013; De Fraiture et al., 2014). Another major concern relates to equity, efficiency and sustainability. It is argued that not all the smallholder farmers such as the women can afford to access the pumps. There are also concerns that the unregulated spread of the pumps may result in over-abstraction, pollution and conflicts (Dessalegn and Merrey, 2015; De Fraiture et al., 2014; Giordano and de Fraiture, 2014; Giordano et al., 2012).

Despite these recent studies, the main gaps remain that evidence relating to the SSPI is geographically confined to the East and West SSA. Furthermore, these studies do not sufficiently address the issues of sustainability in pump adoption processes which may also be fundamental to the achievement of sustainable irrigation development. Given this understanding, empirical evidence from other regions of the SSA remains an important research need supporting the rationale for this research. It is against this understanding that the subsequent research objectives are embarked upon.

8.3 Adoption of SSPI in Malawi

This research employed field surveys in selected Malawian districts to understand the SSPI adopted in Malawi; these were analysed through descriptive statistics.

Pump characteristics

The characteristics of the pumps adopted by farmers in Malawi suggest that technical characteristics of pumps have an important influence in adoption of SSPI. Characteristics that appeared to influence adoption of the different pumps included the sources of energy, portability and ease of operation. Pumps types that are heavier, harder to operate and weigh more are generally less preferred by the farmers. This is demonstrated by the number and types of the pumps being abandoned. Over 70% of treadle pumps that are being abandoned by farmers are the Advaith type and these are perceived as harder to operate and heavier than the Money Makers type. Likewise, over 80% of farmers preferred having individual motorized pumps; usually these pumps have smaller engine capacities and are portable by hand suggesting that possibly these are also preferred because they are portable and use less fuel. Similar understandings on the importance of technical factors such as energy in adoption of irrigation technology were also highlighted by van Averbeke et al. (2011) in South Africa and Djagba et al. (2014) in Benin where the pumped irrigation systems were compared with gravity irrigation systems.

With regard to pump manufacturers, although all motorized pumps in Malawi are imported, only two manufacturers were identified for group motorized pumps while the individual motorized pumps had a number of manufacturers. The markets in Malawi are currently flooded with cheap Chinese-manufactured petrol water pumps, and these are entitled to VAT exemption on irrigation equipment by the government (World Bank, 2011). These conditions may have also contributed to the increased recent uptake of the individual (private) pumps. This corresponds to the general trends observed in other parts of the SSA (Awulachew and Merrey, 2001; Colenbrander and van Koppen, 2012; De Fraiture et al., 2014; Giordano and de Fraiture, 2014; Namara et al., 2013). The research suggests that pump promoters may benefit from recognizing that pump adoption can also be supported by policies that create an enabling environment such as ensuring the greater availability of the pumps to farmers. Conversely, although many organizations are promoting treadle pumps in Malawi, very few commercially distribute these pumps, suggesting that their adoption is highly dependent on the organizations supplying them.

Socio-economic characteristics of the farmers

The research determined that the individual owned pumps are preferred more than the group pumps while most promoting organizations are supporting the group pumps. In Kenya, Scheltema, (2002) also underlined that pumped systems managed by groups of farmers were not sustainable because the financial demands and organization requirements were much higher. That study also found that most pumped schemes failed even before their life span were attained suggesting that management of the pumps was critical. In contrast, the individual owned pumps were found to be successful. These findings from Kenya are consistent with this research suggesting that SSPI adoption would be more effective if pumps are promoted as individual owned. Promoting organizations may only use the groups as points of accessing farmers.

The research suggests that pumps promoted by incentives are adopted by farmers who are typically poorer and they are unlikely to be ready to support the adoption decision. The implication is that pumps adopted by incentive are more likely to be abandoned. These findings are consistent with a number of studies. Chancellor, (2000) questioned the sustainability of promoting treadle pumps to the poor farmers considering that the costs for other pump accessories, e.g. hose pipes, which these farmers may not manage. Fanadzo (2012) argued that the major factors leading to underperformance of the SSI schemes in SSA are the poor technical skills of the farmers. Oni et al. (2011) highlighted that the socio-economic characteristics of farmers are essential for farmers to adopt new irrigation technologies. In Ghana, it was found that the prevailing policies promoting pump irrigation were only in favour of the better-off farmers (Namara et al., 2014). However, this research showed that adoption of these pumps may be sustained if farmers continue receiving external support (Section 7.2.6). This suggests that policies that consider the capacity of the potential pump adopters to operate, repair, maintain and obtain the spare parts of the pumps may be necessary in sustaining adoption. It may be that there are strong 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; Carter et al., 1999; Djagba et al., 2014; Muchara et al., 2014).

Irrigations characteristics of farmers

Related to the pumps promoted by incentives, the study found that there is a mismatch between the pumps adopted and the physical characteristics of farmers' irrigated fields. Most farmers previously practice irrigation on individual irrigated fields with private access to irrigation water sources. The typical irrigated field sizes for most treadle and group motorized pump farmers (incentive farmers) are less than 0.2ha and their water sources are typically small for example, on average, the dimension of most shallow wells are 1.0m diameter and 2.0m deep (Section 6.3.2). Conversely, pumps such as group motorized require bigger irrigated areas and water sources with large water volumes. This findings question the sustainability of these group motorized pumps which are highly promoted to farmers in Malawi. This also questions the basis for NIPDS policy which encourages farmer participation in SSI irrigation development. These findings are consistent with a study in Ethiopia, Awulachew and Merrey, (2001) which highlighted the importance of paying attention to the local knowledge in SSI development and planning. Similarly, Veldwisch et al. (2009) argued that only if new irrigation schemes are embedded in the existing landscapes, tangible improvements in rural livelihoods can be ensured.

The important lesson learnt from this objective is that farmers generally prefer the pumps that are technically easy to operate, managed individually and fit in with their normal irrigation practices. This means that pumps that do not meet these requirements are less likely to be adopted. Policies promoting pumps' uptake need to ensure that the types of pumps promoted are consistent with the requirements of farmers in order to be effectively adopted.

8.4 Factors affecting SSPI adoption

The study found that farmers adopt pumps in order to mainly resolve the technical challenges such as increased irrigated area, reduced labour and simplicity in operation. However, the current policies show that the main focus of many promoting organizations is to encourage rapid adoption through relieving SSPI affordability and/or accessibility. The implication is that the types of pumps promoted do not entirely resolve the farmers' technical needs and hence they are mostly abandoned. For example, farmers require SSPI that reduce labour while most organizations increasingly promote treadle pumps which entirely depend on human energy.

Studies (e.g. Woodhouse, 2012) argue that the current policies to promote the uptake of SSI technologies in developing countries are likely to be based on insufficient evidence. The promotion of SSPI systems in Malawi which does not entirely correspond to the needs of the farmers may support this argument.

The research also found that the major problems inhibiting pump irrigation include the repair and maintenance issues (relates to costs and lack of technical skills), lack of capital for inputs, high operation (fuel) costs for motorized pumps and increased labour demand for treadle pumps. These findings corroborates with most evidence (Van Averbeke, 2011; Chidanti-Malunga, 2009; Djagba et al., 2014; Namara et al., 2013) that linked poor performance of pump irrigation to high cost of operataion and maintenance, lack of credit and high labour demanding.

Nevertheless, despite the challenges, evidence from Malawi showed that other pumps were successful with the provision of continued support from the promoting organizations especially the NGOs. In contrast, the government which is supposed to benefit a large proportion of farmers only support farmers by relieving pump affordability with little or no continued support. This situation is worse with the use of general agricultural extension workers who lack pump technical skills. The implication is that farmers would get insufficient technical support which may result in many pumps promoted by government being abandoned. Government needs to learn from these development approaches utilized by other organizations in order to sustainably promote the uptake of SSPI pumps.

8.5 The application of Rogers model to SSI adoption

8.5.1 Related to adoption pathways

This research found that adoption of SSPI initiated by the incentives is not fully consistent with the Rogers (2003) model (Section 7.2.6). The implication is that researchers who apply the Rogers model in order to understand the adoption initiated by incentives are likely to be misled and offer solutions that may not be sustainable. This suggests that researchers exploring adoption due to incentives should apply the Rogers model with caution. Policies and future research should take into account that while incentives may be an alternative pathway leading to adoption, the potential adopters are likely to require other mechanisms of support to sustain their adoption process. It is 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).

8.5.2 Related to better understanding of success

This research supports the SR finding (Chapter 5) that there is lack of an all-encompassing approach for understanding success in SSPI systems. This corresponds with other studies in SSA (Hussain and Hanjra, 2004; Mutiro and Lautze, 2015) that argued that the present methods are patchy and mostly oriented to particular irrigation schemes or regions. The research proposed a revised definition and classification of success that led to new conceptual framework which highlights the routes taken by farmers who successfully adopt or discontinue using the pumps. A better understanding of success may be fundamental to the development of sustainable approaches in adoption of new SSPI. For example, the number of pumps being abandoned may be reduced if appropriate measures for ensuring SSPI continued-use and success are in place. This may also contribute to reducing the climate change effects through reduction of energy for manufacturing new pumps. Therefore the framework can help to inform sustainable SSI policies on successful adoption processes.

8.6 Research implications

8.6.1 Related to policy

In the context of policy formulation, this research was initiated based on the understanding that the Malawi government is increasingly promoting SSPI (especially treadle and motorized) among the smallholder farmers in order to improve food security and reduce poverty. Based on the empirical evidence gathered in this research, new insights on possible solutions that government may pursue to ensure sustainable uptake of SSPI are proposed:

(i) *Promote individual owned pumps*

The research suggests that adoption of pumps would be more effective if the pumps are promoted to individuals rather than the groups since individual pumps do not completely interrupt the normal farmers irrigation practices. The rationale for this is based on the proportion of the group pumps that are not operational (Section 6.2.5).

(ii) *Encourage adoption of individual treadle pumps to new farmers*

For farmers that are new to pump irrigation (i.e. just changing from using the traditional irrigation methods), it would be more effective if these are encouraged to initially adopt the individual treadle pumps. This proposal is based on the evidence that showed that most individual treadle pump farmers are successful regardless of farmers' less experiences in pump irrigation. This is also backed up by the preferences of the farmers (Section 6.4.15). In addition, treadle pumps require limited technical skills compared to motorized pumps and hence they would be suitable for new adopters. However, to reinforce continued-use and growth of farmers, it would be essential for the promoting organizations to continue supporting the farmers.

(iii) *Use treadle pump farmers as entry points for promoting the motorized pumps*

The research suggests that farmers that initially adopted treadle pumps could be used as an important entry point for organizations that are seeking to successfully promote the motorized pumps. This proposition is based on the evidence that showed that; most individual motorized pump farmers had graduated from using the treadle pumps (Figure 6.4); and the preferences for most treadle pump farmers is to later adopt the individual motorized pumps (Section 6.4.15). Furthermore, findings have demonstrated that farmers who previously used treadle pumps have the potential for sustainably managing the motorized pumps since these would have gained the experiences in pump irrigation. In addition, farmers tend to improve their socio-economic status after adopting the treadle pumps (Kadyampakeni et al., 2015) suggesting that these may help to support farmers in sustaining the costs associated with motorized pumps. It is suggested that organizations promoting the motorized pumps can work hand in hand with organizations that are promoting the individual treadle pumps in order to later step up to the motorized pumps.

(iv) *Encourage motorized pump adoption to new but more affluent farmers by creating enabling environment*

The research suggests that motorized pumps can effectively be adopted by farmers without pump experiences however they need to be financially and socio-economically better off. Evidence has shown that such farmers may be supported by their socio-economic attributes to sustainably manage the pumps (Chapter 6.).

However, these farmers lack technical skills, and in order sustainably promote their adoption, there is a need to build-up the technical competences on pumps across all the levels. This may include the provisions of technically-competent extension workers, well-trained local artisans, clear information on pump operation 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 (Chapter 2). This implies integrating promotion of the SSPI with services and solutions that complement the adoption processes. For example, policies promoting pumps can also ensure availability of cheap pump spare parts.

(v) Consider the capacity of farmers to operate and manage the pumps

It is suggested that pumps that are consistent with the capacity of potential adopters have the likely potential of being continued-use and increasing farmers' investment hence successful. Alternatively, better strategies that can fill the gaps between the pump technical requirements and farmers competences can ensure sustainability of pump adoption. For example, evidence showed that NGOs that combined promoting pump adoption with development of water supply sources for farmers encouraged SSPI continued-use.

These recommendations can also be applied in SSA countries that have related interventions.

8.6.2 Related to contributions to research knowledge

The following contributions to research knowledge are identified.

First, the systematic review findings offers a **valuable contribution to the international science literature by identifying: the key factors that affect performance of SSPI in SSA; and the extent to which technical and socio-economic factors are used as metrics of performance (Chapter 5).** Assessing suitability of the technologies can be subjective especially if those involved in framing the studies also have vested interests. Use of the SR approach offered an alternative method for accessing, appraising and synthesising literature on issues that have mixed evidence and potential for biases such as technology suitability or performance. This approach is unique, robust and offers reliability of the findings.

Second, the research suggested a modification to **the diffusion of innovation model (Rogers, 2003) by including incentives as an alternative pathway leading to SSPI adoption (Chapter 6 and 7)**. This perspective is necessary because farmers persuaded by incentives (free or subsidies) are often poor and are likely to by-pass other stages advocated by the Rogers (2003) model. In this regard, these farmers require particular conditions to support their adoption decision and successfully adopt the pumps. Apparently, these conditions are not sufficiently defined in the Rogers model suggesting that application of the Rogers model to adoption due to incentives is likely to be misled and offer unsustainable solutions.

Finally, the research presents **a novel conceptual framework for better understanding and classifying 'success' in adoption of SSPI (Chapter 7).** The framework is derived by linking the identified adoption pathways (Section 7.2.6 and Figure 7.2) to the models of diffusion of innovations (Rogers, 2003), sustainability chain (Carter et al., 1999) and pathways of impact (Burney and Naylor, 2012). The framework recognizes the gap in the definition of 'success' in SSPI adoption and it offers an improved definition which incorporates the conditions supporting both the incentive and self-motivated farmers' motivation, implementation and successful SSPI adoption. Self-motivated farmers are believed to have been supported by their socio-economic attributes and hence consistent with the Rogers model (2003). Incentive farmers are typically the poorer, the framework emphasizes that these need continued support to reinforce their learning curve and successfully adopt the pumps, increase investments and grow. This novel approach provides future researchers and policy makers with new insights for developing sustainable approaches in promoting the SSPI uptake in SSA.

8.6.3 Related to further research

The analysis showed some elements of success in adoption of group treadle pump farmers (Section 7.3.4). About a quarter of farmers who abandoned the pumps and later changed to join group motorized pumps, eventually graduated to independently adopt (self-motivated) the individual motorized pumps. This is an important insight which requires to be explored further in order to broaden the scope of understanding of 'success' in SSPI adoption. Future investigations may consider mapping the progression of farmers that discontinued using these pumps.

The research also identified that the length of period that group pumps are used before being abandoned differed between the treadle and motorized pumps. This research argued that this could be because of a number of factors as outlined in Section 7.2.4. However, more empirical evidence is required to support this understanding. It may be possible that these differences may have also have contributed to changing the farmers from being incentive to self-motivated adopters thereby indirectly supporting sustainability in SSPI adoption.

It is also useful to carry out a research that analyses the effects of renting and/or borrowing the individual pumps to the pump owners as well as those renting/borrowing to explore whether these have substantial impact on SSPI adoption process and their sustainability.

Finally, the empirical evidence provided in this work is based on a specific region (Central Malawi districts). Future research may consider expanding the scope to other regions in Malawi and/or to other countries in SSA. Furthermore, future research should address the limitations on selection of samples by using random sampling in order to statistically test the different conditions within the framework stages. For example, future research may explore the statistical relationship between the pump adoption pathways and their success or failure in the adoption process.

8.7 Methodological limitations

Research limitations related to the SR are described in Chapter 5, Section 5.5. The field survey methodology had the following limitations:-

- There is a potential for bias since selection of respondents was wholly purposive and highly dependent on information provided by extension workers and key informants. This problem was however alleviated by using snowball sampling to access other respondents. Furthermore, the responses provided by farmers may have been influenced by their assumptions. Since government officials accompanied the researcher during field study, farmers might have assumed that the aim of the research visit was either to distribute more pumps or withdraw the pumps that were discontinued. However, the researcher ensured that the research purpose was clearly explained to the respondents before undertaking the interviews.

- There is possibility for some biasness in the interview responses because some questions were sensitive and offered some forms of expectations to farmers. For example, farmers were asked 'if they were given a chance which pump would they choose?' For this question farmers were warned in advance by the researcher that the question was only seeking to understand their future prospects on the pumps and they should not have any expectations.

- There is a potential for respondents providing mixed information regarding their pumps since some respondents owned different types of the pumps. However, the research ensured that farmers provided information pertaining to each pump owned separately by asking specific questions related to each pump.

- There is a possibility that inadequate information was obtained from other stakeholders. Most of them opted to respond to questionnaires at their own convenient time rather than through direct interviews with the researcher. The study however reviewed some organizations' relevant documents to beef up the information. Further, follow ups were made on interview responses that were not clear.

- Finally, interpretation of the qualitative data is subjective such that its acceptance by the third parties requires a degree of trust in diligence and integrity of the researcher. In this research a number of strategies including reflection, use of independent reviewers in coding and triangulation of data (Section 4.5.2) were used to ensure credibility of the findings.

9 CONCLUSIONS

The research addressed five specific objectives; these and their major findings are summarised below.

Objective one: *To identify the key factors affecting performance (sustainability) of the small-scale pumped irrigation (SSPI) in SSA.*

Evidence relating to pump performance in SSA was found to be limited, lacked standards and was geographically focused within particular regions (treadle pumps-southern SSA, motorized pumps-West and East SSA). Based on systematic review evidence, the research identified that socio-economic and technical factors are critical in affecting the performance of SSPI in SSA. Further targeted research that incorporates a set of key factors such as profitability, yield and pumps' technical efficiency should be undertaken to inform policy formulation of sustainable SSI development.

Objective two: *To understand the small-scale pumped irrigation systems currently being adopted in Malawi.*

Farmers in Malawi have adopted four different types of SSPI, namely group treadle, individual treadle, group motorized and individual motorized. Adoption is driven either by the attributes of self-motivated farmers (and the pumps) or by incentives such as free or subsidized pumps. However, farmers generally prefer individually managed pumps that are easy to operate and fit in with their existing irrigation farming practices. Adoption of SSPI can be more effective if the type of pumps promoted and their dissemination approaches complement the farmers' preferences.

Objective three: *To critically evaluate farmers' and stakeholders' opinions on factors affecting the adoption and subsequent success or failure of small-scale pumped irrigation in Malawi.*

The research identified technical factors such as less labour demand and increased irrigated area as major enablers for motivating farmers to adopt SSPI; 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 the pumps consider the farmers' technical requirements and hence such pumps are less likely to be continued-use. It is suggested that successful adoption can further be supported with policies that integrate SSPI promotion with services and solutions that provide technical support. For example, most NGOs combine the promotion of treadle pumps by incentives with the provision of technical services (training and spare parts) and/or farm inputs packages which encourage pumps' continued-use. The Malawi government needs to benefit from utilizing such policies by integrating promotion of SSPI affordability with services that address farmers' pump technical and socio-economical requirements to ensure successful adoption. These may include easy access to pump spare parts, credit for farm inputs and access to information on pump selection and operation.

Objective four: *To critically evaluate the suitability and application of Rogers* (2003) *diffusion of innovations model to small-scale pumped irrigation in Malawi.*

The research found that adoption of pumps by self-motivated farmers is consistent with Rogers (2003) model while adoption due to incentives shows differences. Self-motivated farmers have better attributes (e.g. good education, large irrigated areas, capital assets, having leadership skills and experiences) and these support their decisions to adopt and continue-using the SSPI. In contrast, incentive farmers lacked most of these attributes which increased their uncertainty towards the pumps. However, the provision of continued external support to incentive farmers allowed them to survive the 'learning curve' (Burney and Naylor 2012) and they continued using the pumps. This shows that the initial conditions leading to continued or discontinued-use of the pumps are significant in the adoption process. It is apparent that the Rogers (2003) model does not sufficiently define the conditions for adoption due to incentives and how successful adoption can be attained.

The research proposes a modification in Rogers (2003) model to include incentives such as subsidized or free pumps as an alternative pathway leading to adoption. It also offers a revised definition and classification which suggests that 'success' in SSPI adoption can only be realized when adopters have accepted the pumps, continue using them and are able to increase investments and/or develop (grow) such as advancing to better pumped systems. This led to the development of a new conceptual framework which identifies the routes taken by farmers who successfully adopt or discontinue using pumps. The framework could assist in effective dissemination of new SSPI by ensuring that relevant strategies and measures for achieving sustainability in adoption processes are clearly addressed.

Objective five: *To inform policies supporting small-scale pumped irrigation development in Malawi and Sub Saharan Africa.*

It is apparent that policy can strongly shape and influence those who adopt SSPI; however the key successes of adoption process arise where it addresses both availability (e.g. affordability) and the associated needs of the pumps and potential adopters. Interventions initiated by the incentives are helpful to support adoption by the poor farmers, but sustainability of such adoption requires more continued support which needs to be included in the strategies promoting SSPI. In the case of Malawi, which has a very large number of poor (SOAS, 2008), public interventions such a the provision of relevant extension services, access to pump spare parts and irrigation inputs should be encouraged to ensure both rapid and successful adoption. Policies that improve access to credit, extension, input and output markets for tobacco farming in Malawi have been shown to increase the ability of the underprivileged farmers to adopt capital intensive crops (Zeller et al.,1998). However, the benefits for adoption due to incentives need to be set against other alternatives such as creating enabling environment for accessing the pumps.

The research showed that interventions that reduce barriers to accessing SSPI have the potential for attracting more affluent farmers (self-motivated). These farmers tend to use the pumps on large irrigated areas and are often innovative to successfully adopt the pumps. It is likely that the benefits realized by these farmers may to a larger extent contribute more effectively to the government's objective of increasing agricultural production. This suggests that adoption due to incentives should only be a short-term. This supports other studies that highlight that incentive initiatives should only play a temporary role in familiarizing farmers with benefits and methods of adopting new technology (Chirwa et al., 2010; Morris et al., 2007).

Second, this research found that lack of technical support systems hinder the success of adoption by farmers (in particular the self-motivated). Farmers have no access to pump extension services, spare parts and lack information related to proper pump selection, use and maintenance, which may result in many pumps being abandoned. Additional measures that overcome these obstacles would be essential to accelerate adoption. First, the lack of extension services and information may be resolved by use extension workers who have the necessary technical skills in SSPI. Currently, the Malawi government uses general agricultural extension workers (Chapter 3) who lack these skills. The government in Malawi has been training irrigation technicians through its agricultural colleges since 2001, but these are not recruited due to bureaucratic issues. Secondly, access to pump spare parts can be improved if import policies that allow pump availability are extended to include an easy inflow of spare parts. These can further be supported by controls and checks on the quality of pumps imported and ensuring that these are accompanied with necessary information that can be easily read or translated for farmers. Analysis showed that most individual motorized pumps had manufacturers' information in Chinese which would have created practical and operational confusion.

Third, the research found that government and many other organizations have long term plans to continue disseminating SSPI to smallholder farmers (Section 6.4.15) through incentives. Considering that sustainability in adoption of SSPI systems requires continued support, this initiative would be more sustainable if the government and other promoting organizations consider reapportioning some of the budgets allocated to distributing incentive pumps to extend to other services that will support sustainable pump adoption. For example, if some of the budgets are devoted towards supporting extension services (e.g. employing extension workers that have the SSPI technical capacity); this would likely address the farmers' technical knowledge needs such as pump management, repair and maintenance. In addition, some of the budgets could be devoted to ensuring farmers' easy access to: irrigation farm inputs (such as fertilizers and seeds); pump spare parts; fuel; and reliable water sources. This would ensure that pumps that are being promoted are continued-use and allow farmers to be successful by increasing investments and growth. This would eventually help farmers to change from being incentive to self-motivated and hence sustainable pump adoption.

Finally, there is a need for the government of Malawi to review its current pump dissemination strategies; SSPI have the potential to contribute to agricultural production if the farmers' immediate needs are integrated with longer-term strategies. Successful adoption involves a chain of stages including motivation, approval and success; the present strategy which encourages rapid adoption (e.g. by relieving affordability) only addresses immediate needs (motivation stage) of the adoption process, but does not guarantee their sustainability. Clear measures that support the conditions leading to pump implementation (approval), continued-use and expansion of farm enterprises (success) are essential for accelerating sustainable technology adoption. The research has highlighted the challenges embedded in the current trends for irrigation technology development (e.g NEPAD, 2003) and provided a new insight on how SSPI adoption should be an integral component for improving food security in SSA thus contributing to achieving the recent Sustainable Development Goals.

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APPENDICES

Appendix A First survey farmers' questionnaire

Informed Consent

Good morning/good afternoon, my name is Jean Mtethiwa. I am currently a PhD student at Cranfield University in England. I am conducting research in ------- (District) in order to learn about your involvement on small-scale pumped irrigation systems in Malawi. The main objective of the research is to assess sustainability in adoption of SSPI in Malawi in order inform policies for supporting irrigation development.

This district is among other (2) that have been chosen as a sample to represent all the districts in Malawi since it is not possible to conduct the research in the whole country. You have been chosen in particular because you are known to have been involved in pump irrigation.

I am therefore going to ask you some questions regarding your pumped systems. Your answers may be recorded and will be analysed together with those of other farmers who are going to participate in this study. The interview will take not more than one hour. Your participation in this interview is voluntary and you are free to participate or not. You are free to withdraw from this research at any stage during the session for a period of up to 7 days from today simply by informing me as after this time it will not be possible to identify your individual data from the aggregated results. I will however appreciate your participation. Your answers will be kept confidential and will not be disclosed in any way so that you could be identified.

I, ________________ confirm I have read and completely and fully understand the information provided on this form and therefore give my consent to taking part in this research.

**The questionnaires have been re-arranged for presentation.

Do you wish to participate in the interview? Yes_________ No _______

Date of the interview_____________________________________2013

Type of pumped system*:___________________________________

SECTION 1: Household demographic data

1. Respondent ID No.______________District___________Village_______
2. EPA :___________Section :_________Scheme (For groups) :_________
3. Sex of the respondent:_______ Age and education level:_____________
4. Household size details:____

SECTION 2: Motivation to adopt the pump/s

5. Please describe what motivated you to opt for the pumped system and why?
6. How did you know about pump irrigation?

(For group pumps only)

7. Why did you join the group scheme?
8. Do you have any management role in the scheme committee? Please explain?
9. Do you wish if you could be taking part in the management of the scheme operation? If no why not and if yes why?
10. Are you satisfied with the general operation of scheme? Please explain
11. Which areas do you wish could be improved in scheme management and why?
12. Are there any benefits in the group pumped schemes? If so what are they?
13. What are the five main problems encountered in the scheme and how do you resolved them?
14. Do you have other irrigation fields apart from the one in the scheme? If yes why and what irrigation method do you use?
15. If you have another irrigation field apart from the scheme which of the fields do you find it better and why is it so?

16. **SECTION 3: Pump profile**

Table A1: Pump profile

<table>
<tr><th>No</th><th>Question</th><th>Response</th><th>Follow up</th></tr>
<tr><td>1</td><td>When did you acquire it and where? (Year)
Year_______</td><td>How?
1. Given for free
2. Loan
3. Privately from dealers
4. Inherited
5. Other ________</td><td>No of irrigated plots_____________
Size of plots irrigated by pump
Irrigated Plot 1 __________
Irrigated Plot 2 __________
Irrigated Plot 3 __________</td></tr>
<tr><td>2</td><td>If you bought by yourself what was the cost of the Pump and other accessories? pipes and what was</td><td>Cost<table><tr><td>Item</td><td>Cost (MK)</td></tr><tr><td>Pump</td><td></td></tr><tr><td>Pipes</td><td></td></tr><tr><td>Other</td><td></td></tr></table></td><td>If acquired by loan or or free from whom?
1. Government
2. NGO Specify __________
3. Other specify</td></tr>
<tr><td>3</td><td>Who assisted you in acquiring the pump and pipes?</td><td>1. Extension worker
2. Colleagues/relations
3. Irrigation expert
4. None
5. Others specify</td><td>Why did you opt for this pump?
1. Increase irrigated land
2. Reduce labor
3. Profitability
4. Market opportunities
5. Other specify</td></tr>
<tr><td>4</td><td>What is the capacity of (for motorized pumps only) and make of your pump</td><td>Hp_________ or
KV_________</td><td>Source of power (If motorized)?
1. Diesel
2. Petrol
3. Other</td></tr>
<tr><td>5</td><td>For those that discontinued using pump when did you last use the pump and why?

Year_______</td><td>Reasons for discontinuous
1. Repair& maintenance
2. Fuel cost
3. Land availability
4. Water availability
5. Produce marketing
6. Other specify</td><td>How many other farmers in your village/area use similar pump for irrigation?

No_________</td></tr>
<tr><td>6</td><td>(For those that discontinued) If still involved in irrigation, which method are you using and why?</td><td>1) Motorized pump
2) Treadle pump
3) Traditional specify
4) Others _________</td><td>Reasons for changing?</td></tr>
<tr><td>7</td><td>What irrigation method did you have before the pumped system and why did you change?</td><td>1) Motorized pump
2) Treadle pump
3) Solar/wind
4) Traditional specify
5) Others specify________</td><td>Reason for changing</td></tr>
<tr><td>8</td><td>Do you find the pumped irrigation profitable?</td><td>Yes/No</td><td>If yes/no how?</td></tr>
<tr><td>9</td><td>What are the three most important limiting factors in pump irrigation?</td><td>1. Land availability;
2. Family labor;
3. Fuel cost;
4. Repair and maintenance;
5. Capital for inputs
6. Marketing
7. Any other specify</td><td>What are the most serious problems affecting your pump irrigation agriculture?</td></tr>
<tr><td>12</td><td>If you were offered an irrigation pump of your choice, which one would you prefer?</td><td>1. Own motorized pump
2. Own treadle pump
3. Group motorized pump
4. Group treadle pump</td><td>Reasons for preference?</td></tr>
</table>

SECTION 4: Irrigation profile

17. What is the source of water for your pump irrigation?

18. What is the estimated distance from the water source to your irrigated field?

19. How do you convey water to from the pump to your irrigated areas?

20. How do you apply water to you crops?

21. What are the five most important crops that you irrigate with your pump and why do you consider them important?

22. Relatively what percentage of irrigated area are these crops grown?

SECTION 5: Pump benefits

23. Are you satisfied with the performance of the pumped system? Please explain

24. Do you find pumped irrigation system profitable? Please explain.

25. For those that discontinued, when and why did you stop using the pump? If still involved in irrigation, what irrigation method are you currently using?

26. In your view what would you consider as success in pump irrigation?

27. Did you receive any support related to pump irrigation? If so what sort of support and from whom?

SECTION 6: Social support systems

28. Where/to whom do you sell your irrigated crops and who normally buy them?

29. Are you satisfied with the available markets that you have and if not why?

30. Do you access any extension services related to the pumps? If so, from whom and how?

31. Do you belong to any membership in organization/associations? If yes which Organizations/association and what role do you have?

SECTION 7: Household socio-economic characteristics

32. Which of these household assets do you own?

Table A2: Household assets owned

#	Asset owned	Detail	Total No. owned	Approximate value[1]	Any comment
1	Dwelling roof	(1)Thatched (2) Iron sheets (3)Other			
2	Total area rain-fed farm	Acres			
3	Total irrigated area	Acres			
4	Livestock	Type:			
5	No and type of pumps owned	(1) Treadle (2) Motorized (4) Other			
6	Bicycle				
7	Pesticide Sprayer				
8	Mobile phone				
9	Motor cycle				
10	Motor vehicle				
11	Color TV				
12	Radio				
13	Oxcart				
15	Other specify				

End of the questionnaire and thank you for your cooperation

Appendix B Second survey farmers' questionnaire

Except for the component that highlighted the aim for the second survey (to verify and enrich the initial findings from my first survey), the informed consent for all the questionnaires was the same.

Section A: General information

1. **Date of the interview**____2014
2. **Respondent ID Number:** _____________**District:**___________________
3. **EPA:**____________________ **Village:**______________________________
4. **Sex (Male/Female)** ______________ **Age**_____________________(years)
5. **Farmers' education levels** _____________________________________
6. **Household size**: ____
7. **Pump adoption status**: Continued motorized pump (individual/group)
   Discontinued motorized pumps (individual/group)
   Continued treadle pump (individual/group)
   Discontinued treadle pumps (individual/group)
   Non Adopter (irrigation method using)
8. Pump year of adoption and specification (Capacity (hp) & manufacturer, source of power)
9. **Means of accessing the pump** (private, subsidized, free, loan, inherited) and if accessed for free or subsidized from who?)
10. **Type of water source** (private well, shared well, stream, pond, others)

Section B: Pump information

1. What was your previous irrigation method before adopting the pump?
2. How did you learn about the pump? Please explain
3. Who assisted you to choose the type of pump that you are having/using?
4. What attracted you to adopt this pump and not one of the other types of pumps?
5. How long have you used this pump?
6. What are the main important crops grown on your pump irrigated field and why?

7. Has the pumps increased your irrigated area? Please explain
    a. What was the size of your irrigated area before you started using the pumps?
    b. What is your present irrigated area?
8. Has the pumps reduced your labour per unit area compared to your previous irrigation method? Please explain
    a. How many people were involved in irrigating an acre of land before and after adopting the pumps?
9. Between the pump and your previous irrigation method, which one do you find it easier and simpler to use/operate? If it is the pump how and if not why not?
10. Do/did you have the problem of repair and maintenance with this pump? If yes how serious and which parts?
    a. What is the specific repair and maintenance issue?
    b. How do you manage it?
11. Does the pump operating cost affect/affected your irrigation activities? If yes to what extent? Please explain.
    a. How much fuel/labour is used in a week?
12. Is the land that you are using for irrigation yours or rented?
    a. If yours how did your acquire the land?
    b. If rented how much do you pay for a season?
13. Do/did you have any problem with the reliability of water supply during irrigation? Please explain.
14. Does the problem of lack of capital for inputs affect your irrigation activities? If yes to what extent? Please explain.
15. How significant is the pump cost compared to other costs including cost of buying the pump, cost of acquiring the land/renting, cost of buying inputs such as fertilizer, seeds and herbicides, costs of operating (fuel or labour) the pumps, cost of repair and maintaining the pumps (provide the order of importance)?
16. Has the pump met your expectation in terms of the benefits?
    a. What were your benefits expectations from the pump?

b. Which of the expectations has been fulfilled and which ones have not?
c. For those not fulfilled what are the possible reasons?

17. Are there any other benefits of the pump? Please explain
18. For those that discontinued using the pump: when did stop you using the pump and why? Please explain.
19. Are you still continuing with irrigation activities? If yes, which method are you currently using and why?
20. If not, what are the alternative means do you have to support your household?
21. For those continuing using the pump, what kind of problems do you perceive that they are likely to affect your continuation with your pumped irrigation system? Please explain?
22. If having more than one pump, are you using both/all pumps? If yes how do you use them? If not, which pump type(s) are you using?
23. If having different pumps, how do you compare the different pumps? Explain
24. If using one pump, do you know of any other pump type available in the surrounding communities? If so how do you compare the other pump with your own pump?
25. What would be your preference on the pump types if you could choose again? Any reason for your choice?
26. Will you be using the same pump in the next five years? If not which irrigation method would you change to? If yes explain why?
27. Which irrigation pump would you recommend to be promoted for other farmers in your area? Please give the reason for your recommendation?

For pump non-adopters only

28. Do you know about the irrigation pumps? If yes, how did you know?
29. Why are you not using the pumps for irrigation?
30. What are the three important crops that you grow on your irrigated field?
31. Do you intend to start using the pumps for irrigation? Please explain

32. Which of the pumps types would you prefer if you were given a choice and why?
33. How do you compare using the pumps to your present irrigation method?
34. What do you think are the major benefits of using the pump that you prefer?
35. What do you think are the main limitations for using the pump that you prefer?
36. Do you think irrigating with the pumps increase the irrigated area or reduce labour or are simpler to use or are profitable?
37. Would you recommend the pump to other farmers in your area? If yes why and if not why not?

End of the questionnaire and thank you for your cooperation

Appendix C First survey stakeholders' questionnaire

1. Date of the interview: ___________________________________2013.
2. Name of the Organization:__________________________________
3. Respondent ID: ____
4. Position of the respondent: _____________Male/Female:_________
5. Village________________; District__________________________
6. Organization goal or aim
7. Organization type, functions and operational level
8. What are the functions of your organization in relation to pump irrigation?
9. Who do you consider as being the most important stakeholders in small-scale irrigation development and why?
10. Which of the small-scale pumped irrigation system technologies is your organization involved, how are you involved and why?
11. What is the extent of development (area irrigated, number of pumps distributed, schemes, number of farmers) for each of the pump system?(*for government officials only*)
12. What is the extent of your involvement (area irrigated, number of pumps distributed, schemes, number of farmers) in the mentioned small-scale pumped systems are currently? (*For all pump promoters except government*)
13. What are the condition for distribute the pumps to farmers and how many have you distributed in the last year? (*For pump distributors*)
14. How many pumps have you manufactured/assembled for past 10 years and where have you sold them? (*For pump manufacturers/distributors*)
15. What kind of irrigation extension services do you provide to pump irrigation farmers? (*For irrigation extension service stakeholders)*

16. What type of donation and level of donation related to pump irrigation do you provide? (*For pump or pump services donors)*

17. How what type of research/training related to pump irrigation are you involved with? (*For researchers and academics*)

18. In your view how do you rate the performance of the small-scale pumped systems in Malawi and why?

19. In you view what are the most important measures of performance for small-scale pumped systems and why?

20. In your view what do you consider as success or failure in small scale pumped systems?

21. In your view which of small-scale pumped systems is the most appropriate for smallholder farmers in Malawi and why do you think so?

22. Are you satisfied with the performance of small-scale pump systems in Malawi? If Yes how and if no why not?

End of the questionnaire and thank you for your cooperation

Appendix D Second survey stakeholders' questionnaire

Section A: General profile

1. Respondent ID Number: ____
2. Position in the organization: ______________________________________
3. Name of the organization: _______________________________________
4. District: ____
5. Organization type: (*Public, Private, Int. NGO, Local NGO, Academic, Project, Other)*
6. Organization Functions: (*Extension, distribution, Marketing, Donor, Training, Other)*
7. Operating level: *(National, Regional, ADD, District, EPA, Section, Other)*
8. Types of pumps promoting: *(Individual treadle, group treadle, individual motorized, group motorized)*
9. If pumps distributor, conditions for distributing: (Free, subsidized, full recovery, *loan, Other)*

Section B: Pump profile

1. What is the main aim for your organization in relation to the adoption of pumps? Please explain?
2. Are you able to meet your expectations/aim by promoting these pumps? If yes, what are those expectations? If not, what is not fulfilled and why is it so?
3. For those promoting only treadle or motorized pumps, why not promoting the other types of pumps?
4. For those only promoting group or individual pumps, why not promoting the group/individual pumps?
5. For those promoting specific pump types why not promoting other pump types?
6. Farmers indicated that they preferred Money Maker pump to the Advaith pump, are you aware about this? If so why is your organization not promoting these pumps? Why do think the farmers prefer the other pump?

7. What do you think farmers would prefer more between the treadle and motorized pumps and between the individual or group pumps? What could be your explanation for this?
8. What do you are the five main reasons why farmers adopt the various pumps?
9. What do think could be the five main reasons why farmers are likely to discontinue with the individual and group motorized and treadle pumps?
10. What do you think is mainly required to support the farmers to continued using pumps in Malawi and why do you think this is important?
11. In the next five to ten years, as an organization would you still be promoting the same type of pumps that you are promoting now? If not what irrigation technology do you think you will change to and why? If yes explain why?
12. Farmers indicated that they preferred individual to group owned pumps? Do you agree with this? Why do you think they prefer the individual owned pumps?

End of the questionnaire and thank you for your cooperation

Appendix E Outline of qualitative content analysis procedure

E.1 Introduction

In order to provide a deeper understanding of factors promoting and factors inhibiting pump adoption, the study analyse the transcribed data from open ended responses from farmers and other stakeholders using content analysis techniques. The transcribed and amended notes from all pump farmers comprised of a total of 85 pages whereas pump non-adopters responses had pages. Stakeholders' interview responses had a few pages (11) of responses since most of them choose to respond by filling up the questionnaires and these were brief. However the documents obtained from the organizations supported the responses from stakeholders.

E.2 Content analysis procedure

The objective of content analysis was to scan through the transcribed farmers interviews texts and organization documents (mandates, goals and strategies) that report on the factors influencing adoption and non-adoption of the motorized and treadle pumped systems. The factors influencing (non) adoption of the pumps from farmers perspectives were referred to as internal factors while those from the stakeholders' perspectives were referred to as external factors. Themes for coding both the internal and external factors were identified based on the SR findings on key performance assessment factors. In the case of new information, additional factors were added in line with principles of qualitative analysis where categories are identified as they emerge from the data.

Therefore after scanning through the interview responses and documents, the factors influencing (non) adoption of the pumps were identified using the following proposed themes: Technical factors (TF) and socio-economic factors (SE) from both the farmers and stakeholders' perspectives. Caution was taken on the interview responses because sometimes they use different wordings to refer to the same factor. These identified themes were further classified into sub themes and codes and are discussed as outlined below:-

E.3 Farmers' perspective

The following section provides a detailed description of the proposed codes for identifying factors influencing adoption from the farmers' perspectives.

E.3.1 Technical factors (TF)

The technical factors (TF) considered the physical characteristics of the pump (in terms of its design, capacity and its output) to influence its adoption. It also considered the physical characteristics factors of the farmers irrigated field to farmers to adopt the various pumps. These technical factors were further classified as pump technical (PT), pump water discharge (PW) and physical characteristics of farmers' fields (PF) as described below:-

Pump technical factors (PT): This refers to the capacity of the pump in relation to its technical design. It can be measured as the mode of its operation such as 'being easy or simple to operate and/or maintain', 'portability', 'durability' and 'the rate of its fuel consumption' and 'availability of spare parts'.

Example: A farmer report that he/she adopted a 5.5HP pump because it is easy to operate or because the pump uses less fuel. This is a purely a pump design *technical factor* that supports the adoption of the pump.

Pump water discharge (PW): This refers to capacity of the pump in relation to volume of water delivery (discharge) output. It measures the extent at which the water discharge capacity of the pump has influenced the farmers to adopt the pump. It can be expressed as 'increased water flow', 'increased irrigated area', 'less irrigated time taken' or 'long irrigation intervals' and 'large water flow'.

Example: A farmer indicates that he is using the treadle pump because he takes less irrigated time to irrigate than using a watering can. This is a technical factor relating to the pump output *capacity (water discharge)*.

Farmers' physical factors (PF): The physical characteristics of the farmers' irrigated fields in relation to the pump requirement such as type and availability water sources, land, type of soil, topography may influence farmers to adopt or abandon the particular pumped system. Farmers' expressions on these factors in relation to the pump adoption were also measured.

Example: A farmer reporting that he was motivated to use the pump because he has a reliable water source or vast irrigated land or land located closer to a reliable water source This can be classified as farmers' fields capacity to access the physical factors supporting or restricting the use of the specific pumps.

E.3.2 Socio-economic factors (SE)

The socioeconomic factors (SE) considered the capacity of farmers to access the pumps (affordability), to manage the pump (Labour) and the ability of the pump itself to provide returns to the farmers (Returns). Detailed description of these proposed codes with examples are discussed in the following section.

Pump affordability (PF): This refers to the means of accessing the pump. It measures the related means of accessing the pumps in relation to the farmers' uptake of the particular pumps. Affordability can be derived from expressions as the pump was adopted because it was cheap or subsidized or given for free or inherited or in the other way supporting or curbing adoption.

Example: A farmer points out that the cost of the pump attracted him to start using it. This is the ability of the farmer to access the pump and hence affordability

Relative Labour saving (LS): The farmers can adopt the pump because they want to save the amount of labour used for irrigation activities or vice versa. It can be expressed directly as to 'reduce labour' or to 'less tiring' and 'less energy demand'. The opposite may be true for non-adoption of pumps.

Example: A farmer explains that he was motivated to use the pump because it is less tiring compared to other irrigated method. This is relative advantage of the pump in saving labour.

Pump Benefits (PB): The pump can be adopted with an aim of increasing returns and these can be expressed as profits, increased yield, income, increased household food security and increased investments.

Example: A farmer reports that he was attracted to start using the pump because he wanted to increase the profits or income from irrigated fields. This can be classified as the pump relative returns.

Socio-support (SS): Farmers can be influenced to adopt the pumps because of the extension services (campaigns), influence from peers and/or availability of markets for irrigated produces.

Example: A farmer explains that he was motivated to adopt the pumps because the people that are doing better (richer) in the community are those that are using the pumps.

E.4 Stakeholders' perspectives

This process involved scanning through the responses from interviews in conjunction with the relevant documents obtained. In the case of responses linked to the farmers' perspectives, these were coded as outlined above. However, since there were other responses that emerged from the data and were not linked to the identified codes, the following codes were used to identify influencing of the various organizations in pump adoption.

Organizational internal influence (OII): This refers to the mandate, goals, mission of the organizations in relation to the adoption of pumps. It measures the internal influence that an organization has in relation to the (non) adoption influence of the various pumped irrigations systems. These can be measured by assessing the organization's mandate or mission or goals. The mission, goals or mandates of the organizations can play a role in influencing the organization to be involved in the promotion of the particular pumped irrigation system.

Example: An organization reports that their mission/mandate is to support the treadle pump irrigation. This can be classified as organizational internal influence on the adoption of treadle pump.

Organization indirect influence (ODI): This refers to the indirect involvement of the organization in influencing the (non) adoption of the pumped systems. This theme/code was further classified based on the level and source of the indirect influence in influencing the (non) adoption of the various pumps as provided in the following section.

(ODI-Direct)-Organization that was involved in executing the pumped irrigation systems because of other indirect internal forces within the organizations. For example, within a strategy/activity of an organization there could be an activity that which supports/restrict the adoption of a particular pumped irrigation system.

Example: One of the organizational goals is to ensure food security for smallholder farmers. However in its strategies to achieve its goal, the organization may be involved in the distribution of the motorized pumped irrigation systems.

(ODI-indirect) –This refers to an external indirect influence that an organization can have in influencing the (non) adoption of the particular pumped system. It measures the level that the externals forces can play an impact on the organizations' involvement in the pumped systems.

For example: A donor of an organization can direct an organization to be involved or not to be involved in a specific pumped irrigation system.

E.4.1 Reliability and validity measures of the method of analysis

The reliability of the content analysis was improved by involving an independent assessment who evaluated at least 20% of the recoded questionnaire responses and documents. The agreement between the researcher and the independent assessor were measured as recommended by Krippendorf, (2004).

E.5 Data extraction:

The data from the interview responses and documents were extracted to an excel spreadsheet document as demonstrated in the Table below.

Table E1: Qualitative content analysis data extraction framework

No	Reason for adopting/limiting pump adoption	Types of pumps	Respondent identification number						Total score
			R1	R2	R3	.	.	Rx	
1	**Pump technical factors (PT)**: Simple or easy to operate								
.	Fuel consumption								
.	Portable								
.	Durable								
.	Availability of spare parts								
.	**Water Discharge (WD)**:								
.	Less irrigation time (WD)								
.	Increased irrigated area (WD)								
.	Increased water flow (WD) Long irrigation times (WD)								
.	**Physical Factors (PF):**								
.	Land availability (PF)								
.	Water availability (PF) Topography /soil type (PF)								
.	**Affordability (PF):**								
.	pump cost (cheap/expensive)								
.	free								
.	**Labour Related: (LR)**								
.	Less irrigation time								
.	Reduced labour								
.	Less tiring Less human energy required								
.	**Pump Benefits (RR):**								
.	Profits								
.	Increased income								
.	Increased yield Increased asset investment								
z									

E.6 Data interpretation

The data extracted were narratively analysed by drawing up a statements based on the magnitude of how the issue had been expressed by the respondents. It also included highlighting the differences in the factors reported and between the various pumped categories. Some of the quotations from the interview responses and documents will be used to strengthen some of the findings. Finally, tables and bar charts were used to compare the level of influence between and within the pumped systems. The findings obtained in this analysis helped to establish the conditions within which the pump adopted were either a success and/or failure.

Appendix F Detailed process and findings of the SR

F.1 Introduction

This section provides the summarized process and findings of the systematic literature review. It was hypothesized that the lack of key factors in assessing performance of SSPI were the cause of the mixed and differences in performance evidence. The process started with conceptualization of irrigation performance assessment, review of related research work and development of the research protocol.

F.2 Conceptual framework and related work

The term 'performance' has several meanings. In general terms it means the accomplishment of a given task measured against pre-set known standards of accuracy, completeness, cost and speed. Bos et al. (2005) described performance assessment as the comparison of the measured value of a parameter against a target or intended value. Irrigation system performance assessment is described as a systematic observation, documentation and interpretation of activities related to irrigated-agriculture with an objective of continuous improvement (Bos et al. 2005). Performance assessment indicators can be categorized into five broad domains including: (i) water delivery and utilization; (ii) agricultural production; (iii) agricultural economics; (iv) socio-economic; (v) environmental. It is recommended that all performance indicators are used to achieve an efficient, productive and effective irrigation system at all levels; however, the choice of which indicators to use in the assessment depends on researchers' interests. The study argues that evidence on performance of SSI pumped systems can only be obtained if the key drivers are identified and their measurement standardised.

A lot of studies have actually reported irrigation performance of various irrigation systems using the recommended indicators. Depending on reasons and perspectives of the study, some studies use all indicators whilst most only select a few in assessing performances of various irrigation systems. Principally, it is recommended that all performance indicators should be used in order to achieve efficient, productive and effective irrigation systems at all levels, however it is argued that using all indicators is expensive such that only selected indicators are used based on the interests and perspectives of the researchers. The challenge therefore is identify such meaningful indicators. Bos et al. (1994) in (Bos et al., 2005), provided seven properties as desirable attributes for performance indicators.

Whilst the properties of indicators provide guidelines for selecting meaningful indicators, it is not clear outlined how an indicator would be preferred more than the other in the event that both indicators have the required attributes. Perhaps indicators can further be classified based on their magnitude of influence to the irrigation system? Possibly some indicators will be critical compared to others and therefore having large influence on performance of the irrigation system. This systematic review attempted to identify such critical factors affecting performance of SSPI systems. The benefit of identifying the key factors is that it will help to form a basis for objectively assessing performance of SSPI.

F.3 The SR question and methodology

The primary research question addressed by the systematic review was **'What are the key factors affecting performance (sustainability) of small-scale pumped irrigation systems in Sub Saharan Africa?'** The SR was undertaken based on the defined search terms and it commenced in March 2013 and was completed in May 2013.

F.4 The SR results

The most significant peer-reviewed journals were *Agriculture Water Management* which had 6 articles followed by *Agriculture Systems*, which had three articles followed by *World Development, Irrigation Science, Irrigation and Drainage and Physics and Chemistry of the Earth* with each two relevant articles. From data source, Academic thesis from various Universities were the most significant source which had four relevant reports whilst the rest databases and peer reviewed journals had each one relevant article as illustrated in Figure A1.

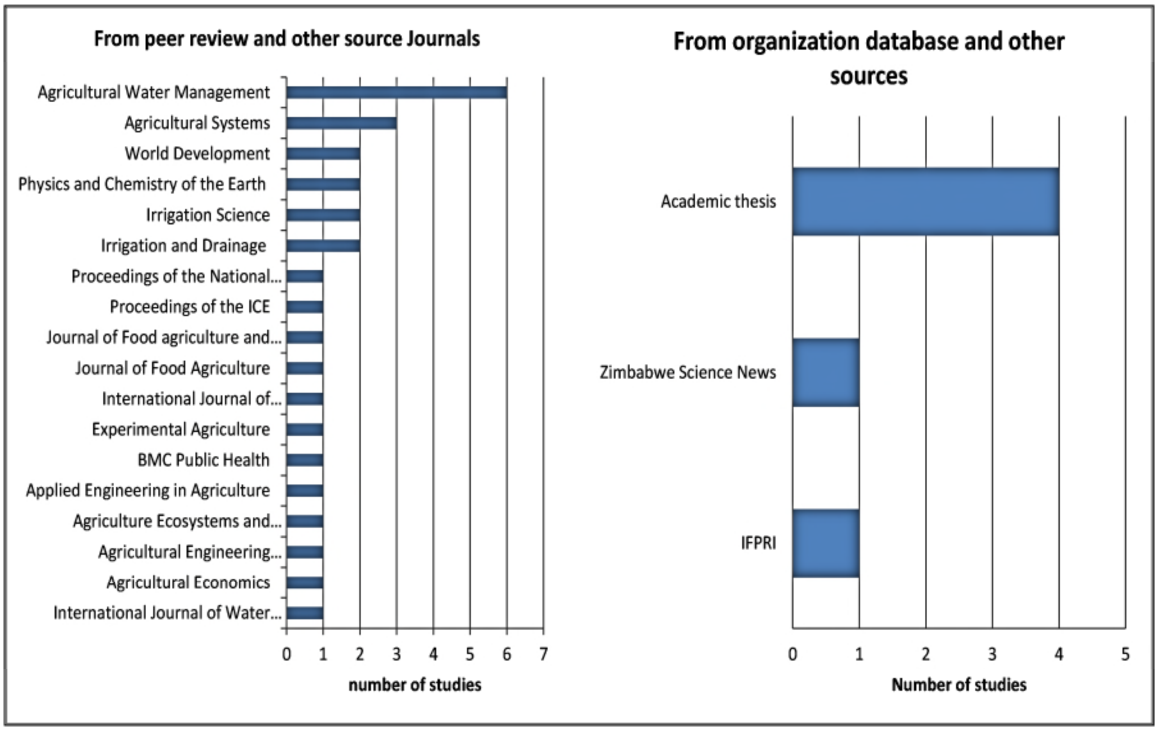


Figure A1: Sources of relevant papers

The results showed that more than half of the papers selected were published between 2008 and 2013 (Figure A2). This could mean an increased interest in SSPI.

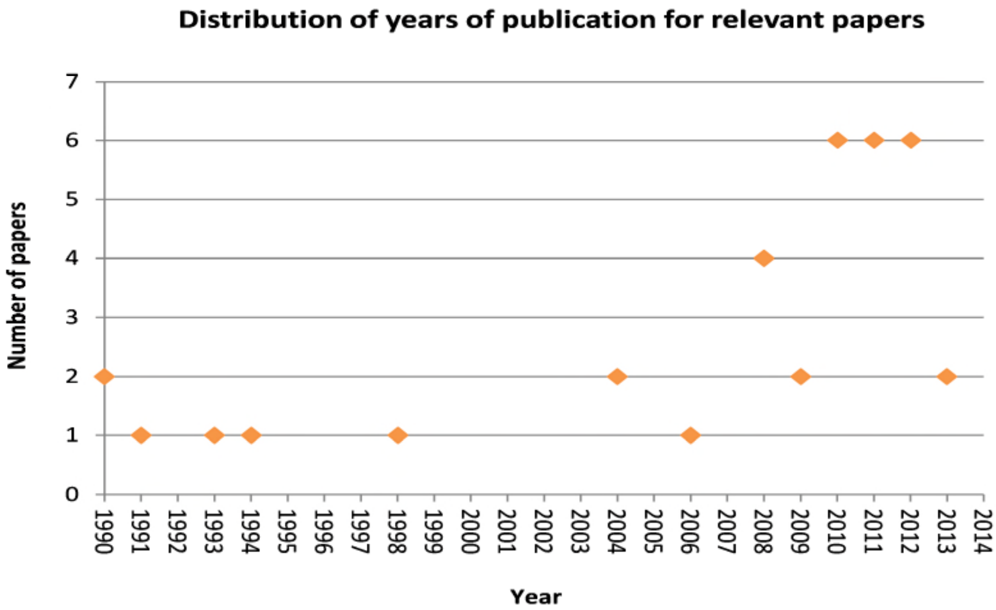


Figure A2: Year of publication for selected papers

The results showed that three countries, Mauritania, Malawi and Ethiopia had the largest number of relevant papers each with six papers, followed by Nigeria with 4 relevant papers, then Zimbabwe with 3 relevant papers whilst Mali, Niger and Kenya had each with two relevant papers (Figure A3).

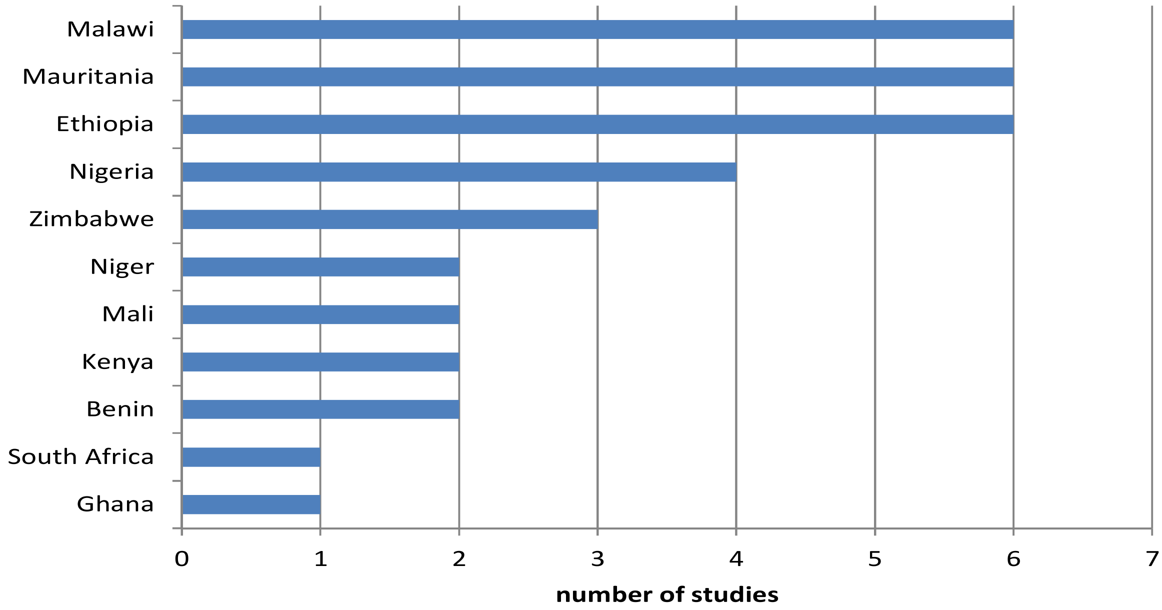


Figure A3: Number of selected studies by country

The results revealed that motorized pumps were more significant pumped irrigation system representing 63% of the total selected papers. It was noted that amongst the studies Mauritania had more studies (6 papers) followed by Ethiopia (5 papers) and then Nigeria (4 papers). Figure A4 summarises the distribution of pumped irrigation studies by country. The results showed that eight countries covered motorized pump irrigation system, four countries covered treadle pumps irrigation system whilst two countries covered solar pump irrigation system and one country covered rope and washer pump irrigation systems.

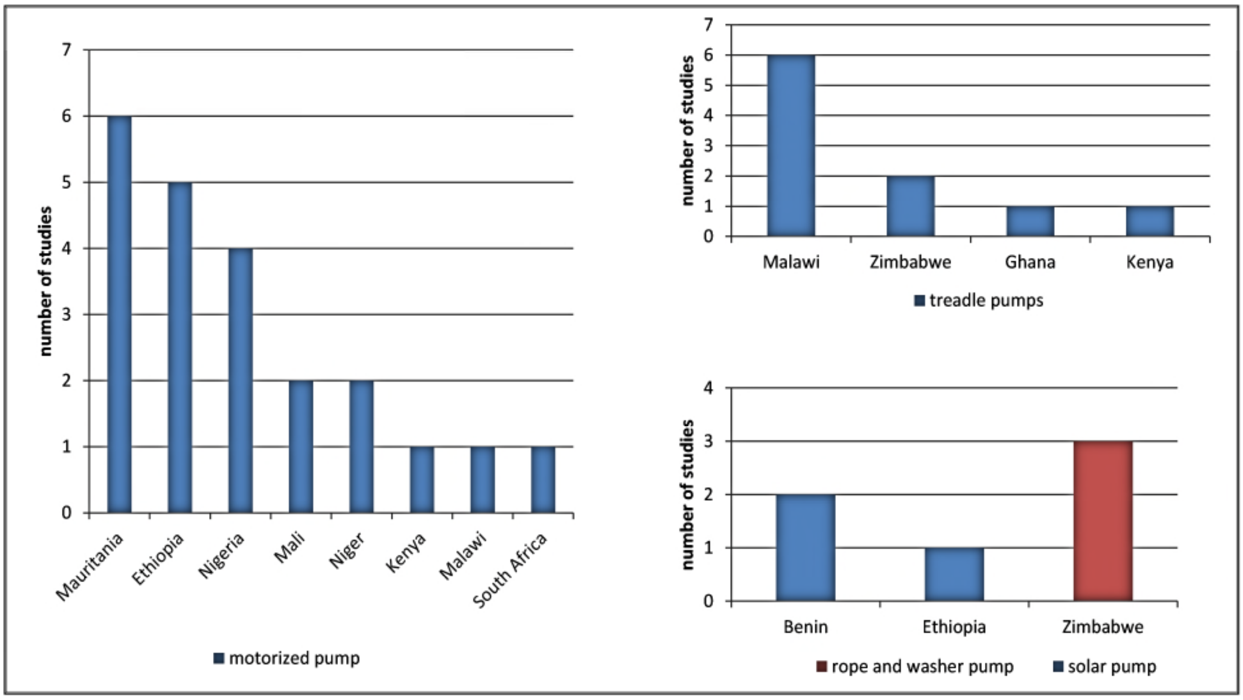


Figure A4: Pumped systems by country

The results revealed that out of the 35 relevant papers, 20 papers reported on specific crops and the distribution of the crops studied per technology is as shown in Figure A5. The results indicate that rice was the most significant crop amongst the relevant papers.

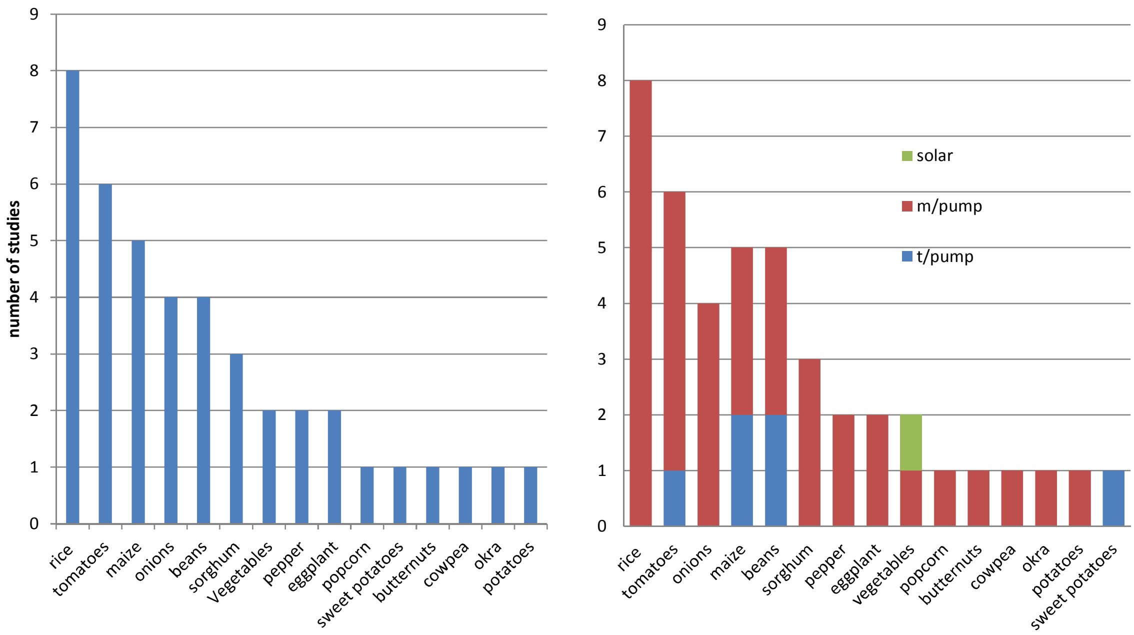


Figure A5: Crops studied by pumped systems

F.5 The SR discussion

Ideally the SSPI are supposed to contribute to socio-economic uplift of rural communities and alleviate poverty (Hussain and Hanjra, 2004). Given such a relationship, it is reasonable to expect that the SSPI interventions would bring about changes in production, income and consumption, employment, food security, and other social impacts contributing to overall improved welfare of the rural communities (Ofosu et al., 2010; Hussain and Hanjra, 2004). However the scope and strength of the above stated changes will in turn be dependent on the agro-climatic, social and spatial characteristics of the area affecting the motorized pumped intervention.

This SR literature supports many of these linkages though the relationship was somehow weak due to the identified effect modifiers. These variations provided challenges in interpreting and synthesizing the results. The narrative results were analysed based on the studies that (1) reported positive performance impact, (2) reported negative performance impact and (3) reported mixed performance impact by the pumped systems and country as summarised below:-

F.6 Narrative synthesis

F.6.1 Motorized pump: positive performance impact

The SR found that socio-economic, agronomic and economic factors dominated the studies that reported positive performance impact of motorized pump irrigation.

<u>Nigeria</u> Nigeria, Baba (1993), carried out a three-year socio-economic analysis on characteristics of equipment used, economic inputs and outputs, water applications pump operation and maintenance to compare the effective performance of motorized pumped systems to shadoof traditional irrigation. The study found that motorized pump irrigation was superior to shadoof in terms of resource use, yield and profits. In another study in Nigeria (Adeoti, 2008), it was found that farms under pump irrigated increased in farm size, family labour and fertilizer application were likely to increase output levels. It was concluded that more returns were realised from irrigated farms than on rain-fed. Similarly,

Takeshima (2012) noted that there was an increased willingness to invest in motorized pumps among farmers facing higher rainfall risks to mitigate the impact of rainfall risks. This implies that farmers found pumped irrigation profitable rain-fed agriculture.

Mali: Dillon (2011), reported positive impact on small-scale irrigation investments on household consumption, assets, and informal insurance from a panel of households. The study revealed that access to irrigation increased household consumption by 27–30% compared to water-recession and rain-fed cultivators.

Ethiopia: Mengistu (2008), reported positive impact of the pumped irrigation schemes on crop revenues by comparing the socio-economic characteristics of two motorized pumped schemes with a traditional irrigation.

Mauritania: One study reported the positive impact of the motorized pump irrigation on profitability of sorghum when compared with rice crop. The study focused on the agronomic and economic performance factors of the system. It was noted even though both crops had similar total above-ground biomass at maturity, sorghum required less irrigation water than rice but the smaller yield resulted in similar irrigation water productivity and fuel (pumping) productivity. Despite the smaller yields, it was found that sorghum profitability was significantly greater than rice by 49% and this was attributed to higher market prices (Garcia-Ponce et al., 2013).

Niger: Another study in Niger by Woltering, (2011) assessed the agronomic and economic performance of the African Market Garden (AMG) of drip irrigation powered with motorized pumped system on okra and eggplants compared to gardens irrigated manually with watering cans. AMG gave higher crop yields and higher returns to investment than the areas irrigated with watering cans. The returns for the AMG on land from eggplant were 55% higher than traditional irrigation. Similarly the returns on water were more than 100% in the AMG than in the farmers practice irrigation.

Ethiopia: Performance of drip irrigation powered with motorized was compared with furrow irrigation systems to examine their effect tomato yield and water use efficiency. It was found that drip system showed the highest values as compared to furrow irrigation (Yohannes and Tadesse, 1998). These finding reflects the importance of measuring agricultural productivity in understanding performance of small-scale pumped systems.

While it may be difficult to compare the above studies by country, the trends and extent use of common indicators in the evidence suggests the significance of particular performance factors in reporting positive impact. In this case, factors such as yield, profits, assets accumulation appeared to be the most important indicators for assessing performance.

F.6.2 Motorized pump: negative performance impact

The review noted that a range of measures were used in studies that reported negative SSPI performance. Although it was hard to compare the findings, it was interesting to note that most of these studies assessed productivity (labour, water and energy) in comparison to financial costs (initial cost) of pumped systems. These appear to suggest that the gains obtained from SSPI cannot meet the cost of purchasing the pumps. The specific findings in the respective countries are as discussed below:

Malawi: Kadyampakeni et al. (2012) assessed the performance of motorized pump against treadle pump, watering can and river diversion. The outcomes of the study were mixed. For example, motorized pumps were found efficient when compared with watering cans but were inefficient when compared with gravity/river diversion. The study used crop revenue, labour and energy cost to measure the performance. The study proposed fuel subsidies on motorized pump irrigation.

Mauritania: Comas et al. (2012), analysed the reasons why SSI had not responded to the expectations. The study compared workload on pump irrigated schemes to traditional subsistence farming. The study reported more workload demand when pump irrigation was combined with traditional irrigation.

Furthermore, the returns on labour and inputs were much better in the traditional subsistence compared to pump irrigated. That study argued that success would only be realized if profitable contributions are obtained from pump irrigation. Garcia et al. (2011) used productivity of land, irrigation water, and fuel to diagnose the performance of 22 irrigation schemes on the banks of Senegal River. It was found that all the productivity (land, water, fuel) measures were far below the potential. Moreover, the water delivery capacity was insufficient in more than 30% of the schemes. This was attributed to the poor maintenance but interestingly the study also found that irrigation intensity in the rehabilitated schemes was even lower (less than 0.66).

Kenya: The study evaluated efficiency of ten pumps by comparing them against their designed optimal engineering standards including pump design, energy (fuel) consumption, pump power and head losses parameters. The study found numerous challenges including pump selection, design and use that led to the poor performance. Furthermore, out of 10 pumps evaluated, 6 operated below the optimal design efficiency level while fuel consumption rate of each pump varied. The varied fuel amounts used was attributed to different factors in farms like topographic elevations, water conveyance distance and different make and model of pump (Kang'au et al., 2011).

Nigeria: In Nigeria, Takeshima (2010) attributed the failure of irrigation technologies to the transaction costs, it was noted that there were higher costs involved when farmers procure motorized pumps thereby making it difficult for others to access the pumps. These effects were worse among the female farmers. While the study demonstrated the importance of considering initial costs in motorized pumped systems, it also reveals the existence of hidden costs in the pumped systems which can negatively affect adoption.

The review has noted that studies that reported negative impact have basically assessed the productivity of labour, water and energy and the financial costs (initial cost) of the pumped systems. This questions the sustainability of SSPI adoption.

F.6.3 Motorized pump: mixed performance impact

The review noted over 50% of selected studies reported mixed (both positive and negative) performance impact of motorized pumps systems. Most studies used mixed indicators in their assessment. Interestingly, technical (system and pump) assessments combined either with socio-economic or purely economic factors dominated these studies.

Ethiopia*:* In Ethiopia, the socio-economic assessments of two motorized pump irrigation schemes showed positive impact of the development (Assefa et al., 2008). This was evidenced by the net farm income from the crops grown and increased household incomes of the participating families. However, when the same schemes were technically assessed by Van Helsema et al. (2011), it was found that the schemes were inefficient and in particular one of the scheme's irrigation efficiency was found to be as low as 35%. This was despite the fact that the yields and economic returns of the irrigated crops for the scheme were reported higher.

Mauritania: Mateos et al. (2010) evaluated the rehabilitation of a small irrigation scheme along the Senegal River. The study established that before rehabilitation the scheme was operating satisfactorily with proper maintenance but after rehabilitation, reliability and flexibility of water distribution were noted to have been reduced, even though more families had access to irrigation. It was also noted that pumping capacity was insufficient to cover crop water requirements. Another study in Mauritania assessed and diagnosed the performance of 22 small and medium size community-managed irrigation schemes and noted that a third of the schemes' water delivery capacity was insufficient and irrigation intensity in rehabilitated schemes was lower in about half of the schemes (García-Bolaños et al., 2011). Garcia et al. (2013) found that irrigated sorghum cropping was more profitable than irrigated rice in the same schemes. While revealing that on average they were no differences between in performance the large schemes and small-scale schemes, Borgia et al. (2013) found that small schemes were more variable, particularly in input-use efficiency. This finding was arrived by assessing their average land productivity and energy cost.

Using a model to evaluate the impact of production scenarios, Connor et al. (2008) also reported mixed impact of the intervention beside the Senegal River, in Mauritania. The study identified family types with distinct resources, extending current practice to a more diverse use of irrigated land by introducing alternative summer and winter crops. The analysis noted that expansion of the irrigation area, and more diversified cropping was going to provide more families with access to irrigation but the small area available to each family was not going to sufficiently produce grain or straw unless cropping was intensified. It also raised concerns over the sustainability of the shrubland due to expanding the irrigation area. While the pumped irrigation is considered as an option for increasing crop production in this case, it is also considered as a threat to the environment.

Two studies assessed performance of the pumped system through social analysis and they both reported mixed performance impact. In Mali, Ton (1990) while acknowledging the importance of the pumped systems in increasing the returns, the study expressed fears on water control inequity. Similarly, in Ethiopia, Awuluechi (2010) noted that they were technological and managerial issues that were associated with SSPI systems which needed attention. However it was found that pumped irrigated systems were more efficient than flood irrigation.

South Africa: Yokwe, (2009) investigated productivity and value of water in two smallholder irrigation schemes. In both the schemes, water value estimated for vegetables (cabbage, tomatoes and butternuts) was greater than water value for dry maize. However, when the willingness to pay (WTP), gross margins and accounting costs of the schemes and farm level were used to estimate the relative value of water productivity, the study reported that farmers showed low willingness to pay than their gross margin of output. Furthermore, the accounting cost was found less than the gross margins. These problems were attributed to the lack of extension and training.

F.6.4 Treadle pumps

The results showed that treadle pump was second most reported pumped irrigation system among the selected papers representing 23%. It was further noted that more than 60% of studies on treadle pumps were from Malawi, probably because these were highly promoted by the government. Kenya, Zimbabwe and Ghana had each with each one study on treadle pumps. Most studies (70%) on treadle pump irrigation reported positive performance impact especially related to food security, poverty reduction and total crop revenue. The few studies that reported negative impact attributed the poor performance to labour (Joseph and Yamikani, 2011; Chidanti-Malunga, 2009). Specific findings on treadle pump irrigation are as discussed.

Malawi: Treadle pump interventions were reported both as positive and negative in Malawi. For negative, Chidanti-Malunga (2009) found negative impact of the intervention on gross margins of maize crop as compared to traditional wetland irrigation irrigation. These were highly attributed to the labour costs. In another laboratory assessment study, (Yamikani- Josephy, 2011), also found that the pump was labour intensive but with very small discharge rates (an average of 0.78 l/s) achieved regardless of the Body Mass Index (BMI) of the operator. It was argued that because of the small discharge rates, treadle pump operators take long hours to pump in order to meet the crop irrigation requirements.

With regard to positive performance, Mangisoni (2008) used the head count poverty index to assess the impact of treadle pumps adoption on poverty. Pump non-adopters had most serious poverty levels compared with the adopters. Kamwamba-Mtethiwa et al. (2012) argued that relatively well-off farmers had significantly higher probability of adopting treadle pumps than poor farmers. The study questioned the dissemination approaches and targeting, considering the fact that treadle pumps were typically geared towards poor smallholders. Another study reported positive performance impact on total revenue when compared treadle pump irrigation to motorized pump and watering cans

(Kadyampakeni et al., 2012). It was argued that technologies that less labour were more appropriate for smallholder farmers.

Ghana: In Ghana, Adeoti et al. (2008) found that availability of labour and increased number of extension visits per year increased the probability of farmers adopting treadle pumps. The study suggested that increased in irrigated area had the highest impact on poverty followed by adoption of treadle pump and literacy level of farmers.

Kenya: Pandit (2010) carried out a study to test the feasibility of providing a micro-irrigation pump to HIV-positive farmers in order to evaluate its impact on health and economic impact on HIV-positive patients and their families. While the study aimed at demonstrating the feasibility of an income-generating micro-irrigation intervention among HIV- positive patients and the collection of health and economic data, it was found that family income improved significantly however the loan repayment rates were low- and this was attributed to the drought that occurred in Kenya during the intervention period.

Zimbabwe: Chegerwe, (2004) assessed the efficiency of different treadle pump designs combined with different drip designs. The results showed that it was viable to irrigate drip irrigation gardens up to a size of 1000m2, if the treadle pump and drip kit were well matched. It was proposed that such garden would ensure food security of farmers and generate significant income. Another study compared the efficiency of treadle pump to rope and washer pump and reported that sustainable outputs of at least 1 l/s were easily achieved at low lifts up to 5 m with the treadle pump (Faulkner et al., 1990). However, these findings are not consistent with the recent findings of the average discharge rates of treadle pump obtained in Malawi by Chidanti- Malunga (2011). Perhaps the design of the pumps assessed were different considering the time difference in time (10years) between the studies.

F.6.5 Solar pump

Benin: Two studies used socio-economic factors in their performance assessment with measures in gross margins, income total per capita daily consumption, food access, food utilization and availability (Burney and Naylor, 2012). Although the assessment was only conducted after one year of implementation, it was observed that there were significant returns on production amongst the solar pump farmers.

Ethiopia: One study assessed performance of solar pump by comparing it with fuel pumped system. The study focussed on the pumped system technical factors which included pump efficiency, flow rate, hydraulic energy and daily volume to measure the performance. The solar pump showed more efficiency than the fuel pumps (Jeffreys, 2010).

F.6.6 Rope and washer pump

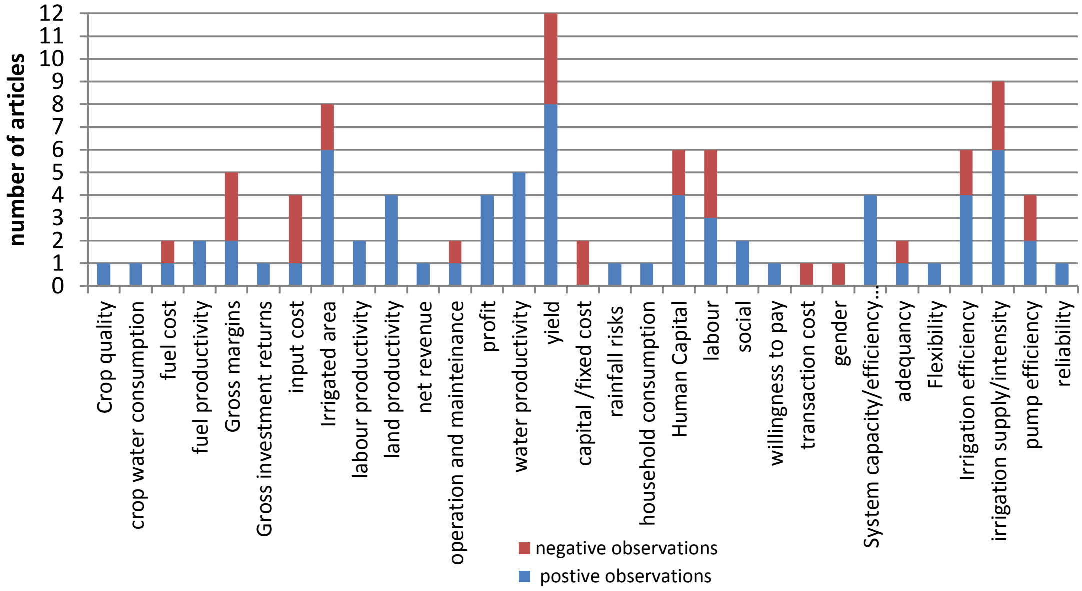
Zimbabwe: The results showed that the selected two studies that assessed pump technical efficiency of rope and washer pump were both carried out in Zimbabwe and they both reported positive performance impact. It was observed that all the studies on rope and washer pumped systems were old studies (1990s), assesses the technical pump efficiency and were carried out by same authors (Faulkner et al., 1990; Faulkner and Lambert, 1990). Perhaps the fact that they are old studies could be an indication of decreased interest on use of pump type in SSA region.

F.7 Quantitative synthesis

Due to effect modifiers contained in studies, less data was available for quantitative synthesis. However attempts were made on performance assessment factors and reported crop performance on specific countries.

F.7.1 Motorized pumps

Figure A6 summarizes the list of indicators used to interpret both positive as well as negative performance impact of motorized pumped systems.



FigureA6: Frequency of specific indicators by studies

These indicators were further grouped into six categories and their frequency of use in motorized pumped studies (Figure A7).

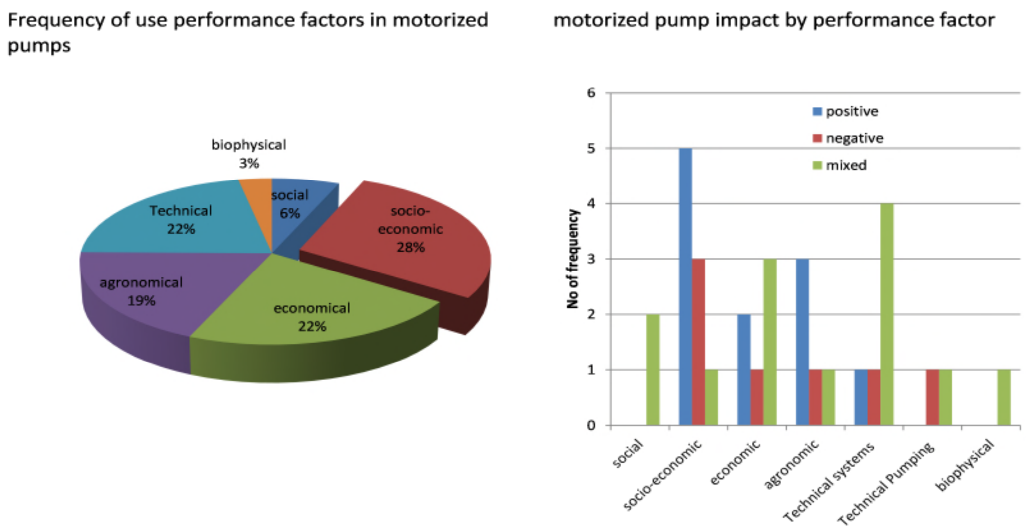


Figure A7: Performance factors' use and impact in motorized pumps

Performance Impact on crops

Only studies on motorized and treadle pump had detailed information on performance of specific crops. Apart from rice, tomato, onion and maize were other important crops studied in a number of countries. For example, in Mauritania, all studies assessed rice crop with only one study combining with sorghum. It was noted that yield was the centre of focus in most studies and its assessments ranged from direct to indirect measurements, estimating the crop costs to estimating the crop revenue. Given such observations, the following were some of the quantifiable results on crops studied under motorized pump systems.

Rice: Figure A8 summarises the reported yield of rice crop from different studies and change in rice yield after motorized pump intervention. Large variations of rice yield were observed within as well between countries. While these may be attributed to the 'effect modifiers', the variations are however big considering that some of these assessment were from within same country i.e. Mauritania. These could be attributed to the different performance factors used.

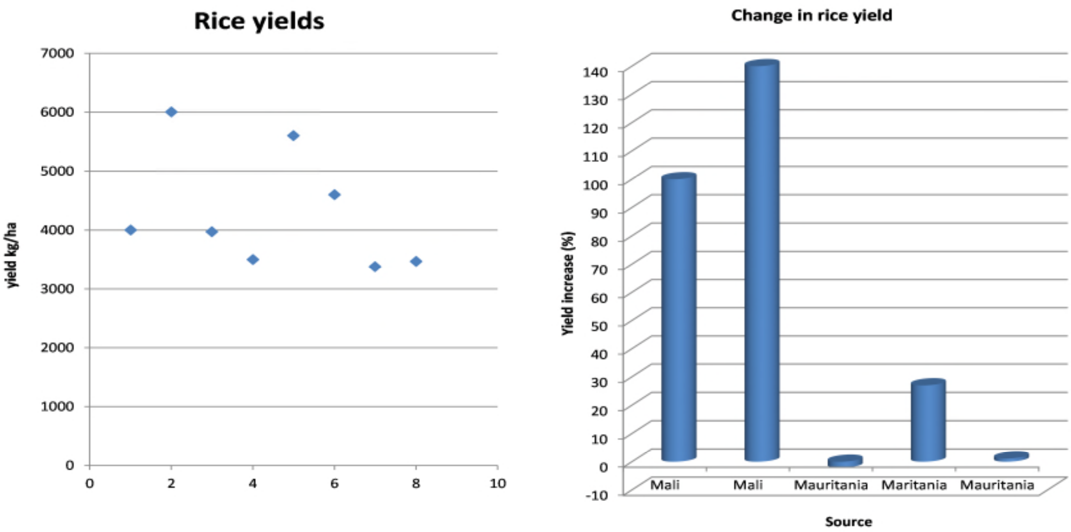


Figure A8: Rice yields and changes with motorized pumped systems

Tomato

Figure A9 shows the reported yields of tomato crop from different studies and the changes with the intervention. On average, tomato yields under motorized pump systems showed similar trends. While the expectations were increased yield after the intervention, in other cases the controls showed better yield than the intervention. This could be attributed to the management system of the crops. On the other hand large differences were noted in reported change in yields of tomatoes after intervention. Probably different varieties and measures could explain the differences.

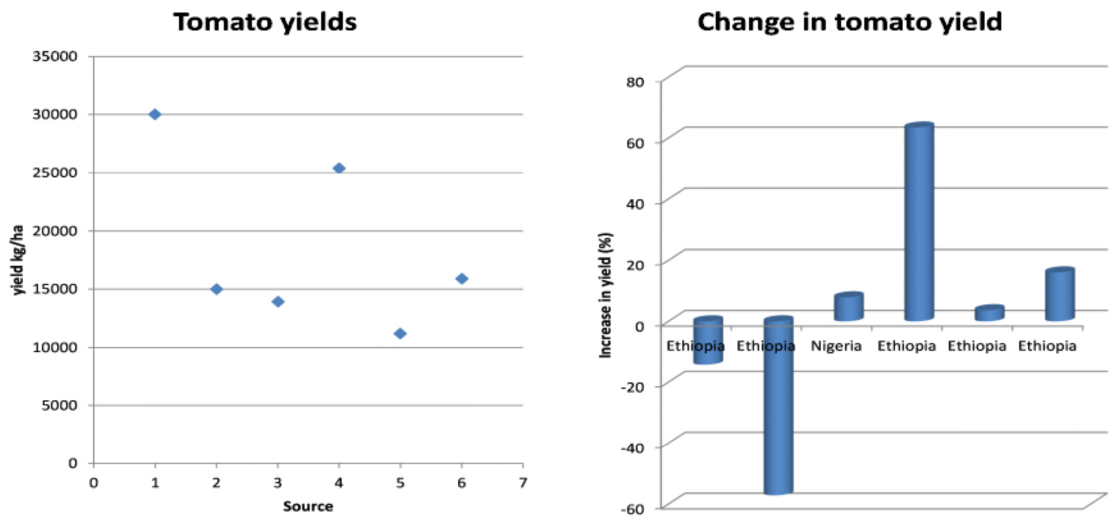


Figure A9: Tomato yields and changes with motorized pumped systems

<u>Onion</u>: Figure A10 shows the reported onion yield crop from different studies. Except for one study the reported onion yields under motorized pump irrigation systems were within the same range on average.

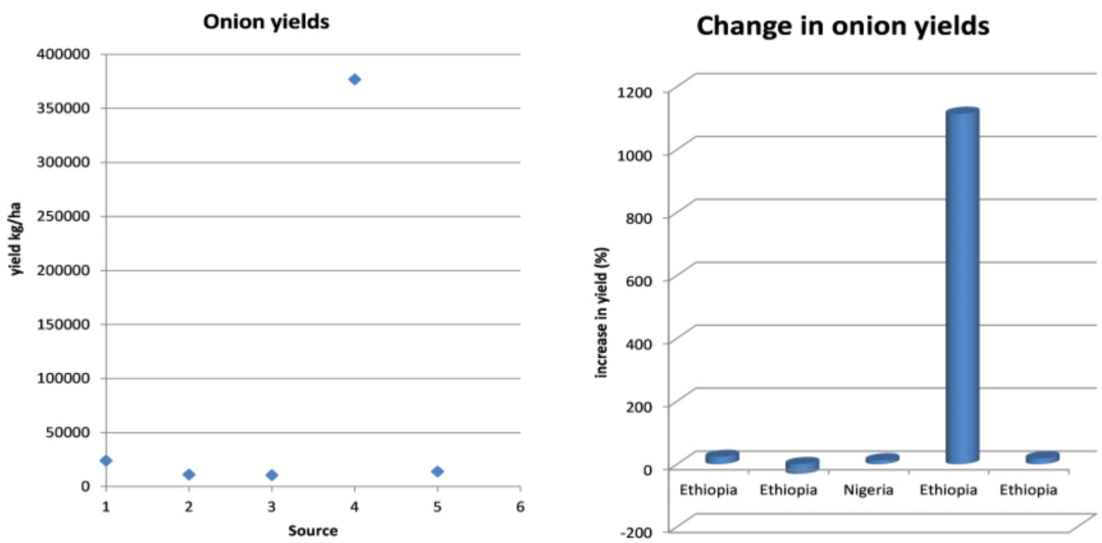


Figure A10: Onion yields and changes with motorized pumped systems

<u>Beans</u>

Figure A11 shows the reported beans yield crop from different studies. A wide variation of beans yield was reported in the studies within and between countries. The negative return in bean yield was attributed to pump fuel cost,

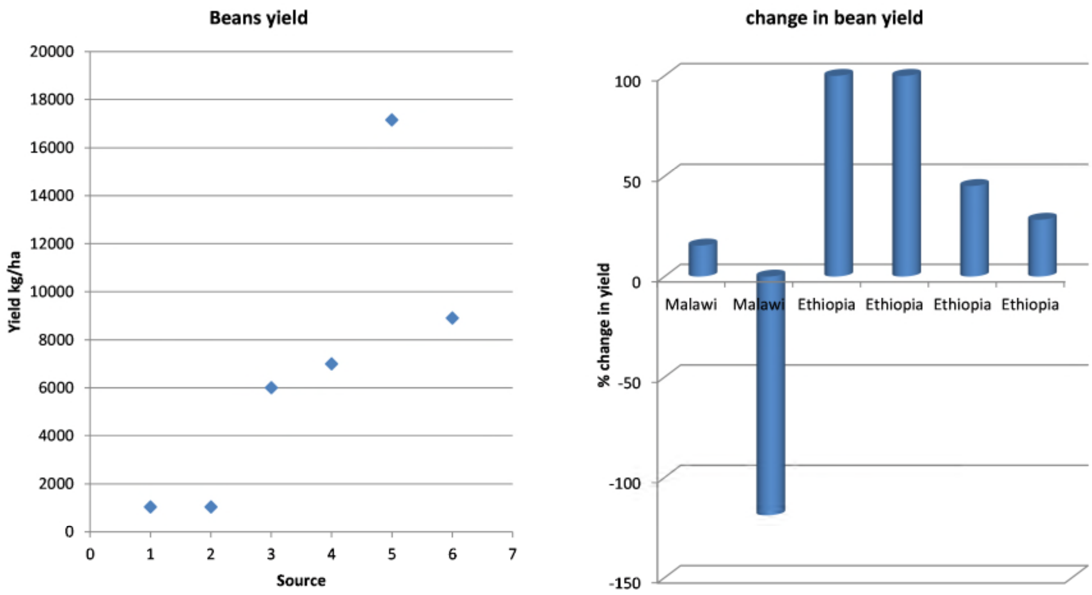


Figure A11: Bean yields and changes with motorized pump intervention

F.7.2 Quantitative analysis: Treadle pumped system

The reports on treadle pumps studies also used a wide of performance indicators which when grouped together (Figure A12). As noted in motorized pumped systems, socio-economic assessments dominated in treadle pump studies and it was observed that most studies reported positive impact. Interestingly for studies that reported negative performance of treadle pump were studies carried out by the same researcher and specifically labour dominated as a performance measure in studies that reported negative impact.

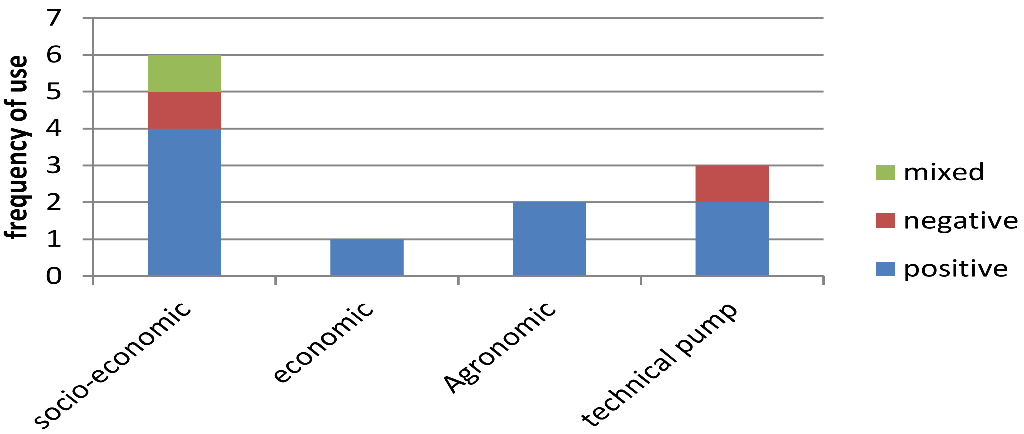


Figure A12: Performance factors by impact used in treadle pumps

Impact on crops

Only two studies and were both conducted in Malawi focused on crop production impact under treadle pumped irrigation systems. Crops that were assessed include beans, tomato and maize. Varied crops yields were reported on performance impact of treadle pump irrigation systems (A1). The trends in yield change showed that treadle pumps were more effective when compared with watering cans and motorized pump but inefficient when compared with gravity/river diversion irrigation systems. It was noted that the effect on labour influenced the differences.

Table F1: Treadle pump irrigation impact on crop yields (Malawi)

Crop	**Source**	**Compared irrigation system**	**Yield (t/ha) without**	**Yield (t/ha) with**	**% Yield Change**
Maize	Fandika et al. (2012)	Furrow treadle pump- variety 1	5.48	5.78	5.1
		Furrow treadle pump- variety 2	4.8	4.91	2.2
		Furrow treadle pump-variety 3	4.98	5.32	6.4
Beans	Kadyampakeni (2012)	watering can	0.88	1.27	30.9
		river diversion	2.28	1.27	-78.9
		motorized pump	1.04	1.27	18.2
	Fandika et al., (2012)	Furrow treadle pump-variety 1	0.72	0.74	2.7
		Furrow treadle pump-variety 2	0.81	0.95	14.7
Tomato	Fandika et al., (2012)	Furrow treadle pump	no info	60.3	-
		Furrow treadle pump	no info	78.9	-

Appendix H Proof of manuscript acceptance

On Mon, May 11, 2015 at 10:08 AM, <schultz1@kpnmail.nl> wrote: 11-May-2015

Dear Mrs. Mtethiwa,

It is a pleasure to accept your revised manuscript IRD-14-0095.R3, title: "ASSESSING PERFORMANCE OF SMALL-SCALE PUMPED IRRIGATION SYSTEMS IN SUB SAHARAN AFRICA;EVIDENCE FROM A SYSTEMATIC REVIEW; IRRIGATION À LA PARCELLE EN AFRIQUE SUB-SAHARIENNE- ÉVIDENCE SUR LA PERFORMANCE DES SYSTÈMES À POMPAGES ; MISE EN EVIDENCE A L'AIDE D'UN EXAMEN SYSTÉMATIQUE" in its current form for publication in Irrigation and Drainage.

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Following this, an invitation email with access instructions will be sent to your colleagues.

Thank you for your contribution.

Best regards,

Prof. em. Bart Schultz

Irrigation and Drainage

Appendix I Chi square tests results

Table H: 1 Chi-square test between classifications of farmers and characteristics of pumps, irrigation and farmers in the survey areas

Variable (Pump/irrigation/farmer characteristic)	Classifications of farmers		
	Group and individual)	**Incentive and self-motivated**	**Treadle and motorized)**
Pump capacity (motorized pumps)	0.000	0.000	-
Pump manufacturers (treadle pump)	0.000	0.020	-
Pump Manufactures (motorized pump)	0.000	0.000	-
Pump operational status	0.000	0.000	-
Irrigation methods used before the pumps	0.000	0.000	0.000
Irrigation water sources	-	-	0.000
Irrigation water conveyance methods	0.004	-	0.002
Farmers education level	-	0.020	-
Farmer irrigated area	-	0.000	0.000
Farmer source of pump awareness	0.000	0.000	0.000
Farmer means of accessing pumps	0.000	-	-
Farmer number of pumps owned	0.000	-	0.000
Farmer access to extension services	0.010	0.000	0.027
Farmer membership in cooperative societies	-	0.000	0.000
Farmer support services received	0.000	0.000	0.000

***Chi-square test exact probabilities of the associations between three classifications of farmers and selected characteristics of pumps, irrigation and farmers in the surveyed districts in Malawi.*